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CONTENTS

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Expected Growth of the Textile Industry in India in 2024

Dear Readers,

As we enter 2024, the Indian textile industry stands at the tip of a significant transformation. One of the pivotal drivers of growth for the textile sector this year is the robust improvement in domestic demand. With the Indian economy on a steady path of recovery, consumer confidence has surged. This is reflected in increased spending on apparel and home textiles. The government's initiatives to boost rural incomes and urban employment are also crucial in enhancing purchasing power.

On the international front, the textile industry is witnessing a gradual recovery in exports. After a period, the demand from key markets such as the United States, Europe, and the Middle East is picking up. Indian exporters are capitalizing on this revival by leveraging their strengths in quality, cost-competitiveness, and timely deliveries. Additionally, the diversification of export destinations and the penetration into emerging markets are contributing to a steady growth in export figures. Technological advancements and innovation are at the heart of the industry's growth narrative in 2024. From sustainable practices in manufacturing to the adoption of digital tools for enhancing operational efficiency, the textile sector is embracing change. Innovations in fabric technology, smart textiles, and eco-friendly production processes are not only meeting the evolving demands of consumers but also positioning India as a leader in sustainable textile manufacturing.

With the new Government formation in this June'2024, Shri Giriraj Singh, Minister of Textiles and Shri Pabrita Margherita, Minister of State for Textiles proactively support and make policy reforms to boost the textile Industry. Initiatives like the Production Linked Incentive (PLI) scheme for textiles, enhanced focus on technical textiles, and investment in textile parks are creating a conducive environment for growth. These measures are aimed at boosting production capacity, attracting investments, and enhancing the global competitiveness of Indian textiles.

Recently Artificial Intelligence (AI) has been very much used in Textiles. AI in Textiles includes smart textiles integrated with sensors for environmental and health monitoring. Automated quality control systems use AI to find flaws and uphold strict product standards. By predicting equipment breakdowns, AI-powered predictive maintenance reduces downtime for machines. Supply chains are optimized using AI, which improves inventory control and logistical effectiveness. Using data from social media and the market, trend forecasting uses AI to predict the next trends in fashion. AI-driven design tools also increase accuracy, decrease wasteful material use, increase manufacturing efficiency, and facilitate the creation of novel, environmentally friendly textile goods.

Using data from social media and the market, trend forecasting uses AI to predict the next trends in fashion. AI-driven design tools also increase accuracy, decrease wasteful material use, increase manufacturing efficiency, and facilitate the creation of novel, environmentally friendly textile goods.

Finally, as we navigate through this promising landscape, the Journal of Textile Association of India remains committed to providing insights, analysis, and updates to keep our readers informed and engaged with the industry's evolving dynamics. Let us embrace the opportunities that lie ahead and work collectively towards a thriving future for the Indian textile industry.

With best wishes,

Dr. Aadhar Mandot
Hon. Editor

T. L. PATEL, President

Economic growth of Indian Textile Industry

T. L. PATEL, President

Greetings to all the members of The Textile Association (India)!!!

It is my privilege to address you through this edition of our esteemed bi-monthly journal. The textile industry in India has a rich heritage and plays a pivotal role in the economic growth of our nation. As we navigate through these dynamic times, it is crucial for us to stay informed, connected, and work collaboratively to overcome the challenges and leverage the immense opportunities that lie ahead.

The textile sector in India has witnessed remarkable advancements in terms of technological innovation, sustainability practices, and diversification of product portfolios. From the traditional handloom and handicraft segments to the modern, high-tech manufacturing units, our industry has demonstrated remarkable resilience and adaptability.

As the President of The Textile Association (India), I am proud to witness the collective efforts of our members in driving the industry forward. Your unwavering dedication, innovative mind-set, and commitment to excellence have been the driving force behind the textile sector's growth and global recognition.

I urge all of you to continue your relentless pursuit of excellence, strengthen your industry linkages, and explore new avenues for collaboration and knowledge-sharing. Together, we can reinforce the position of the Indian textile industry as a global leader, renowned for its quality, creativity, and sustainability.

I look forward to working closely with all of you and contributing to the collective success of our vibrant textile ecosystem.

T. L. PATEL
President
The Textile Association (India)

Risk Return Relationship of Indian Textile Companies during Pre & Post Covid-19

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Abstract:

Background: One of the oldest and fastest-growing industries in the world is textile manufacturing. It's an essential and significant component of the Indian economy in terms of output, foreign exchange profits, and creating jobs. The global COVID-19 pandemic has impacted almost every nation on Earth. COVID-19 has not only seriously endangered human life but also seriously upset the social, political, administrative, religious, and economic order on a worldwide scale. The stock markets all around the world have crashed.

Methods: This research aims to investigate the risk-return relationship of Indian textile companies both during and after the COVID-19 pandemic. The only source of data for this study is secondary data. Data has been gathered from the NSE websites to examine the risk and return relationship of Indian textile companies both during COVID-19 and after the COVID-19 pandemic. We have gathered the stock prices of Indian textile firms from 2018–19 to 2022–2023 (April–March). Then, to determine their true earnings, risk, and volatility, returns, standard deviation, and beta were taken into consideration.

Results: It was discovered that the companies' returns performed worse when compared to the benchmark index. The market index returns and the returns of individual equities showed varying degrees of weak to substantial association.

Conclusion: The pandemic affected the stock price positively and negatively for major stocks listed in the textile sector. This demonstrates that the impact of COVID-19 was felt by the Indian textile industry as well

Keywords: *Covid 19, Risk, Return, Stock performance, Textile*

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1. Introduction

The textile manufacturing industry is one of the oldest and fastest-growing industries in the world. The textile industry in India is the largest and most influential sector of the economy in terms of output, foreign exchange profits, and employment generated. Its relevance for social and economic cohesiveness is strengthened since it is dominated by a large number of small and medium-sized firms, which are often concentrated in certain regions and greatly contribute to their wealth and cultural legacy. This industry's propensity for non-random spatial concentration, with distinct patterns of productive specialization in some areas, is a crucial feature [12]. India's textile and apparel sector is thought to have significant export potential and generates a lot of jobs. It is a priority sector according to notifications from the Planning Commission, the National Manufacturing Competitiveness Council, and the NMP. The textile sector in India offers a suitable sample basis for comparing manufacturing productivity based on scale. It leads the industry for small-scale, or micro, small, and medium-sized, enterprises (MSME), as well as having an adequate number of large-scale businesses [2]. India has one of the most diversified textile industries in the world, ranging from the highly capital-intensive complex mills sector to the hand-spun and hand-woven textiles sector. The knitting, hosiery, and distributed power loom sectors make up the majority of the textile business.

Dating back several centuries, the textile industry in India is one of the country's oldest sectors of the economy. Approximately 15% percent of India's overall exports come from the textile industry, making it one of the biggest contributors even today. It is among the biggest employers and labor-intensive as well. The hand-spun and hand-woven textile industries are at one extreme of the Indian textile industry's diversity spectrum, while the capital-intensive modern mills sector is at the other. The majority of the textile industry is made up of the decentralized power loom, hosiery, and knitting industries.

Remarkably, the Indian textile sector has undergone structural upheaval, constantly resurrecting and reinventing itself to cater to the demands of international consumers. Indian businesses have begun raising the standards and pursuing their HR strategies with vigor to enhance their brand and foster general growth. India is a global leader in yarn and fabric production, with consistently rising export quality goods. The Indian textile industry is highly innovative, self-sufficient, and autonomous.

The robust local and foreign demand is expected to support the growing Indian textile sector in the coming years. The retail industry has grown rapidly over the last ten years due to

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increased consumerism and disposable income. The entry of significant international corporations like Marks & Spencer, Guess, and Next into the Indian market has made this easier. It is estimated that the Indian apparel market will have expanded at a Compound Annual Growth Rate (CAGR) of 11.8 percent, or 180 billion US dollars, by 2025.

1.1 Growth of the Textile Industry in India

Among the oldest and fastest-growing sectors in the world, the Indian textile industry is particularly significant to the country. The country became a sourcing hub with a competent workforce because of the easy access to raw materials including cotton, silk, wool, and jute. The Indian economy also heavily relies on the textile industry primarily reliant on producing and exporting textiles.

It accounts for about 14% of industrial production, 4% of GDP, 17% of export revenue, 18% of industrial sector employment, and 27% of the nation's total foreign exchange profits from textile exports. In India, the textile sector is the second-largest employer after that. 45 million people are directly employed by it, and millions more trained and unskilled workers can still find work in this business (IBEF, 2019). India is home to the world's largest textile and apparel industry, both domestically and internationally. The nation began exporting in the mid-1960s and is known for its beautiful workmanship [6]. Since then, the industry has helped the country achieve extraordinary socioeconomic growth during the past 40 years. At present, the industry is valued at US$ 200 billion. Its contributions to India's industrial production in the country amount to 13%, its export revenues to 16%, its gross domestic product to 3%, and around 45 million direct jobs [7].

2. Literature Review

2.1 Effect of Covid 19 on Textile Industry

One of the oldest businesses in the Indian economy, the textile industry dates back several centuries. Even now, accounting for over 15% of all exports, the textile industry remains one of the biggest contributors to India's export earnings. The textile sector is one of the biggest employers and one that requires a lot of work [9]. As a result of the coronavirus pandemic (COVID-19), the World Health Organization (WHO) declared a worldwide emergency on January 30, 2020. On June 29, 2021, there were 180,817,269 lab-confirmed COVID-19 cases and over 3,923,238 deaths globally. Lockdowns, quarantines, and rigorous global containment efforts (government-imposed travel restrictions) could not reduce the incidence of COVID-19 cases [10]. The year 2020 began with the global COVID-19 epidemic, which has affected nearly every country. Along with posing a serious threat to human life, COVID-19 has severely disrupted global social, political, administrative, religious, and economic order. The cancellation of the biannual fashion week by the Design Council of India severely undermined the designers' promotional strategies. Retail sales stopped and malls across the country were forced to close as a result of the enforced social separation. The losses Increased over time since the local businesses were ill-prepared to move their sales online [6].

The globe is facing challenges on all fronts due to the novel coronavirus, including economics, healthcare, politics, planning, and societal values in general. This has never happened before in human history. It is the worst nightmare of the policymakers, attempting to lessen its fatal effects on society and the economy while also seeking to slow its spread. The world was unprepared to handle a situation of that size when it happened. A lockdown appeared to be the only practical way to try and slow the virus's spread. On March 21, 2020, India also declared a nationwide lockdown, which is thought to be among the strictest lockdowns in the world [10].COVID-19 has affected the economy of any country extensively [15]. The government of India has taken many corrective steps to meet this situation correctly and establish a balance between the demand and supply side for industries.

Even before the COVID-19 pandemic, the textile and clothing sector had lower cash reserves and larger debt ratios than other sectors, making it more financially vulnerable. The entire financial market eventually felt the repercussions of the pandemic, and the textile and apparel industry in particular saw a sharp reduction in firm performance as investor confidence was lowered due to COVID-19 worries [1] Nonetheless, the COVID-19 epidemic has hurt the textile industry's expansion. A large number of textile factories have closed. Owners of textile businesses have been forced to make tough decisions due to the crisis, including reducing salaries, terminating employees, and asking for unpaid leave [5]. The COVID-19 pandemic had a comprehensive impact on the fashion and textile industry in India. Kanupriya states that to comprehend the effects of a crisis, one must consider both the demand-side (social distance, consumer demand, and exports) and supply-side aspects (production, supply chain, employment, pricing of key raw materials, and imports). Regarding demand for the industry, consumer behavior during the crisis has significantly decreased. The nation's small- and mid-size clothing firms, as well as designers, are suffering as a result of closed retail locations. Throughout the world, the stock markets have collapsed [5]. Stock price collapse invariably resulted in significant losses for investors. Fears about the crisis and how it would affect the international economy quickly expanded to other parts of the world. Global markets saw similar falls following the U.S. market's worst-ever point declines, according to the China Daily report "Coronavirus: US stocks see worst fall since 1987" on March 17, 2020. That is, especially in situations like these, the U.S. market's performance served as a leading indication of the highs and lows of the world market [3].

3. Research Gap

Based on the previous studies, it can be inferred that numerous studies have been conducted about the effects of COVID-19 on the textile industries worldwide, including India. These investigations have focused on various elements such as supply and demand, supply chain tactics put in place during the pandemic, and more. However, to the best of our knowledge, no one examined the risk and return relationship of the Indian textile companies that are listed in NSE during COVID and post-COVID. Our research on the Risk and

Return connection of Indian textile enterprises was motivated by the findings of our analysis of the effects of COVID-19 on textile production, demand, and supply circumstances, as well as the effects on exports and imports.

3.1 Objectives of the study

- To study the Risk-Return relationship of Indian textile companies during pre and post covid
- To determine stock performance during COVID-19.

3.2 Scope of the study

One of India's oldest economic sectors, the textile industry dates back several centuries. India still receives a significant portion of its exports from the textile industry. It has a unique place in the nation. This is mostly because the country is a sourcing hub for raw commodities like cotton, silk, wool, and jute and has a trained labor force. In the Indian economy, it is also quite important. The year 2020 began with the global COVID-19 epidemic, which has affected nearly every country. Along with posing a serious threat to human life, COVID-19 has severely disrupted global social, political, administrative, religious, and economic order. Throughout the world, the stock markets have collapsed [5]. Considering the S&P 500 as a comparative benchmark, the study focuses on the risk-return relationship of these textile companies and determines market performance during and post-COVID period.

4. Research Design

4.1 Methodology

The only source of data used in the present study is secondary. Data has been gathered from the NSE websites to examine the risk and return relationship of Indian textile companies both before and after COVID-19. The stock prices of Indian textile companies from 2018-19 to 2022-23 (April-March) have been collected. The stock performance of these companies during the COVID-19 period has been determined. Then, Returns, Standard deviation, and Beta were considered to know their actual Earnings, Risk, and Volatility.

4.2 Evaluation Parameters

i. Standard Deviation:

A stock's overall risks are measured by its standard deviation. It indicates the degree to which the stock's return deviates from the returns of the benchmark.

ii. Beta

Regression analysis is used to compute beta, which measures how sensitively a security's returns respond to changes in the market. When a security's beta value is 1, it suggests that its price will follow market movements. If a security has a beta of less than one, it will be less volatile than the market. The price of the asset will be more volatile than the market if the beta is more than one.

5. Results and Discussions

This study focuses on data analysis and interpretation. Specifically, the researcher calculated examined, and interpreted the data gathered from secondary sources through the websites of the S&P Indices, NSE Indices, and other websites. For the study, the researchers primarily took into account the following evaluation parameters:

- Returns.
- Beta.

5.1 Stock returns

In the present study, the authors have collected data from 192 Textile companies listed in the Sensex and randomly selected 147 companies for the risk and return analysis. The data have been collected for the recent five financial years from 2018-19 to 2022-23.

Table 1- Returns of the selected companies

Year	Above Median Value = (1.76112)	Below Median Value = (1.76112)
2018-19	147 (100%)	NIL
2019-20	128 (More than or equal to 6)	19
2020-21	NIL	147 (100%)
2021-22	NIL	147 (100%)
2022-23	147 (100%)	NIL

The benchmark S&P returns have been compared to the stock returns of each company. For analytical purposes, the benchmark index's median return was used, and in 2018–19, every company outperformed the benchmark index.

Even with the initial impact of COVID-19, 128 companies' returns have surpassed those of 2019–20. The textile industry was not significantly impacted by the COVID-19 outbreak since it was still in its early phases. The returns of these companies outperformed the benchmark index's performance.

During the years 2020–2021 and 2021–2022, these specific companies' performance was negatively impacted by the Covid-19 epidemic. These stocks have underperformed in the benchmark returns.

Over the year, the benchmark return for 2022–2023 changed. The textile sector rebounded after the COVID-19 epidemic, with every selected enterprise exceeding the standard.

Beta: A beta of more than one implies that the stock is more volatile in the risk analysis, while a beta of less than one indicates that the stock is less volatile. The author's analysis of the study revealed that every stock in the sample had a beta of less than 1.0, indicating lower market volatility.

Correlation: The stock returns of all companies are compared with the returns of the benchmark index (S&P)

Table 2 - Correlation between S&P BSE and Textile companies

Year	< 0.30 (Week)	0.30-0.70 (Moderate)	> 0.70 (Strong)
2018-19	39	84	24
2019-20	38	57	52
2020-21	53	82	12
2021-22	106	41	0
2022-23	59	76	12

According to the study, 57.14% (84/147) of the studied companies demonstrated a moderate level of performance in terms of returns in 2018–19, with 26.53% and 16.33% exhibiting weak and strong performance, respectively. The year 2019–20 saw a moderate–strong connection, with 38.77% (57/147) of the selected companies exhibiting a moderate correlation and 35.37% (52/147) demonstrating a strong correlation.

The correlation in 2020–21 varied from week to moderate. Of the 147 companies, 55.78% (82/147) demonstrated moderate correlation and 36.05% (53/147) showed weak correlation. This demonstrates the effect of COVID-19 on textile manufacturers.

72.10% (106/147) of the firms in 2021–2022 showed a weak correlation between the benchmark and the stocks. The weak correlation can be attributed to the COVID-19 epidemic, which impacted most industries, including the textile and apparel sectors. The industries worked to regain market share up until 2021–2022. The market began to gradually expand again in 2022–2023 and returned to the state where the correlation was between weak and moderate.

5.2 Stock Performance during Covid 19

Table 3 - 1st Covid wave Impact– 31/03/2020 March to 31/11/2020 November

Negative impact	Positive impact	No impact
ABFRL	ARVND	ABSC
ACML	AYMS	AKII
ARVINDFA	CENK	AMSP
BATA	DGJM	AXITA
BD	DOLLAR	BANSAL
BHIT	GNPL	BHX
BWSL	GTFL	BLB
CVC	ICNT	DCM
FLFL	KPR	DCMVL
GBGLOBAL	LBS	DMT
ICC	PAG	LUX
KTG	PRTM	RLXF
MUNI	TTAN	SREE
RW	VARH	ZE
SIYA		
SPAL		
TCNSBR		
VIP		
ZDC		

Note: All the stocks are Indian listed i.e. In Equity

The above-mentioned stocks for both 1st and 2nd wave pandemics are majorly impacted stocks, the highlighted stocks have too much volatility and have a major impact of COVID-19.

5.3 Analysis

The COVID-19 pandemic has impacted many stocks positively, and negatively, and for some stocks, there was no impact at all. The stocks listed in the above table had major implications. The stock of companies such as ABFRL, BATA, BD, FLFL, GBGLOBA, and RW were too volatile and fluctuating. These stocks' prices have been impacted negatively. The price of ABFRL fell from 247 Rs to 167 Rs within three months of the pandemic. In the same way, the price of BATA fell from 1650 to 1318 for just 3 months of the horizon of a pandemic. BD stock price fell from 94.45 to 61.19 Rs. FLFL price fell from 414.15 to 76.1 which has been decreased to the extent of 81.6% this Represents a huge negative impact on the FLFL. GBGLOBAL price fell from 774 to 514 Rs. RW stock price fell from 504 to 272 Rs. These are the stocks that have been impacted negatively. Stocks such as CENK have been positively impacted because of the pandemic, the price increased from 159 to 211 Rs within a 3 3-month horizon i.e. 32.7% increase. GNPL prices have been increased from 257 to 327 Rs. LBS price has been also impacted positively from 102 to 153 Rs during the pandemic period from March 2020 to May 2021. PAG price also indicated positive growth in share price from 22146 to 22746 Rs which is trading at a high price compared to other stocks in this particular sector. Even PRTM price has also increased within a horizon of 3 months during the pandemic from 32 to 84 Rs. These are the stocks that had a positive impact. Some stocks, like ABSC, AKII, AXITA, LUX, RLXF, SREE, ZE, etc had no impact.

Table 4 - 2nd Wave Impact

Negative impact	Positive Impact	No impact
DGJM	ABFRL	ALOK
GBGLOBAL	ACML	ASHM
GNPL	ARVINDFA	FLEXI
JAKHARIA	BATA	ITFL
LGHL	BHTI	JAIPURKU
PAG	CENK	MOCF
SELM	CVC	MUNI
STD	FZT	PASHCL
UPGL	DOLLAR	PDSL
VEKASL	GEXP	ZDC
VIFL	GTFL	
UREL	ICC	
VTEX	ICNT	
	KDDL	
	KEKL	
	LUX	
	RW	
	SPRT	
	VARH	

5.4 Analysis

The 2nd wan wave of COVID also had an impact on several stocks positively, and negatively, and for some stocks, there was no impact. Some stocks which had a negative impact in the 1st wave had a positive impact in the 2nd wave, and BATA which had a negative impact in the first wave, had a positive impact in the 2nd wave. BATA price increased from 1312 to 1619 Rs. GNPL had a positive impact in the first wave, and the aftermath of the first wave impacted positively GNPL share price, which increased from 400 to 524 Rs. SELM stock price had a huge negative impact there was a greater extent of decrease in the price from 2350 to 1350 Rs, a difference of 1000 Rs decreased within two months of the horizon. ACML's stock price decreased in the first wave, whereas in the second wave, its stock price started to increase, the stock was trading at Rs 527 at the end of the first wave, and aftermath of the second wave the stock was trading at 1571 Rs which is 198% of increase. CENK stock price continued with a positive increase even in the second wave. Even the stock price of CVC increased from 697 to 1937Rs within a month's time horizon. DOLLAR stock price has also increased from 135 to 311 Rs. LUX stock price also increased from 944 to 3105 Rs which represents a 228% increase. These were the major impacts on the stocks because of the pandemic effect. Some stocks such as ALOK, ASHM, FLEXI, ITFL, etc had no impact on the stock performances because the stock price fluctuated normally and stable.

6. Discussions

In the comparison of stock returns of the textile companies with the benchmark indices S&P we observe that before the Covid-19 epidemic, all the textile companies were fetching good returns compared to the benchmark index. It followed till the announcement of the countrywide lockdown in March 2020. (Median return of the benchmark was taken as base). Even with the initial impact of COVID-19, 128 companies' returns have surpassed those of 2019–20. The textile industry was not significantly impacted by the COVID-19 outbreak since it was still in its early phases. The returns of these companies outperformed the benchmark index's performance. The COVID-19 pandemic had a detrimental effect on these particular companies' performance in 2020–2021 and 2021–2022. These stocks have not met the benchmark returns.

The author discovered that every one of the chosen equities had a beta of less than 1.0, indicating that the stocks were less volatile than the market. The year 2020–21 saw a range of correlations, from weak to moderate. In 2021–2022 showed a weak correlation between the benchmark and the stocks. The COVID-19 pandemic, which affected the majority of industries, including the textile and garment sectors, is responsible for the weak correlation. Up until 2021–2022, the industries tried to reclaim market share. In 2022–2023, the market started to progressively grow once more, reaching a state where the correlation was between weak and moderate. COVID-19 has severely disrupted global social, political, administrative, religious, and economic order. Throughout the world, the stock markets have collapsed [5]. All these findings show that the Indian Textile companies are also not an exception among the companies who experienced the downfall in the market.

7. Conclusion

Over the past 40 years, the sector has contributed significantly to the nation's remarkable socioeconomic growth. The year 2020 began with the global COVID-19 epidemic, which has affected nearly every country. There was a decline in the performance of the capital market throughout that period. The pandemic affected the stock price positively and negatively for major stocks listed in the textile sector. The current study discovered that the companies' returns, particularly in the years 2020–21 and 2021–22, performed worse when compared to the benchmark index. The correlation between the returns of the market index and individual stocks ranged from weak to moderate. In conclusion, this gives evidence that the Indian textile sectors were not an exception to the effect of Covid 19.

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'A Study on Impact of Digital Marketing on Customer Buying Behavior towards Electronic Goods – A Case Study

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Abstract:

The aim of the paper is to study the impact of digital marketing on consumer buying behavior towards electronic goods for the fulfillment of the above stated objective, A Study on impact of digital marketing on consumer buying behavior towards electronic goods: Case study of Hyderabad city, we have made a questionnaire inspired from the previous studies done on this topic and collected the responses of 200 respondents. Findings indicate that majority of respondents use the online shopping because they find wide variety of products online followed by the respondents using the online shopping because they find lower prices there. Majority respondents are satisfied with the items bought through digital channel. Most of the respondents use the websites to purchase online e-goods an important conclusion is that respondents of age group 18-30 years are highly affected with the digital marketing and purchase the items more often followed by the respondents of the age group 31-45 years. We can also see that the respondents of age group above 45 years are least affected with the digital marketing followed by the respondents of age group less than 18 years.

Keywords : *Consumer Behavior, Buying Behavior, Digital Marketing, Online Shopping, Electronic Goods*

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1. Introduction

Marketing includes the identification of needs of the prospects, producing and delivering the product and services which can satisfy the needs of them. So, marketing refers to satisfy the needs and wants of the target consumer. Marketing includes the Promotion, Creating awareness of the Product and Service. Marketing Activities includes advertising, promoting, selling and delivering. The customer who utilizes the product or service, as well as other businesses. The use of technology in marketing enables precise knowledge of customers' preferences, behaviours, and purchasing trends, all of which are used to design the most effective marketing strategy for those customers [3]. Various digital marketing platforms can be utilized to advertise products and services to both existing and prospective customers. E-marketing, web-marketing, and internet marketing are additional terms used to describe digital marketing. It assists them in locating the ideal customers for their products and services. Digital marketing refers to the practise of advertising goods and services through various electronic platforms. The primary objective of digital marketing is to attract both current and potential customers by allowing them to interact with the company through various digital media. Business and marketing practises have changed as a result of the pervasive use of information and communication technologies, particularly the Internet. The act of making tangible goods accessible for purchase over the internet is referred to as electronic commerce.

Customers typically find a product by visiting the retailer's website or by using a purchasing search engine to locate additional sellers. This demonstrates the availability and pricing of identical products at a variety of online retailers [6], by 2020, customers will be able to make Internet purchases using a variety of computers and other electronic devices, including desktop computers, notebook computers, tablets, and smartphones. Business-to-consumer, or B2C, online shopping evokes the physical analogy of purchasing products or services at a traditional "brick-and-mortar" store or retail centre. Business-to-business (B2B) internet purchasing, also known as B2B shopping, is the process of establishing an online store that allows businesses to make purchases from other businesses. On a conventional online store, customers can peruse the company's product and service offerings, view photographs or videos of the items for sale, read product descriptions, learn about the features of the products, and view the prices of the products. Customers who shop online frequently use the "scan" features to narrow down their search to particular manufacturers, brands, or products. In order to successfully complete an online transaction, customers must have access to the Internet and a valid form of payment, such as a credit card, a debit card with Interac capabilities, or a service like PayPal. For digital products such as apps and digital audio songs, the e-retailer typically transmits the file to the purchaser via the Internet. The three businesses that rule the online retailing sector are Alibaba, Amazon.com, and eBay.

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i. Consumer behavior

Consumer behaviour is the study of individuals, groups, or businesses and the processes they use to select, acquire, use, and dispose of products, services, experiences, or ideas to satisfy their needs and desires. The study of consumer behaviour can be used to accurately predict the future and better comprehend the past.

ii. Online buying behavior

Online purchase behaviour, internet purchase behaviour, and buying behaviour are additional terms that are used to describe consumers' online purchase behavior [5]. Linear relationships exist between online activity and variables such as logistical support, product characteristics, e-stores, knowledge characteristics, and the homepage. The conversation According to a previous study, people who lead wired lifestyles and have limited leisure time spend less time buying goods online.

iii. Factors influencing online consumer behavior

A variety of variables, including social, cultural, educational, racial, personality, climate, and resource availability, influence an individual's online purchasing behaviour. Simply stated, there are a variety of factors at play. In other words, it is a complex combination of numerous components. It depends on a variety of variables, some of which are within our control and others over which we have no influence. We cannot control certain aspects of an online transaction, such as the environment and the customer's personality. However, there are other aspects of an online transaction that we can influence, such as the characteristics of the product or service, etc. Identifiable attributes that can be used to identify the products or the store selling them. The presence of an attractive website, the promotion of trust, and the provision of comprehensive information regarding the products and services under consideration all contribute to a more favorable purchasing decision.

iv. Digital marketing on consumer buying behavior towards electronic goods

The Internet provides a digital medium for seller-buyer commercial communication. As a result, those interested in learning more about various options and products have access to a more direct channel of communication [10]. Technology-enabled digital platforms have a variety of communication tools that aid in reaching the appropriate populations and meeting the necessary requirements. The fact that there are benefits does not negate the fact that there is a disadvantage, which is an excessive amount of information that consumes time and can lead to impulsive purchases by customers. The purchase of electronic products is very common and can be accomplished with relative ease using conventional brick-and-mortar methods. In addition to this, enticing window exhibits, attentive and personalised service, appealing discounts, and buy-back policies all play a role in luring consumers. Digital networks will only become more prevalent. But the research of internet buyer behaviour will give an insight on the trends and impact. This will enable marketers to review their strategies suiting to current requirements making it more impactful.

In the context of business, "digital marketing" refers to a marketing strategy that promotes products and services via the Internet and other online-based digital technologies, such as desktop computers, mobile phones, and other digital media and platforms. Consumer behaviour refers to the study of individuals, groups, or organisations as well as all of the activities associated with purchasing, utilizing, and discarding products and services. Consumer economics is another name for this discipline of study. Consumer behaviour is the study of how consumers' beliefs, opinions, and proclivities influence their purchasing decisions.

The objective of the Consumer Behavior Reports was to provide media organisations, market analysts, and business owners with beneficial information regarding trends in online purchasing, consumer behaviour, product pricing, and market share. A consumer behaviour study found that of the 10% of online shoppers who have made a purchase using their mobile phone, the majority (58%) have done so to acquire digital content for their phone. Although some consumers have not advanced beyond rudimentary mobile personalization and casual gaming, some internet consumers have made substantial purchases from their mobile phones, such as: consumer products (51%), computers (37%), books (36%), clothing (20%), and jewelry (20%). Consumer Behavior Report from April 2009

Consumer behaviour in the electronic environment is much more important than in the real world, and a crucial understanding can be attained if the factors that influence purchasing decisions are ignored and made evident. Online consumers dread the opportunity to physically scrutinize the product, which is a particularly influential factor in the purchase decision. As a result, consumer behaviour patterns in traditional environments may diverge significantly from those in online environments.

v. Objective

A Study on impact of digital marketing on consumer buying behavior towards electronic goods: Case study of Hyderabad city

vi. Literature review

Aimed at gaining more insight in the effect of digital marketing by focusing on the millennial consumer in the retail industry [11]. An exploratory study was conducted with 14 millennial consumers in the Gauteng region and unstructured interviews were used to explore qualitatively the impact of digital marketing on millennial consumers. The findings of the study revealed that millennial consumers found digital marketing useful for their intentions, namely to get better deals on the products and services they had intended to acquire. The study identified possible issues which could hamper the adoption of this form of marketing such as privacy issues. Millennials find advertisements that are visually appealing favorable and they tend to react to advertisements

Explored the influence of such digital marketing on the buying behavior of consumers [8]. This study has used questionnaires for the purpose of data collection from the respondents of Chidambaram who made online purchase. The respondents are selected on the basis of simple random sampling and the sample size of the study is 100. The data collected for the study is put into regression analysis for further interpretation of the data. The study reveals the finding that the digital marketing has got a positive influence over the buying behavior.

Focused on the role digital marketing poses on consumers' behavior and satisfaction [9]. The study further identifies the factors influencing the use of digital marketing in the Nigerian telecommunication industry. The results showed that digital marketing thus has a significant relationship with consumers' behavior and satisfaction. This further indicates that consumers appreciate regular and timely access to information provided on telecommunications products, services, and networks via digital marketing channels in making purchase decisions.

Analyzed the influence of various digital marketing components on the consumer buying behavior towards electronic products [7]. The sample size of the study is 500 respondents who were selected on the basis of judgment sampling. The data was analyzed with the help of factor analysis and regression. It was found from the study that five out of the six constructs of digital marketing influences the consumer buying behaviour significantly.

Providing insights to the understanding of consumer behaviour which has become very complicated with the existence of the world of social media [14]. The findings revealed that impulse buying is affected by the posi- tive attitude towards the recommended advertisings, which are influenced by both informativeness and credibility as values perceived from the recom- mended advertisings. This study provides some useful practical implications for the F-commerce administrators, advertisers, promoters, and consumers.

Examined the impact of social media platforms and brand awareness in relation to the consumer decision-making and buying behavior patterns influenced by social media [2]. The study highlights the benefits of using social media platforms and brand awareness strategies that can be utilized through the online social media systems and gives a contemporary research gap, in how frequent businesses are engaging with social media.

Focused on the standpoint of digital marketing communication of branded cosmetics in Bangladeshi customers [1]. The primary data was collected from Dhaka (Capital of Bangladesh) through online using convenient sampling and the sample size was 665. Chi-square along with hypothesis test was applied. The outcome of the result shows digital marketing communication could trigger on every stage of buying decision behaviour with high involvement in buying branded cosmetics. This study also showed that customers have positive feelings towards digital platforms during this pandemic (COVID-19).

Researched on the influence of digital marketing and digital payment on consumer purchase behaviour in Coburg, Germany [13]. From this research, it is concluded that the availability of extensive information, variety of products, level of satisfaction and level of education are the most essential factors influencing digital marketing and digital payment and this will lead to an increase in the digital payment methods with more security in the future. Also, bitcoin will not be accepted as a future digital payment method.

Determined an enlightening and logical analysis of the numerous aspects related to digital marketing and customer behavior [4]. This paper has shown that digital marketing has a big effect on businesses today, given the growth of social networks and the role of the modern consumer, who prefers digital platforms for a wide range of activities and situations.

Investigated the impact of digitalization on consumer behavior and their choices of virtual shopping in the retail sector of Bangalore [12]. Most people in the Bangalore area prefer to bring their Essentials through offline shopping. It is recommended that companies formulating this virtual shopping introduce their product with relevant details and descriptions.

vii. Research methodology

For the fulfillment of the above stated objective, A Study on impact of digital marketing on consumer buying behavior towards electronic goods: Case study of Hyderabad city, we have made a questionnaire inspired from the previous studies done on this topic and collected the responses of 200 respondents. We have done the graphical study on the responses of 200 respondents to draw the insights from the raw data. Also, we have made the crosstab to check the effect of digital marketing on buying behavior of consumers of different age groups. All the tables, graphs and crosstab are made with the help of SPSS.

2. Data analysis

3. Interpretation

Sr. No.		Category	No. of Respon dents	Percen-tage of Respon-dents
1.	Gender	Male	120	60
		Female	80	40
2.	Age	Below 18 years	26	13
		18-30 years	100	50
		31-45 years	62	31
		Above 45 years	12	6
3.	Profession	Employee	46	23
		Business	38	19
		Student	62	31
		House-wife	30	15
		Any other	24	12
4.	Monthly Income	Below 10000	26	13
		10000-25000	80	40
		25000-50000	60	30
		Above 50000	34	17

Sr. No.		Category	No. of Respon dents	Percen tage of Respon dents
5.	Frequency of	Once Annually	24	12
	Online Purchase	2-5 Purchases Annually	88	44
		6-10 Purchase Annually	68	34
		Above 10 Annually	20	10
6.	Reasons for	Easy Buying Option	16	8
	Online Shopping	Wide Variety of Products	60	30
		Various Methods of Payments	40	20
		Lower prices	52	26
		Others	32	16
7.	Reasons for	Easy Buying Option	16	8
	Online Shopping	Wide Variety of Products	60	30
		Various Methods of Payments	40	20
		Lower prices	52	26
		Others	32	16
8.	Customer	Strongly Agree	70	35
	Satisfaction in	Agree	74	37
	Purchase through	Neutral	38	19
	Digital	Disagree	12	6
	Channel	Strongly Disagree	6	3
9.	From which	Social Media	64	32
	Digital Channel	Websites	84	42
	you bought	Email	4	2
	products	Advertising	38	19
		Others	10	5
10.	Availability of	Excellent	66	33
	Online	Good	78	39
	Information	Average	44	22
	about Product	Poor	12	6

From the collected data of 200 respondents and using the above table we can classify the respondents based on their gender, age group, income and profession etc. From the table we can interpret that 60% respondents are male and the rest 40% respondents are female. Similarly, 13% respondents belong to age group less than 18 years, 50% respondents belong to age group 18-30 years, 31% respondents belong to age group 31-45 years and the rest 6% respondents belong to age group above 45 years. Similarly, 23% respondents are employees, 19% are enrolled in business, 31% are students, 15% are house wives and the rest 12% are enrolled in some other profession. Similarly, 13% respondents are having less than 10k monthly income, 40% respondents are having 10-25k monthly income, 30% respondents are having 25-50k monthly income and the rest 17% are getting more than 50k per month. Similarly, 12% respondents do online shopping once in a year, 44% respondents do online shopping 2-5 times annually, 34% respondents do online shopping 6-10 times annually and the rest 10% respondents do online shopping more than 10 times annually.

8% respondents use the online shopping because they find it providing easy buying option, 30% respondents use the online shopping because they find wide variety of products online, 20% respondents use the online shopping because they find there various methods of payments, 26% respondents use the online shopping because they find lower prices there and the rest 16% respondents use the online shopping because they find some other benefits there.

35% respondents are strongly agree with the satisfaction provided through digital channel shopping, 37% respondents are agree with the satisfaction provided through digital channel shopping, 19% respondents are neutral with the satisfaction provided through digital channel shopping, 6% respondents are disagree with the satisfaction provided through digital channel shopping and the rest 3% respondents are strongly disagree with the satisfaction provided through digital channel shopping.

32% respondents use social media platforms for buying online products, 42% respondents use websites for buying online products, 2% respondents use email for buying online products, 19% respondents use advertisements for buying online products and the rest 5% respondents use some other ways to shop online.

33% respondents says that there is excellent Availability of Online Information about the Product, 39% respondents says that there is good Availability of Online Information about the Product, 22% respondents says that there is average Availability of Online Information about the Product and the rest 6% respondents says that there is poor Availability of Online Information about the Product.

4. Pros of digital marketing:

Figure 1 - Digital Marketing

a. Interpretation

From the collected data on 200 respondents and using the above bar graph we can interpret that 44 out of 200 respondents strongly agree with the fact that digital marketing is very convenient in the context of shopping of electronic goods, 112 out of 200 respondents agree with the fact that digital marketing is very convenient in the context of shopping of electronic goods, 30 out of 200 respondents are neutral with the fact that digital marketing is very convenient in the context of shopping of electronic goods, 10 out of 200 respondents disagree with the fact that digital marketing is very convenient in the context of shopping of electronic goods and the rest 4 out of 200 respondents strongly disagree with the fact that digital marketing is very convenient in the context of shopping of electronic goods.

Similarly, 28 out of 200 respondents strongly agrees with the fact that website features are affecting the consumer buying behavior of electronic goods, 106 out of 200 respondents agrees with the fact that website features are affecting the consumer buying behavior of electronic goods, 40 out of 200 respondents neutral with the fact that website features are affecting the consumer buying behavior of electronic goods, 14 out of 200 respondent disagree with the fact that website features are affecting the consumer buying behavior of electronic goods and the rest 12 out of 200 respondents strongly disagree with the fact that website features are affecting the consumer buying behavior of electronic goods.

Similarly, 50 out of 200 respondents strongly agree with the fact that the digital/online marketing is helpful to save their time while shopping, 120 out of 200 respondents agree with the fact that the digital/online marketing is helpful to save their time while shopping, 18 out of 200 respondents are neutral with the fact that the digital/online marketing is helpful to save their time while shopping, 9 out of 200 respondents disagree with the fact that the digital/online marketing is helpful to save their time while shopping and the rest 3 out of 200 respondents strongly disagree with the fact that the digital/online marketing is helpful to save their time while shopping.

Only 8 out of 200 respondents strongly agree with the fact that digital marketing is secure way for shopping of electronic goods, 90 out of 200 respondents agree with the fact that digital marketing is secure way for shopping of electronic goods, 42 out of 200 respondents neutral with the fact that digital marketing is secure way for shopping of electronic goods, 40 out of 200 respondents disagree with the fact that digital marketing is secure way for shopping of electronic goods and the rest 20 out of 200 respondents strongly disagree with the fact that digital marketing is secure way for shopping of electronic goods.

b. Risk of digital marketing

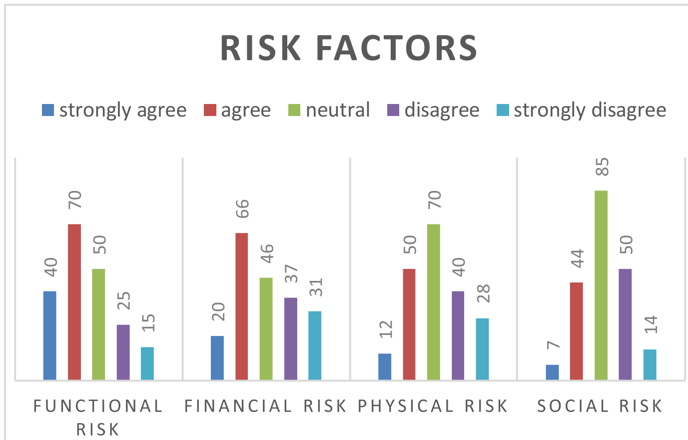

Figure 2 – Risk Factors

Interpretation: from the collected data on 200 respondents and using the above bar graph we can interpret that 40 out of 200 respondents strongly agree with the fact that there is a possibility of functional risk; i.e., the product may not work as expected in the digital marketing, 70 out of 200 respondents agree with the fact that there is a possibility of functional risk; i.e., the product may not work as expected in the digital marketing, 50 out of 200 respondents are neutral with the fact that there is a possibility of functional risk; i.e., the product may not work as expected in the digital marketing, 25 out of 200 respondents disagree with the fact that there is a possibility of functional risk; i.e., the product may not work as expected in the digital marketing and the rest 15 out of 200 respondents strongly disagree with the fact that there is a possibility of functional risk; i.e., the product may not work as expected in the digital marketing.

Similarly, 20 out of 200 respondents strongly agree with the fact that there is a possibility of financial risk; i.e., the cost of product is more than utility in the digital marketing, 66 out of 200 respondents agree with the fact that there is a possibility of financial risk; i.e., the cost of product is more than utility in the digital marketing, 46 out of 200 respondents are neutral with the fact that there is a possibility of financial risk; i.e., the cost of product is more than utility in the digital marketing, 37 out of 200 respondents disagree with the fact that there is a possibility of financial risk; i.e., the cost of product is more than utility in the digital marketing and the rest 31 out of 200 respondents strongly disagree with the fact that there is a possibility of financial risk; i.e., the cost of product is more than utility in the digital marketing.

Similarly, 12 out of 200 respondents strongly agree with the fact that there is a possibility of physical risk; i.e., the product performs in a way that causes injury to the user in the digital marketing, 50 out of 200 respondents agree with the fact that there is a possibility of physical risk; i.e., the product performs in a way that causes injury to the user in the digital marketing, 70 out of 200 respondents are neutral with the fact that there is a possibility of physical risk; i.e., the product performs in a way that causes injury to the user in the digital marketing, 40 out of 200 respondents disagree with the fact that there is a possibility of physical risk; i.e., the product performs in a way that causes injury to the user in the digital marketing and the rest 28 out of 200 respondents strongly disagree with the fact that there is a possibility of physical risk; i.e., the product performs in a way that causes injury to the user in the digital marketing.Similarly, 7 out of 200 respondents strongly agree with the fact that there is a possibility of social risk; i.e., the product performs in a way that embarrasses the user in the digital marketing, 44 out of 200 respondents agree with the fact that there is a possibility of social risk; i.e., the product performs in a way that embarrasses the user in the digital marketing, 85 out of 200 respondents are neutral with the fact that there is a possibility of social risk; i.e., the product performs in a way that embarrasses the user in the digital marketing, 50 out of 200 respondents disagree with the fact that there is a possibility of social risk; i.e., the product performs in a way that embarrasses the user in the digital marketing and the rest 14 out of 200 respondents strongly disagree with the fact that there is a possibility of social risk; i.e., the product performs in a way that embarrasses the user in the digital marketing.

4. Crosstab between age of respondents and frequency of online purchase of e-goods

i. Interpretation

From the collected data on the 200 respondents and using the above crosstab we can interpret that respondents of age group 18-30 years are highly effected with the digital marketing and purchase the items more often followed by the respondents of the age group 31-45 years. We can also see that the respondents of age group above 45 years are least affected with the digital marketing followed by the respondents of age group less than 18 years.

ii. Data analysis

Findings indicate that majority of respondents use the online shopping because they find wide variety of products online followed by the respondents using the online shopping because they find lower prices there. Majority respondents are satisfied with the items bought through digital channel. Most of the respondents use the websites to purchase online e-goods.120 out of 200 respondents agree with the fact that the digital/online marketing is helpful to save their time followed by the 112 out of 200 respondents agree with the fact that digital marketing is very convenient in the context of shopping of electronic goods.70 respondents agree with the fact that there is a possibility of functional risk; i.e., the product may not work as expected in the digital marketing, followed by the 66 respondents agree with the fact that there is a possibility of financial risk; i.e., the cost of product is more than utility in the digital marketing. An important conclusion is that respondents of age group 18-30 years are highly affected with the digital marketing and purchase the items more often followed by the respondents of the age group 31-45 years. We can also see that the respondents of age group above 45 years are least affected with the digital marketing followed by the respondents of age group less than 18 years.

Table 2 – Frequency of online purchase of e-goods

age * frquency of online purchase of e-goods Crosstabulation

Count

		frquency of online purchase of e-goods				
		once annually	2-5 prchases annually	6-10 purchases annually	above 10 purchases annually	Total
age	below 18 years	10	16	0	0	26
	18-30 years	1	20	60	19	100
	31-45 years	3	50	8	1	62
	above 45 years	10	2	0	0	12
Total		24	88	68	20	200

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A Short Review- Use of Cyclodextrin for Insect Repellent Textiles

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Abstract

Now a day, for better health personal hygiene is essential, in this regard manufacturing of specialty value-added textiles are booming. Numerous essential oils and aqueous extracts of some plants are encapsulated during textile finishes. Several compounds have been utilized such silica, melamine formaldehyde and urethanes by scientist as protective layer for controlled release. In addition to these above mentioned techniques, cyclodextrins (CDs) are been effectively utilized in textile finishes

Keywords: *cyclodextrin, electrospinning, functional, mosquito-repellency, micro-encapsulation*

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1. Introduction

Textile finishes can be classified into two classes, viz., functional and aesthetic. The functional finishes are intentionally applied to alter properties like durability, care, and comfort. By using chemical wet processing methods functional finishes can be achieved. Common functional finishes are antimicrobial, durable press antistatic, UV protection, flame retardant, self-cleaning, water repellent, soil-resistant, and wrinkle recovery [1].

Aesthetic finishes intensify the fabric apparel properties. They can modify the surface, luster, texture, and drape of textile substrates. Both mechanical and chemical methods can be used to impart such finish; mechanical processes can place greater emphasis on this finishing [2].

Insects have numerous applications that can be considered both beneficial and harmful to human beings and they have a considerable involvement in human life. If we focus on harmfulness of insects then we realize that they transfer many diseases, which may adversely affect human life. Besides these they can potentially damages the agricultural products and materials also [3].

Insect such as mosquitoes, flies, ticks, fleas, lice, ants, chiggers, etc. causes skin irritation, swelling, pain and illness to humans after being bitten [4]. In addition, insects may transfer parasites and pathogens that can disperse numerous diseases to human after biting them. These insects become the vector for annihilating disease pathogens such as malaria, dengue, and yellow fever [5]. Pathogens and parasites are responsible of vector-borne diseases among human beings.

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Vectors are living creatures such as parasitical bugs that outspread the infective diseases either among mankind or from animal to mankind. They suck pathogens along with blood from an infected host (human/animal) and subsequently infuse it into another host. Among the many other Mosquitoes are popular examples of vector [6].

It is found that every single year, more than 500 million people around the globe infected with malaria [7]. Most of the cases leads to death of infected people due to lack of awareness, financial conditions, polluted environment etc. These infectious diseases not only found in sub-Saharan Africa, but also in Asia, Latin America, parts of Europe, Middle East and Pacific countries. In addition to this it is observed that the global existence of dengue has been accelerated in recent decades [8].If we notice that there are more than 3000 species of mosquito, however some of them leads to death and diseases, viz., Anopheles, Aedes and Culex etc.

Ticks are external parasites, living by consumption of the blood of mammals, birds, and sometimes reptiles and amphibians. Tick responsible for diseases which include various diseases such as Lyme disease (most common in United States country) [9], Crimean–Congo hemorrhagic fever, tularemia, babesiosis, ehrlichiosis, Bourbon virus, bovine anaplasmosis and the Heartland virus [10]. Flea, the commonly known as Siphonaptera, comprises more than 2,500 species which live as external parasites of mammals and birds. Fleas outspread the plague [11] among rodents as well as potentially transfer the various disease to humans when they suck their blood [12].

Ants are common around the world, with the largest populations found in rain forests. The sting of jack jumper ants can be lethal for humans [13] while Fire ant stings can result in severe symptoms such as chest pains, nausea, and dizziness to shock, and occasionally cases, coma [14]. For protection against the biting harmful insects, protective clothing is most effective and convenient way to covers most of the human body. There are numerous kinds of insect-repellent products such as sprays, body lotions, stickers, and even wristbands available in the market. Insect-repellent textiles need to be effective long-lasting after multiple washes. Insecticides are the chemical substance used to kill or repel insects. There are two types of insecticides being utilized most one is repellent insecticides another is contact insecticides.

Repellent insecticides repel insects and pests instead of causing their death however contact insecticides comprise the neurotoxins which make insects and pests unconscious when they come in contact [15]. Repellent insecticides force the arthropod (insects and pests) to move away from the host by preventing the activeness of arthropod's sensors and confuse them.

Insect repellents generally classified into two sub classes, (1) Synthetic chemicals and (2) Natural chemicals most of which are oils extracted from various plants such as citronella, lemon, eucalyptus, and permethrin [16]. The importance of insect repellents for human use is very essential, since there are very few vaccines are available as prevention measure and treatment of any disease is also not very cost effective. Hence it become necessary to induce insecticidal chemical finishing textiles and clothing works [17].

It is well known fact that good personal hygiene is very necessary for better health. In this regards inventions and research is been carried out by scientist world-wide and definitely will be carry out in future also [18]. Now a days specialty value-added textiles, such as aromatic textiles [19] are flourishing [20]. Numerous essential oils and aqueous extracts of some plants widely employed in different fields [21]. However, these oils or extract are need to be coated / encapsulated during textile finishes hence, due their high volatility and chemical instability the finishing applied is never long lasting and its effectiveness fades away very soon [22]. In this regards several compounds have been utilized to tackle the above mentioned problem such silica, melamine formaldehyde and urethanes by scientist [23]. In addition to these above mentioned techniques, cyclodextrins (CDs) are been effectively utilized in textile finishes [24].

Cyclodextrins are cyclic oligosaccharides, comprising 5 or more α-D-glucopyranose units linked with 1-4 glycosidic bond [25]. In general CDs contain six to eight units of glucopyranose in a ring form viz., α-CD, β-CD and γ-CD (Figure 1) [26] forming toroid and bucket like structure.

Textile industry is very sensitive towards the price of the finished product in market. The cost effective raw materials and methods are always encouraged by this industry and hence β-CD used more in various applications than α-CD, and γ-CD.

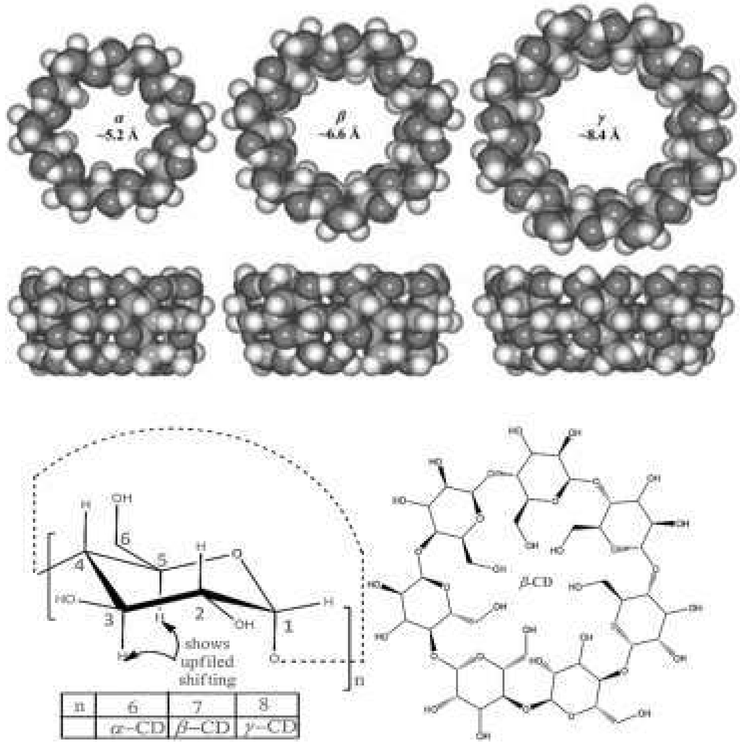


Figure 1: Various forms of structures of cyclodextrins

Textile industry is very sensitive towards the price of the finished product in market. The cost effective raw materials and methods are always encouraged by this industry and hence β-CD used more in various applications than α-CD, and γ-CD.

2. History of Cyclodextrin

The great scientist M. A. Villiers about 130 years ago (1891) isolated crystalline compounds by digesting the starch with Bacillus amylobacter, having composition to be $(C6H10O5)2 \cdot 3H2O$ which subsequently verified to be a cyclodextrin. Initially, M. A. Villiers called these products "cellulosine", due to their resemblance in chemical and physical properties of cellulose. Further, twelve years later, Schardinger, was able to separate two crystalline products, dextrins A and B, which were described as "Schardinger sugars". Further, few more scientist contribute in this research area [27].

3. Cyclodextrins (Cds)

3.1 Properties of Cyclodextrins

The central cavity of cyclodextrin is hydrophobic in nature than the outer surface which is hydrophilic due to -OH (hydroxyl groups). The larger opening of cyclodextrin contains the secondary hydroxyl groups while towards the smaller openings primary hydroxyl groups are present (Figure 2).

The three common Cds (a,#b, g-CD) were profoundly studied [28]. Though the d-CD have nine glucopyranose units in ring form it was proved that the d-CD did not show any major solubilization effect on sparingly soluble chemicals in water with some exemptions. The larger CDs are having collapsed structure in which their actual cavity smaller than a,#b, g-CD hence not suitable to form inclusion complex with guest molecules (Figure 3).

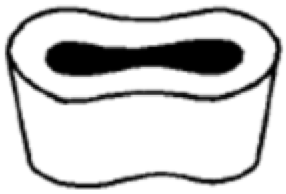


Figure 3: Schematic presentation of "Collapsed cylinder" structure of the a- CD and g-CD in aqueous solution than b-CD it is very difficult to isolate both a- CD and g-CD during their formation which leads to easy availability of b-CD along and inexpensive in market. Hence b-CD is first choice of scientist to use it and explore it. The various physical and chemical properties of CDs are tabulated (Table 1).

Table 1 - The various physical and chemical properties [30] of cyclodextrins

Sr. No.	Property	Cyclodextrin		
		α	β	γ
1	Glucose units	6	7	8
2	Empirical formula (anhydrous)	$C_{36}H_{60}O_{30}$	$C_{42}H_{70}O_{35}$	$C_{48}H_{80}O_{40}$
3	Mol wt (anhydrous)	972.85	1134.99	1297.14
4	Cavity length, Å	8	8	8
5	Cavity diameter, Å (approx)	~5.2	~6.6	~8.4
6	Approx volume of the cavity, $Å^3$	174	262	427
7	Solubility (water, 25°), Mol L^{-1}	0.1211	0.0163	0.168
8	Water of Hydration	~6.0	~12.0	~13.0

3.2 Inclusion complex formation

The cyclodextrins form inclusion complexes (host–guest complexes) with a very wide range of solid, liquid and gaseous compounds without any breaking or making of covalent bonds during formation [31]. The formation of inclusion complex with a guest molecule is depended on two key factors.

a) The first is the relative size of the cyclodextrin to the size of the guest molecule. Wrong sized guest molecules will not fit properly into the cyclodextrin cavity.

b) The second critical factor is the thermodynamic interactions among the cyclodextrin, guest and solvent. The favorable net energetic driving force pulls the guest into the cyclodextrin's cavity and forms the host-guest complexation.

It is found that α-CD suitable to complex low molecular weight molecules or compounds such as aliphatic side chains, β-CD are capable of complexion the aromatics and heterocycles and γ-cyclodextrin can accommodate larger molecules such as macrocycles and steroids. Heating elevates the solubility of the complex but, destabilizes the complex. The heat stability of the complex varies with guest, most complexes are stable up to 50–60 °C, while strongly bounded or highly insoluble complex are stable at higher temperatures also. Water is the most ordinarily used medium in which complexation reactions can be carried out. The availability of CDs for complexation is depend upon the solubilization in provided solvent. Up to certain increased amount of water, the solubility of CDs increases which leads to ease of complexation. However, as the amount of water is increased further, the cyclodextrin and the guest do not get in contact easily which retards the rate of complexation. Volatile guests can be removed complexation by heating. With highly volatile guests, this can be prevented by using a sealed reactor or by refluxing the volatile guests back to the mixing vessel. This property allows to use the CDs for controlled release of guest molecules whenever required. Generally, host-guest complex is stable and having prolonged shelf life at ambient temperatures under moisture free conditions. Replacement of the guest by some other guest requires temperature change. In numerous instance, water can substitute the guest. The Vibrational Raman Optical Activity experimental evidence showed that CDs have conformation flexibility. The theoretical molecular dynamics studies indicate that the CDs are able to modify their shape in order to accommodate different guest molecules. In conclusion, cyclodextrins do not have a rigid truncated-cone structure and due to their flexibility, wide range of inclusion complex can be achieved [32].

4. Applications of Cyclodextrins

4.1 In Synthetic Chemistry

Cyclodextrins have been widely used in organic syntheses, due to its ability of forming inclusion complex with reactive partners and also some time they can catalyze chemical reactions with high selectivity as well as transfer hydrophobic molecules into aqueous medium [33].

4.2 In Pharmaceutical

Cds, are useful in pharmaceutical auxiliaries with versatile smart utility resulting from the inclusion of polymers, have been broadly used as drug delivery systems. Several CD's derivatives used as drug carriers and designed for potential use in a clinical trial. CD's able to form an assembly of cyclodextrin-based Metal-organic frameworks (MOFs) which have the porous features of MOFs and to show encapsulation capability of CD for drug delivery. Recently cyclodextrin is successfully utilized in ocular drug delivery systems, including drug/CD complexes, in nanocarriers and microcarriers as nanoemulsions, nanoparticles, micelles, liposomes, nanosponges, microparticles, and microspheres. Additionally, cyclodextrin are found to be very applicative in formation of various hydrogels such as, supramolecular hydrogels, contact lenses etc., CD-based inserts are also developed by some scientists [34-35].

4.3 In Soil and fertilizer technology

Soil Bioremediation includes the use of living organisms to remediate polluted sites, and is cost-effective and environmentally benign remediation technique. Bioremediation of contaminants consist of various techniques such as bio-degradation using soil microorganisms, phytoremediation using plants, or vermiremediation using earthworms. In addition to these techniques CD's also can be utilized in soil bioremediation. Cyclodextrins (CD's) can be utilized as environmentally benign alternative to organic solvents or synthetic surfactant for growing organics bio-availability in soils. CD's forms inclusion complexes with pollutants which enhance its aqueous solubility and accelerating their bioremediation in soils. Especially hydroxypropyl-β-cyclodextrin (HPBCD) and randomly methylated-β-cyclodextrin (RAMEB) are being utilized due to due to their good water-solubility, biocompatibility, non-toxicity and moderate biodegradability. These CD's derivatives forms inclusion complexes with industrial chemicals waste and pesticides [36-37].

5. Classification of Insect repellents

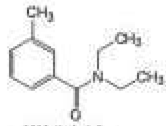
5.1 Synthetic Insect repellents

There is endless market demand for insect repellency in various material such as creams, sprays, non-volatile liquids, merchandising etc [38-39]. It is very difficult to full fill the market demand of insect repellency by using only natural insect repellents. The quality of most of the natural insect repellents can be compromised by various factor such as geographical conditions to grow the specific plants, consistency in active ingredient of isolated material from plant. In addition to these natural insect repellents are biodegradable and hence their activity may be diminished after some time. As being natural material we have to consider the environment factors also which can affect their availability.

All the above mentioned factors leads to invention of synthetic chemical which bears the anti-insect property. Some of the most used synthetic insect repellents are listed below [40],

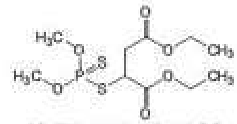
- DEET,
- Picardin,
- Allethrin,
- Permethrin,
- Malathion.

The structure of the above mentioned synthetic insect repellents is as follows,



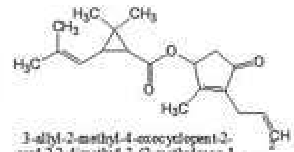
N,N-diethyl-3-methylbenzamide

(DEET)



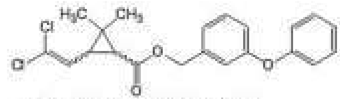
1,2-di(ethoxycarbonyl)ethyl O,O-dimethyl phosphorodithioate

(Malathion)



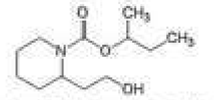
3-allyl-2-methyl-4-oxocyclopent-2-enyl 2,2-dimethyl-3-(2-methylprop-1-enyl)cyclopropanecarboxylate

(Allethrin)



3-phenoxybenzyl 3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate

(Permethrin)



sec-butyl 2-(2-hydroxyethyl)piperidine-1-carboxylate

(Picaridin)

- N, N-Diethyl-meta-toluamide (DEET)

N, N-Diethyl-meta-toluamide commonly known as DEET [41] is one of the largely used the active ingredient insect repellent. Initially application of DEET was studied and effectively used by the US Army in 1946 and afterwards made available in public domain after 1957. The Environmental Protection Agency has patented over 230 DEET comprised products by more than 70 different companies around the various parts of world. DEET is largely utilized as a skin lotion, and its actions carry on for 4to 5 hours. If DEET coated on fabrics directly, it undergoes degradation under even gentle laundering conditions and hence it cannot be applied directly [42].

- Malathion

Malathion is an organophosphate pesticide and broadly applied in agriculture and human residential areas as pest control to achieve mosquito destruction. In some countries such as Australia and California, mixture of corn syrup and Malathion utilized to repel the Mediterranean fruit fly while in Australia it is still in use as anti-mosquito agent. In Canada and the United States, malathion was used against the West Nile virus [43].

- Allethrin

The Allethrin have low toxicity toward humans and the avian organisms. Allethrin used in some household insecticides such as RAIDTM and mosquito coils. Though Allethrin is not deadly to adults, but is lethal to children. Addition to this it is lethal to fish and aquatic invertebrates [44].

- Permethrin

Permethrin is a class of pyrethroids [45], works against the target insect through contact or ingestion act as a mild insect repellent. Pyrethroids kills insects by making the nervous system hypersensitive to sensory stimuli. Permethrin has particularity against insects, and its cis-isomer has the maximum insecticidal activity. Merchandises treated with Permethrin and DEET together, to achieve effectual protection from mosquito-borne diseases such as malaria and dengue.

- Picaridin

Picaridin is not only efficient against mosquitoes and other insects, but also to a dermal irritant. The mode of action of picaridin is still unknown. Picaridin's harmful vapor inhibits the insect by affecting its taste and olfactory senses [46].

5.2 Natural Insect repellents

Some plant bears the active ingredient of insect repellency and can be extracted or isolated from roots, stems, leaves, flowers, fruits, or seeds. Most of these active ingredients are volatile oil in nature however, those are water soluble need to extracted in aqueous conditions. The major concern is regarding their controlled release mechanism during its use. Some important, easy available and easy to isolate natural mosquito repellents are listed below,

- Citronella oil,
- Castor oil,
- Clove oil,
- Eucalyptus oil,
- Cedar oil,
- Rosemary oil,
- Peppermint oil,
- Lemongrass oil,
- Geranium oil,
- Chrysanthemum oil.

Among the all above mentioned insect repellents, Chrysanthemum was found to be superior over the others in insect repellency action. Chrysanthemum shows its activity against mosquitoes for a prolonged period even after exposed to the environment [47].

Citronella oil can be effectively used for mood elevation during depression, deodorizing, sterilizing, and bug repelling. These essential oils can be applied onto cotton fabric by direct application, emulsion application, or micro-encapsulation application method [48]

6. Mechanism of repellent action

The insect repellency against blood-sucking insects such as mosquitoes can be classified into two variety based on the action pathways—

a) Transpiration repellency involves the sensory system of insects. In this category insects do not come in direct contact with surface treated with the active repellent ingredient. Repellent block insect's humidity sensory holes, which stops the moisture sensing capacity. Due to this insect unable to detect rise in atmospheric carbon dioxide concentrations which is indication of human body around themselves.

b) Direct repellency involves the effect on peripheral nervous systems when contact is made by insect. Here the active ingredient forces the insect to avoid and not to touch (ward off) the treated surface before bloodsucking. The active ingredients such as DEET shows behavior-modification in insect and inhibits cholinesterase activity [49].

7. Evaluation methods for mosquito-repellency

The mosquito repellency need to be confirm and quantify using standard methods according to the WHO (World Health Organization) and the American Society for Testing Materials. There are few methods by performing them mosquito repellency can be evaluated. The more common test is Cage test, Cone test, Field test and Excito chamber test etc. Correct evaluation by using sophisticated analytical techniques is the most important aspect for any finished fabric. Scientist has contributed their ideas and construct some working models and testing methods to confirm and quantify mosquito repellency. The mosquito-repellency test was carried out by counting the number of insects landing on the arm covered with treated and untreated fabrics. The treated fabric presented the highest and the long-lasting protection against insects than the fabric sprayed with active ingredients [50].

7.1 Cone test

The cone test [51] is applied to measure the toxicity of insecticide treated bed nets against malaria, which is also capable to analyze the toxicity of other finished textiles. The standard WHO plastic cone was located on top of the treated surface of the sample and secured using a masking tape. Then five to ten female mosquitoes were blown inside the cone with aspirator and the mosquitoes were exposed to the treated surface. The numbers of mosquitoes resting on the treated samples were counted within a 3-min exposure. At the end of the exposure, the mosquitoes were transferred to the plastic cones for further observance. Next, a plastic cup was kept in an insecticide-free air furnished with 10% sucrose solution. The number of paralyzed test mosquitoes was determined 1 h later the exposition and the death rate was observed after 24 h. The mosquito repellency was measured using the following formula below,

$$\%\ \text{Mosquito mortality} = \frac{(MR - MC)}{(100 - MC)} \times 100$$

Where, MR= the mosquitoes' mortality using a test replicate, MC = the mosquitoes' mortality using control samples.

7.2 Cage test

The cage is covered with transparent mosquito nets for easy measurement. It has holes in one side, covered with nets for the introduction of the arms of human subjects. Accordant to WHO accepted standards, the cage needs to be filled with 200 mosquitoes that have been starved all-night and only were provide with sucrose solution. Modify standards uses a lesser number of mosquitoes in the cage at least 30 mosquitoes, which provides high accuracy and better understanding of the typical biting behavior. Volunteers should not be active user of tobacco and should avoid use of fragrance or repellent products for 12 h before the test. The volunteer will insert left arm function as the control while the right arm as the testing of the treated specimen for a period of 3 min. If at least two mosquitoes landed or bite within the 3 min, the test will proceed. If there no mosquito lands within 3 min, the hand will be withdrawn from the cage. The number of mosquito landed counted independently with the digital camera. The exposure is carried out in every 30 min up to 8 h or until the repellency fails. Each test sample was carried out in triplicate at 28#= 2C and 80±5% RH with a 5-min wait period between replicates. The time between use of the treated materials was registered as the protection time. The percentage of repellency or protection time was calculated using the formula below,

$$\%\ \text{Mosquito protection} = \frac{(U-T)}{U} \times 100$$

Where, U = the number of mosquitoes on untreated samples or control samples and T = the number of mosquitoes on treated samples.

7.3 Excito chamber method

The mosquitoes were kept hungry overnight or for a minimum of 4 h before the test. The action of mosquitoes was observed in terms of the number of escaped mosquitoes (to another space) and mosquito's leftover inside the chamber which was filled with the activated mosquito repellent material. The measurement is registered after 10 and 30 min of influence. The test carried out in daylight and repeated four times. The percentage of mosquito repellency was measured using the formula below,

$$\%\ \textit{Mosquito repellency} = \frac{(\text{NES} + \text{NDE})}{\text{NEX}} \times 100$$

where NES = the number of mosquitoes escaped,
NDE = the number of mosquitoes dead and
NEX = the number of mosquitoes exposed.

The observations collected and further processed in ANOVA software for final results. Almost all textile materials are subjected to washing; so the wash durability can be according to AATCC61 and AATCC143 standards.

8.0 Insect repellent finishing on textiles

8.1 Micro-encapsulation method pad-dry-cure technique

Microcapsules could be spherically formed, whereas some others are unsymmetrical and variably formed, with an amount of smaller droplets of core material inserted throughout the microcapsule. Three different states of matter viz., solids, liquids, and gases could be micro-encapsulated. The controlled release of active ingredients from the capsule depends on the density, permeability and biological properties of the polymeric wall. Mechanical stimuli, chemical stimuli, thermal stimuli and diffusion are four mechanisms for releasing the core materials from the encapsulation. The material that is utilized for encasing the core can be termed as the wall material, shell, membrane, or coating. Microcapsules might have single wall or multiple walls of variable thicknesses around the core material [52]. DEET is one of the best insect repellent and it gradually released from the microcapsule. DEET microcapsules repels, inhibits blood-feeding and kills mosquitoes for a period of at least 6 months. Baker and coworkers have filed a patent on mosquito repellent band comprising micro-encapsulated DEET [53].

Micro-encapsulation effectively used in industries such as pharma, food, perfumery, and textile. In textile industry, it can be used for some wet processing such as dyeing, printing, and finishing.

8.2 Cyclodextrin applications

Cyclodextrin gives superior textile finishing to various fabrics such as cotton, cotton blends, and other fabrics. A wash-resistant, and insect-resistant, acrylic fiber with durability of >20 washes was developed by treating fibers with beta-cyclodextrin, isobornyl thiocyanoacetate, and siloxane. Insecticides such as permethrin and bioallethrin were incorporated into the cyclodextrins cavity of the modified cotton fabrics. The results showed that the loading of insecticide on the finished fabrics increased with the increase in the quantity of cyclodextrin which subsequently accelerates the repellent action against mosquitoes. Limonene was incorporated in the cavity of cyclodextrin attached with cotton fabrics via monochlorotriazinyl (MCT-β-CD) [54].

9. Conclusions

The use of cyclodextrins in the textile industry has been enhanced. CDs furnish unusual functional properties. CDs form inclusion complexes hence successfully applied for skin-care substances, bioactive substances such as biocides, insecticides, and drugs. Along with these applications CD's potentially used in manufacturing of value added textiles.

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A Study of Inclusivity in the Fashion and Textiles Industry

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Abstract

Societal beauty ideals for women were always shaped by cultural, historical, and geographic factors that contributed to bias and discrimination. The fashion industry is witnessing a change, with inclusivity and diversity becoming the dominant trends, encompassing age, skin tone, ethnicity, sexual orientation, body size, etc. The fashion industry has recognized the importance of representing diverse voices and perspectives. This shift towards inclusivity and diversity is a positive development.

This study examines perceptions of inclusivity in the Indian textiles and fashion industries. A mixed-methods approach is used to study how these industries comprehend, embrace, and practice inclusivity.

The literature review explores size and gender inclusivity, body positivity, and the effects of social media on the fashion industry. It discusses how brands adopt inclusive approaches to marketing and the overall shopping experience. Luxury brands, once synonymous with exclusivity, align with the concept of inclusivity.

A survey of the Indian population indicated that respondents were knowledgeable about inclusivity in fashion, linking it to "Fashion for All." H&M and Zara were mentioned frequently when discussing inclusive brands in India. Respondents expressed willingness to support and potentially pay more for inclusive brands, although some expressed reservations about higher prices.

The fashion industry actively embraces diversity, challenges norms, and advocates inclusivity. Although progress has been made, significant gaps remain in creating authentic and inclusive fashion experiences to cater to diverse individuals. As the industry continues to evolve, embracing diversity, challenging conventions, and promoting inclusivity will continue to shape the future of fashion, making it a more accessible and empowering space.

Keywords: *Gender Inclusivity, Inclusivity, Indian Fashion Industry, Perceptions, Size Diversity*

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1. Introduction

The perception of beauty has been transformed in the contemporary world, embracing a broader array of attributes. For centuries, societal beauty standards have propagated limited ideals, particularly for women. The quintessential attractive woman has been defined by a slender build, full bosom, narrow waist, curvy bottom, well-defined jawline, high cheekbones, full lips, rosy complexion, and long flowing hair. These standards have been shaped by cultural, historical, and geographical factors deeply rooted in biases and discriminatory attitudes. A slight deviation from these standards was considered exotic, whereas a substantial deviation resulted in individuals being deemed unattractive [1]. Consequently, these individuals were marginalized and excluded from mainstream narratives.

The fashion industry holds a prominent position in society, serving as a platform for self-expression, cultural representation, and identity formation. Fashion is inclusive and universally applicable, transcending the boundaries of age, gender, race, ethnicity, and body type. Fashion has become a global phenomenon, a language understood and spoken by many. The industry has witnessed substantial change, with diversity and inclusion emerging as dominant trends. Diversity in fashion entails promoting a diverse group of individuals who exhibit distinct characteristics, such as age, skin color, race, orientation, and body type. People aspire to be heard, seen and represented [2].

Over the years, the fashion industry has significantly shaped societal norms and influenced individual perceptions. As fashion continues to evolve, there is a growing call for inclusivity, urging the industry to embrace diverse perspectives, challenge prevailing stereotypes, and celebrate individualities. Recently, inclusivity in fashion has garnered increasing attention, fostering a more equitable and representative industry that transcends traditional boundaries and norms.

Inclusion can be defined as 'the act of including someone or something as part of a group, list, etc., or a person or thing that is included' and as 'the idea that everyone should be able to use the same facilities, participate in the same activities,

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and enjoy the same experiences, including people with a disability or other disadvantages' [3].

The Oxford Language Dictionary defines inclusion as the practice or policy of providing equal access to opportunities and resources to people who might otherwise be excluded or marginalized, such as those with physical or mental disabilities or those belonging to other minority groups. From a historical perspective, access to clothing products has not belonged to every class for centuries [4].

1.1 Significance of the Study

This study investigates the extent of inclusivity within the Indian fashion industry, specifically its capacity to incorporate various body sizes and genders. India is renowned for its diversity, but there is a concern that its textiles and fashion sector may not fully represent or cater to this heterogeneity, potentially failing to meet contemporary consumers' expectations of inclusivity.

This research endeavors to interpret how inclusivity is comprehended, embraced, and implemented in Indian fashion by analyzing the opinions and attitudes of individuals within this heterogeneous society. The findings of this study offer valuable insights to fashion industry stakeholders, thereby facilitating better alignment with evolving societal expectations for inclusive representation of diverse body sizes, genders, and beyond. Comprehending these perceptions and attitudes is crucial for the fashion industry to adapt and become more inclusive, aligning better with evolving consumer expectations.

1.2 Objectives

This study aims to fulfill the following objectives:

1. Evaluate the level of inclusivity in the textile and fashion sectors by reviewing the current literature.
2. Investigate the effects of social media on shaping perceptions of inclusivity through a review of existing literature.
3. Obtain opinions of the Indian populace concerning inclusivity within textiles and fashion spaces through an online survey.

1.3 Review of Literature

The fashion industry has always endorsed a particular standard of size, color, gender, and body shape that fashion publications and runways have widely promoted. However, not all consumers conform to these standards. Inclusivity aims to embrace and celebrate diversity in size, ethnicity, gender, and other characteristics by creating an environment where individuals of different backgrounds feel valued and welcomed [5].

Brands are now expected to cater to consumers of all body types by offering a range of sizes, from plus sizes (3XL and above) to smaller sizes (XS and below), and catering to various heights, from petite to tall. The demand for size inclusivity reflects collective consumer consciousness and changing attitudes [6].

Inclusivity extends beyond considering the body in clothing. Consumers have become accustomed to seeing various faces, skin colors, and styles on the runway and brands instead of having a uniform perception of beauty [4].

1.3.1 Body Positivity

The body positivity movement emerged as a social campaign to embrace all bodies, regardless of size, shape, skin tone, gender, and physical capabilities. The modeling agencies' constant demand for models to be "white, skinny, young, and female" was one of the first areas of fashion inclusivity to be publicly scrutinized. The body positivity movement has been hailed as "the biggest rebellion against the dearth of diversity and positive self-image in the fashion industry." The prevalence of eating disorders, diet, and the pursuit of perfection, which social media has aggravated, has been displaced by currents that encourage individuals to love and accept their bodies [4].

The body-positive movement has led to an increase in women's self-acceptance of their bodies, resulting in a rise in support for body-positive fashion brands [7].

1.3.2 Size Inclusivity: Plus Size

The fashion industry derives 15 percent of its revenue from the plus size. This market segment has evolved beyond dull colors and unflattering silhouettes to cater to the diverse needs of customers, maintaining its aesthetic identity across offerings of all sizes. Fit is as important as the availability of plus-size options. Moreover, Indian body types and sizing differ significantly from those in the US or UK, making it necessary for brands to invest in research to gather data to develop well-fitting garments for customers of all sizes [6].

Plus-sized customers often face insensitive treatment from the sales staff or feel judged by their size. Stores must prioritize sensitization and training of staff to ensure a positive shopping experience. Some customers prefer online shopping because of their convenience and ability to filter items according to size and fit [6].

1.3.3 Gender Inclusivity: Gender-Neutral Fashion

While it is common for women to wear men's clothing, men who wear women's attire receive less acceptance from society, suggesting the presence of underlying gender biases. Designers such as Rohit Bal and Arjun Saluja pioneered gender-fluid fashion in the early 2000s. Wendell Rodricks's gender-fluid collection at Lakmé Fashion Week 2007 disrupted gender norms, influencing designers to explore non-binary aesthetics. In the 2010s, celebrities and designers embraced and promoted gender-neutral fashion, culminating in Anjali Lama's historic walk as the first openly transgender model at Lakmé Fashion Week in 2017. In the 2020s, the fashion industry is endorsing unisex designs that prioritize comfort and self-expression, breaking the barriers of traditional gendered clothing [8]. The growing acceptance of unisex clothing signifies a shift towards openness and equality in society. Unisex fashion represents a step towards personal freedom and societal progress. There is an increasing demand for gender-neutral clothing in India, particularly in metropolitan areas, indicating a growing acceptance of gender diversity [9].

1.3.4 Role of Social Media in Promoting Inclusivity

Over the past decade, social media has emerged as an effective marketing tool that allows marketers to promote brand awareness among consumers. It is recognized as the most transparent, engaging, and interactive form of public relations [10]. Influencers and creators promote awareness and education, thus contributing to brand inclusivity [6]. An array of LGBT+ and plus-sized influencers strive to eradicate stigma and promote inclusivity by using social media to share educational messages [11].

Social media has changed fashion communication, giving visibility and a voice to communities that the fashion world has historically ignored [12]. The fashion sector employs social media platforms to study prevailing trends and predict consumer behavior. Social media have made the fashion industry more accessible to the public [10]. Consumers use social media platforms to showcase their support for those who feel excluded. Championing these changes on social media is essential to fostering a more inclusive and accepting society [11].

1.3.5 Steps Taken by Brands to be Inclusive

It is essential to incorporate inclusivity into a brand's marketing strategy. Featuring diverse individuals in promotional materials allows customers to envision themselves using a product or service. Collaborating with influencers and digital creators representing various sizes, genders, and body types is critical for brands that wish to engage with a diverse customer base. Modeling agencies must recruit models of diverse sizes, skin colors, and heights to ensure that no individual feels underrepresented, and mannequins should be produced in a range of sizes [6].

The luxury industry has attempted to include non-binary individuals in its marketing campaigns to challenge traditional norms. For example, Chanel launched a makeup line for men in Korea and recruited a transgender model to represent the brand. Recent developments in the beauty industry have led to a greater emphasis on diversity, with brands like Fenty and Dior offering over 40 different shades of foundation. Luxury brands adapt to clients from various social backgrounds by lowering the prices of certain items or by collaborating with bridge brands to make luxury products more accessible. Another strategy is establishing a "sister" brand, targeting a less affluent market. Such brands include Marc by Marc Jacobs, Must de Cartier, and See by Chloe. The United States is trending towards "affordable luxury brands," such as Michael Kors, Coach, and Kate Spade. This sector appeals to the younger generation, who can purchase "luxury" items at a significantly lower price [13]. Luxury is an integral aspect of the identities of brands such as Chanel and Dior; destroying it would equate to the end of their essence. These brands must democratize themselves intelligently and inclusively to maintain their positions in the market. They must balance inclusivity and exclusivity to maintain their unique identities [13].

Significant transformations have occurred in the fashion communication spaces. Editorial policies of conventional fashion publications show progress toward inclusivity by embracing the visual representation of previously excluded individuals in mainstream social narratives. Established and emerging photographers' works highlight imperfect faces, curved bodies, disabled physiques, and fluid identities. This shift in focus aims to broaden the perspective and overcome the limitations of the gaze by including those previously marginalized [14].

2. Materials and Methods

This study employs a mixed-methods approach to investigate perceptions of inclusivity in Indian fashion. To capture perceptions of inclusivity in fashion, a survey was administered to the general population through a Google Forms link. The survey used open-ended and close-ended questions to understand the nuances of individual perceptions. It consisted of demographic information to collect data on participants' age, gender, location, occupation, and socioeconomic background; a section on awareness and perception of inclusivity to evaluate participants' understanding of inclusivity in fashion and their familiarity with inclusive fashion brands; and a section on purchase intention and preferences to assess participants' willingness to purchase from inclusive fashion brands and their willingness to pay a premium price for inclusive brands.

2.1 Sample Size and Selection

Profile: Anyone over 18 years of age could participate in the survey.

Sample size: Three hundred questionnaires were sent, and 279 responses were received. The sample was selected using Convenience sampling.

3. Results

The fashion and textile industry has been criticized for promoting a narrow ideal of beauty that prioritizes specific physical attributes such as size, color, gender, and shape. There is a growing demand for inclusivity and diversity in fashion. The body positivity movement seeks to embrace individuals from all backgrounds and identities that challenge conventional beauty standards and promote acceptance and self-love for all bodies. Social media have played a significant role in this shift towards greater inclusivity and representation, as individuals and organizations have used these platforms to challenge stereotypes and share diverse perspectives. Brands have taken notice of this demand for inclusivity, offer more inclusive designs, and create a welcoming shopping experience for all customers. This shift is also reflected in the evolution of fashion magazines, which prioritize inclusive representation and authenticity, featuring a more comprehensive range of faces, bodies, abilities, and identities.

The literature review serves as a foundation for understanding the historical evolution of inclusivity within the fashion industry, its multifaceted dimensions, and its effects on individuals and societies. Drawing from this literature, the study focused on collecting primary data through a survey distributed among the adult population. The survey's primary objective was to investigate the perception and acceptance of the term "inclusivity" in the context of fashion among the Indian population.

The survey was administered to 300 individuals, and 279 participants provided their responses, yielding a response rate of 93 %. Of the participants, 73.1 percent were from Maharashtra, and 15.7 percent were from Delhi and the NCR. Of the respondents, 79.2 percent were female, 18.6 percent were male, and the remaining did not specify their gender. 44.8 percent of the participants fell within the age bracket of 35-44 years, 35.1 percent were in the 18-24 age group, and 14.3 percent were in the 25-34 age group. 26.1 percent of respondents reported a monthly family income of more than INR 500,000, 29.3 percent had an income between INR 100,000 and INR 250,000, and 31.1 percent had an income between INR 50,000 and INR 100,000. 42.2 percent of the participants held a Postgraduate degree, while 25.8 percent had a Bachelor's degree. Regarding occupation, 37.6 percent of respondents were employed, 40.1 percent were students, and 22.2 percent were entrepreneurs.

Participants were asked whether they identified with any of the "socially different" categories, such as being plus-sized, having dark skin, being transgender, being skinny, or having a disability, among others. The participants were allowed to select multiple options. A majority, 55.1 percent, chose the "none of the above" option, while others selected categories such as plus-sized, skinny, and dark-skinned. Regarding fashion, 36.5 percent of respondents closely followed the latest trends, while 39 percent were somewhat aware of them. Only 20.7 percent were somewhat unaware, and only 3.8 percent were completely unaware of the latest fashion trends.

When asked about inclusivity in fashion, almost 62 percent of the respondents were familiar with the term, while 18.6 percent were not. The rest were unsure. When asked about what inclusivity in fashion means to them, varied responses summarized "Fashion for All" as the essence of inclusivity.

As shown in Figure 1, most respondents (65.9 percent) opined that an inclusive brand extended its reach to diverse sizes. Moreover, some contend that inclusivity encompasses catering to individuals from all socioeconomic backgrounds and those with disabilities. Additionally, inclusivity is linked to sustainability, encompassing a more comprehensive range of skin tones and cultural groups.

When asked if they were more likely to purchase from a brand that uses models similar in age, gender, and body shape to their own, 45.1 percent responded that it made no difference, while 37.7 percent said yes.

Regarding willingness to purchase genderless clothing, 55.1 percent responded with Yes, 17.2 percent with No, and 27.7 percent were unsure.

When asked about finding clothes that fit them in terms of size, color, budget, and help express their identity, a majority (36.5 percent) said they find such clothes sometimes, while 31.8 percent said they find them often. Around 19.6 percent always find the clothes that express their identity, while another 12.8 percent are rarely able to find such clothes, as seen in Figure 2.

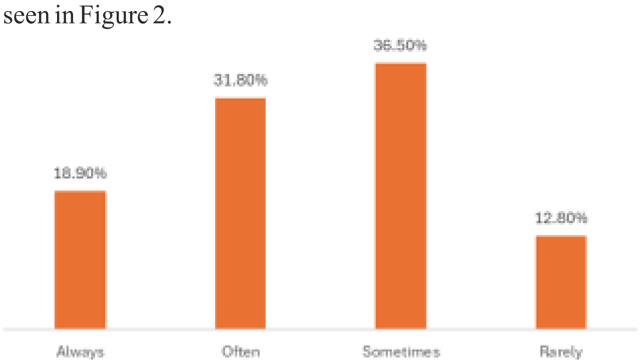

Figure 2: How often do you find clothes that fit you in terms of size, colour, budget and help express your identity?

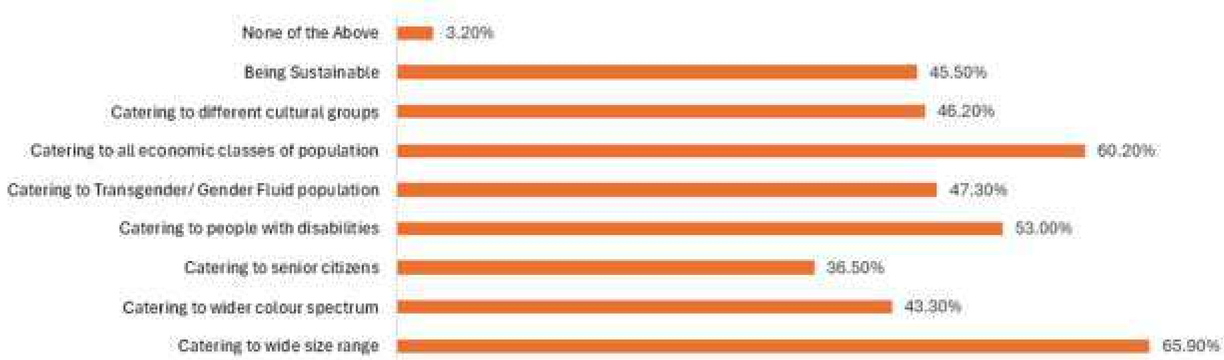

Figure 1 : Which all statements according to you makes a fashion brand Inclusive? (Multiple options can be selected)

As seen in Figure 3, when respondents were asked about inclusivity in the Indian Fashion Industry (brands), 37.7 percent indicated that certain brands are inclusive, 31.1 percent stated that only a few brands are inclusive and diverse, and 7.4 percent believed that the Indian fashion industry is not inclusive and diverse.

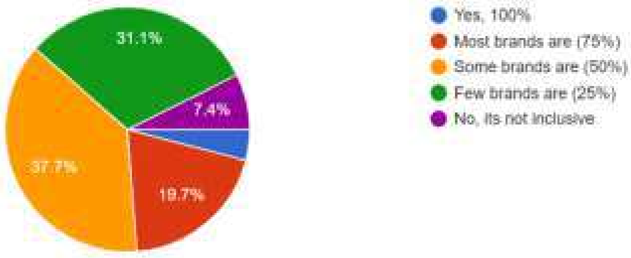

Figure 3: Is the Indian Fashion Industry (Brands) inclusive and diverse?

When asked about the brands they feel are inclusive, the respondents frequently mentioned H&M, Westside, Amydus, Zara, Marks & Spencer, TrueBrowns, Doodlage, Biba, AND, Global Desi, and House of Masaba.

Figures 4 and 5 show that 53.7 percent of respondents preferred Inclusive brands over other brands, while 39 percent would 'maybe' rate them higher. However, only 26.1 percent of respondents were willing to pay a premium price for an Inclusive brand, and 47.6 percent would 'maybe' pay a premium for an Inclusive brand.

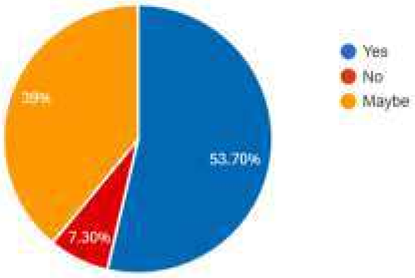

Figure 4: Will you rate an Inclusive Fashion Brand higher than the one that is not?

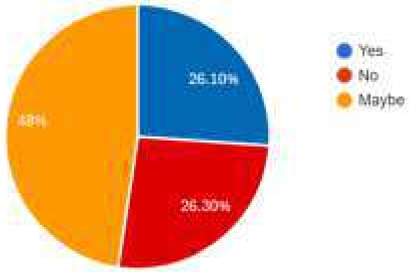

Figure 5: Will you be willing to pay a premium for Inclusive fashion brands?

The study also reveals that individuals within the 18-24 age bracket exhibit a greater awareness of inclusivity. Approximately 80% of respondents from this group are familiar with the term, 57% rate inclusive brands higher than others, and 75% might be willing to pay a premium for such products. Additionally, this age group is the most inclined to purchase gender-neutral clothing.

In contrast, the 25-55 age group demonstrates lower levels of awareness, with only 49% of respondents familiar with the term inclusivity with respect to fashion. However, a higher percentage (50%) of this group rates inclusive brands favorably and may be willing to pay a premium. Approximately 42% of this age group expresses interest in purchasing gender-neutral clothing.

When examining gender differences, 62% of female and 45% of male respondents report being aware of inclusivity. Among these groups, 55% of females and 45% of males prefer to purchase brands that practice inclusivity, and 48% of females and 70% of males indicate they would be willing to pay a premium for such products. Furthermore, a similar proportion of male (50%) and female (50%) respondents express interest in buying gender-neutral clothing.

The survey indicated that Indian consumers prefer inclusive brands, highlighting the need for a varied size range, aesthetic accessibility, and diverse representation in marketing. To address this, brands should offer gender-neutral clothing, ensure accessibility to physical and online stores, conduct staff training for inclusive services, collaborate with diverse influencers, and research local sizing needs to better cater to the Indian market's unique requirements.

4. Conclusion

The study explores the concept of inclusivity in the textile and fashion industry, which seeks to challenge historical beauty standards and embrace diversity. The study employs a mixed-methods approach, utilizing a literature review and survey to understand perceptions of inclusivity in Indian fashion.

The literature review highlights the development within the fashion industry as it progresses from upholding rigid beauty standards to advocating for inclusivity and diversity. In the past, the industry favored the specific dimensions of size, color, gender, and shape. However, recent style trends indicate a shift towards accommodating a broad range of body types, ethnicities, and genders.

The body positivity movement has emerged to challenge these traditional norms, advocating for the acceptance of all body types, and resulting in increased support for brands that align with these values. Social media have played a crucial role in this transformation, promoting diverse representations and challenging stereotypes, thus shaping consumer expectations of inclusivity.

Gender inclusivity has also gained traction, with designers and brands introducing gender-neutral fashion, reflecting societal shifts towards non-binary and fluid gender identities. Luxury brands are adapting to these changes, balancing inclusivity with their exclusive image, and fashion communication is evolving to highlight their diverse and previously marginalized identities.

The survey targeted 300 individuals, yielding 279 responses, with a substantial portion originating from Maharashtra and exhibiting diverse demographics, including gender, age, and income. The majority of participants were educated and held various occupational positions. Regarding inclusivity in fashion, 62% were acquainted with the notion, primarily defining it as "Fashion for All," highlighting the importance of accessibility, diversity in sizing, and representation. Brands such as H&M, Zara, and others were acknowledged for their inclusive initiatives. Gen Z shows high awareness and preference for fashion inclusivity and gender-neutral clothing. Millennials and Gen X have lesser awareness but still support inclusive brands and show significant interest in gender-neutral options. Across genders, while females are generally more aware of inclusivity, males are more likely to pay a premium, with both genders equally interested in gender-neutral clothing. The survey disclosed the overall support for inclusivity and a nuanced perspective on its implementation and economic implications within the Indian fashion industry.

The fashion industry is increasingly recognizing the importance of inclusivity, which involves accommodating a diverse range of body sizes, shapes, and identities. Size inclusivity has become a significant aspect of the industry, with various sizes being offered to ensure that everyone feels represented and confident. Inclusivity in the fashion industry encompasses gender and cultural diversity. Social media has emerged as a critical platform for marginalized voices to influence and reshape fashion narratives, fostering global connections and community support. Inclusivity in fashion is becoming a core value rather than a trend, necessitating continuous evolution to meet consumer expectations and promote diversity. The industry's progress in embracing various identities and cultures signifies a move towards a more inclusive, representative, and empowering fashion future. This journey underscores the need to expand inclusivity, ensuring that fashion is a space where everyone feels seen, heard, and valued.

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A Study of the Recent Trends in Indian Carpet Industry and Roadmap Ahead

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Abstract:

The editorial examines the Global as well as Indian Carpet Industry. Here the discussion begins with providing the overview of the Global Carpets Industry followed by discussions on Indian carpet Industry. The study highlights on various success factors affecting acceptance of Carpets followed by weaknesses, opportunities and challenges of the carpet industry

Keywords: *Acceptance, Carpets, opportunities, threats, overview, strengths, weaknesses*

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1. Introduction

Carpet is a Floor Layer which is made completely by human hands by knotting, tufting or weaving, in which handspun Yarn of natural fibers is used with its very unique character and design. Carpets especially Handmade are works of art which bear beauty and sophistication to any space. They are fashioned by means of a variety of methods and materials, and each type of handmade carpet narrates its own story making it very exclusive in features and style. The assortment of materials and techniques used in producing these carpets is enthralling.

Carpets like other products are bearing properties which can be defined both by their physical descriptions and by their meanings as per society. Carpets have a practical value and a restrained life as the carpet may be made of any good material but each of them have a limited life. Nevertheless, a carpet is a product with a very strong social meaning. Most relevant example to this is Turkmen carpet which has a deep representational meaning ascribed to status of a newlywed and the skills and possessions that she had given at marriage. The tradition of gifting carpets at the time of marriage has remained till today as a valuable social ritual in Afghanistan.

2. Materials & Methods

The objective of the study is to provide an outline of the Global Carpet industry then shifting the focus to Indian carpet Industry. The study would also analyse the strengths, weaknesses, opportunities and threats for Indian carpet Industry. Information has been poised from various sources including books journals research papers websites for the reason of study. This study uses secondary data, with texts and modern scholarly works, to explore the strengths, weaknesses, opportunities and threats for Indian carpet Industry. A literature review involved examining journal articles, books, manuscripts, and historical records to gain insights into the industry's state. These resources have been studied to understand the industry's perspective and progression. The combination of these methods has enabled a detailed exploration and records of the Indian Carpet industry.

3. Results and Discussion

3.1 History

The origin of Carpets is still considered furtive but assuredly, ruddling arrangements of floor covering clothes are present since 7000 BC. There are various narrations regarding the progression of carpets. Indian Carpet industry is oldest and legendary businesses in the world. Carpets generally are crafted through weaving, knotting, tufting, knitting, braiding, or felting. The creating of Indian Hand-crafted Carpets is considered very time utilizing and workforce demanding. Currently India is considered a centre in Southern Asia for manufacturing numerous forms of Handmade Carpets. There are several notable carpet centres in India including Rajasthan, Punjab, UP, J & K, Haryana, MP, Bihar, Himachal Pradesh, West Bengal, Andhra Pradesh, Karnataka, etc. Each centre has a cluster of weavers and makers of carpets. Hand-knotted carpets and rugs have a rich history in India, dating back to around 985 CE, with Mahabalipuram identified as one of the oldest production centers in the country. While some historical accounts suggest that the carpet art form originated elsewhere and was introduced to India by the Mughals from Turkey and Persia, evidence indicates that it became deeply entrenched in Indian culture during the Mughal era.

As the Mughal Empire rose to power in India, resident artisans began creating carpets for Mughal emperors, incorporating elements of Mughal and Islamic art and architecture into their designs. Carpet weaving thus became an integral part of Indian culture from that period onward. Historical records from the fourteenth century document the widespread use of carpets in cities like Daulatabad, Delhi, and Multan, reaching new heights of prominence in the

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sixteenth century under sustained Mughal patronage. Emperor Babar, who reigned from 1526 to 1530, played a significant role in introducing and promoting the art of carpet weaving in India. He imported carpets from Turkey and Persia, laying the foundation for the establishment and proliferation of this craft within the country. Mughal emperors actively engaged artisans to produce elaborate carpets for their palaces and courts. These Mughal carpets were renowned for their vibrant colors, opulent use of gold and silk threads, and intricate designs, showcasing the artistic brilliance of the era.

In 1851, handmade carpets received significant acclaim in Indian history for their exceptional quality, designs, weave, and color palette at the prestigious London exhibition. Following the British colonial period, the carpet industry experienced a resurgence in various regions of India, marked by variations in designs, colors, quality, weaving methods, and materials used. Over time, carpet weaving proliferated across the Indian subcontinent, with different regions developing their unique styles and techniques, contributing to the rich tapestry of Indian carpet craftsmanship.

3.2 Theoretical Background

The presence of small and medium-sized exporters with substantial export capacity, alongside skilled weavers capable of crafting intricate and unique floor covering designs, is the primary strengths of Indian carpet production [1].

16 carpet manufacturers in Jaipur were examined in a study, with each zone consisting of four randomly selected units. The research revealed consistent tools and processes across all areas involved in hand-knotted carpet production. Highlighting the industry's significance, the findings underscored its role in meeting foreign exchange requirements and providing employment opportunities. The study emphasized the necessity for professionally trained, well-equipped, and informed designer clippers, finishers, and production managers within the industry [2].

The carpet industry not only offers employment opportunities for educated and skilled women but also for semi-skilled women, thus empowering them [3].

A study highlighted carpet weaving as a major cottage industry in India, employing thousands of village artisans and making substantial contributions to the economy through both balance of payments and employment generation [4].

A study on Carpets explored the multifaceted uses of carpets, whether as floor coverings or decorative items. The research concluded that handmade carpets offer healthier usage compared to machine-made ones [5]. There has been a decline in demand for handmade carpets in the international market due to consumer preferences shifting towards cheaper, less durable, and modern designs over traditional, costlier options [6]. 4P's are essential for the Indian Carpet Business. These tools play a crucial role in devising future strategies and enhancing sustainability within the market. It was further observed that while traditional markets may have reached saturation points, new markets present opportunities for growth [7].

There has been an emphasis upon the Carpet sector's prominence due to its low capital investment requirement and substantial export prospective [8].
In 2014, the economic growth potential of handicrafts was highlighted, with a suggestion to organize artisans into cooperatives to enhance the marketing of their products [9].

In 2012, it was analysed that the majority (90%) of carpet weaving occurred in households using family labour, with only a small portion (10%) operated by hired workers in factories. Many factories were observed to be small-scale, owned by individuals with limited resources, and employing only a few workers, including children. This socio-economic structure positioned individual weavers at the base, with exporters and major manufacturers often separated from them by layers of intermediaries [10].

3.3 Size of the Global Carpet Industry

As per latest market investigation piloted, the global Carpet market is poised to achieve a CAGR of 4.6% from 2023 to 2032. In 2022, the market size is projected to reach USD 64.99 billion, with an anticipated valuation of USD 97.41 billion by 2032 [11].

The carpet market encompasses the manufacturing, distribution, and sale of carpets, rugs, and other flooring products. It includes a wide range of carpet types, such as tufted, woven, needle-felt, and knotted carpets, along with carpet tiles and area rugs. These products find applications in both residential and commercial settings, driven by factors such as aesthetics, comfort, insulation, acoustics, and safety.

As a significant segment of the global flooring industry, the carpet market is influenced by various factors, including economic conditions, trends in interior design, technological advancements, and environmental considerations.As per The Brainy Insights, the size of the carpet market was valued at USD 72.39 billion in 2023 to USD 110.82 billion by 2033 [12].

3.4 Growth of the Indian Carpet Industry

India at this time is a leader in creating handmade carpets may it be the volume or value. The glory of Indian handmade carpets is acknowledged worldwide because of its distinguishable share in the global exports. The volume of exports is as high as 90% of the total production. Throughout April-November 2019, hand-crafted carpets exported from India was USD 916.15 million. Just USA only has 48.84% share out of total export of INR. 10207.91 Crores in 2018-19. 27.25% of the Indian carpet exports are steered to Europe [13].

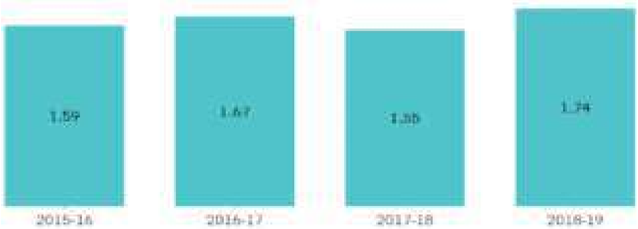

Figure 1: Growth of Carpet Industry from 2015-19 as per report from Mordor Intelligence

The Indian government has made significant strides in fostering the development of the carpet industry. Carpet Export Promotion Council was instituted in 1982 under the Ministry of Textiles, Government of India for research, development, and quality assurance within the sector. Additionally, the Indian Institute of Carpet Technology (IICT) was inaugurated by the Ministry of Textiles in 2001, aimed at cultivating skilled professionals and fostering design innovation within the carpet industry. Despite these initiatives, the industry's growth remains hindered. Research by Das et al. highlights the industry's struggle with innovation and outdated technology, leading to a significant portion of carpet weavers seeking opportunities in other sectors. Despite its global prominence, the Indian carpet industry grapples with various challenges. Das et al. underscore issues such as low wages, exploitation of labor, limited job opportunities, minimal job security, and the pervasive influence of intermediaries as major obstacles confronting the industry [14].

India plays a pivotal role in the global carpet market, with a remarkable 90% of the country's rug production being exported. In the period of April-November 2019 alone, India exported handmade rugs worth INR 64,407.19 crore (USD 916.15 million). Renowned for its expertise and heritage in handmade rugs, India leads in both volume and value of production, boasting a significant share in global exports. These rugs reach over 70 countries worldwide, with major importers including UK, USA, Germany, Canada, Australia, South Africa, Europe etc. The evolving dynamics of globalization present new opportunities for the burgeoning Indian carpet market. India's Carpet & Rugs Market is projected to reach USD 7.13 Bn by 2028, growing at a CAGR of 6.15% as per Research & Markets [15].

Figure 2: Market Forecast of Indian Carpet & Rug Industry as per report from Research & Markets

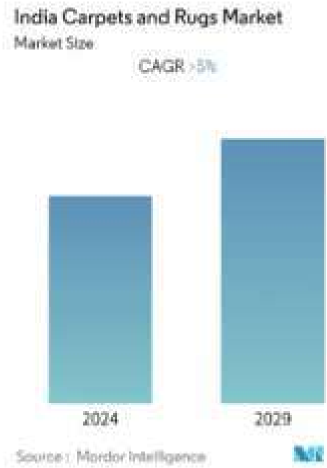

Figure 3: Predicted Growth of Carpet Industry from 2014-29 as per report from Mordor Intelligence

3.5 Problems of carpet industry

There are several problems currently faced by the Indian carpet Industry.

- There has been an upsurge in the cost of raw materials. Studies show that cost of raw materials have emerged by about 50% in recent years. Also, downgrading of rupee has increased the cost of bring in raw materials.
- Deficiency of skilled work force is the next issue. It is very relevant to mention that artisans are not paid well, and conversely not everyone is interested to pay more for buying hand crafted products so people are moving towards buying machine made products. Also, most weavers are largely cultivators, working as crafts worker during the lean agrarian months.
- There is a strong global Competition and Indian carpets face tough competition from nations like Iran, China and Nepal. Iran accounts for approx. 25% of exports, China about 20% and Nepal about 10% [18].
- There has been a lot of possibility for strengthening Exports of Indian Handmade Carpets but Indian Carpet industry sees lack of quality infrastructure due to political indifferences and to marginal investing in R and D which lacks supervising system which is required to evaluate the development of projects.
- Though all efforts are being done to promote Indian carpets in international market but then there has been dissention involving task of CEPC in providing platform to Indian Carpets at global levels.
- Lack of Infrastructure-Government has put in a lot of efforts by initiating various schemes but most of the initiatives have really not worked very well due to lack of development in power, roads and drinking water there is a strong need to develop banking facilities so that the industry can reach its full potential.

3.6 Growth trends

Carpet weaving in India is deeply rooted in tradition, tracing back to 16th-century Persian influences. Typically hand-knotted, Indian rugs feature diverse and intricate arrangements in designs. The country's carpet business primarily thrives as rustic, labour-concentrated cottage industry.

Indian silk Carpets & rugs stand out for their originality, vibrant colors, superior quality, captivating designs, and long-lasting durability. However, there's a noticeable shift in demand towards tufted rugs, driven by the affordability of synthetic materials and reduced labour requirements in their production. International consumers are increasingly favouring washable and budget-friendly rug options, reflecting evolving preferences in the global market.

The carpet market has witnessed notable growth trends in recent years, characterized by the following key developments:

- Surge in Demand for Eco-Friendly Carpets: There is a notable uptick in the demand for carpets crafted from sustainable and recyclable materials. Increasing environmental consciousness among consumers is driving the preference for eco-friendly carpet options.The manufacturers are engaged in a lot of Research and development to create innovative and sustainable Carpets. The adoption of eco-friendly materials is another key aspect of sustainable manufacturing. Traditional manufacturing processes often rely on materials that are harmful to the environment, such as plastics derived from fossil fuels or metals mined through destructive practices. However, there is a growing trend towards using renewable and biodegradable materials, such as bamboo, recycled plastics, and organic cotton. These materials offer comparable performance to their conventional counterparts while significantly reducing environmental impact

- Expansion of the Construction Industry: The burgeoning construction sector, especially in developing nations, has fueled heightened demand for carpets in both commercial and residential constructions .

- Technological Advancements: Ongoing advancements in carpet manufacturing technology have paved the way for the production of high-performance carpets boasting enhanced durability, stain resistance, and ease of maintenance.

- Augmented focus on Design and Aesthetics: Design and aesthetic appeal have become paramount in the carpet industry, particularly in residential settings. Consumers are actively seeking carpets that can elevate the visual allure of their living spaces and harmonize with their interior décor. The Carpet Industry also follows the Trend Predictions to Design and create Carpets which are structurally, functionally and aesthetically strong .

- Rise in Renovation and Remodeling Projects: With more individuals opting to stay in their residences and undertaking home upgrades, there has been a noticeable increase in the demand for carpets in renovation and remodeling endeavors.

- Emergence of Online Sales and Distribution: The proliferation of e-commerce platforms has revolutionized the carpet market, enabling customers to conveniently purchase carpets online. This trend has facilitated greater accessibility to a diverse range of products and enhanced price comparison opportunities for consumers [16].

- Sustainable manufacturing practices, resource conservation, and the adoption of eco-friendly materials:these are crucial components of building a more environmentally responsible industrial sector. As the global population continues to grow, the pressure on natural resources intensifies, making it imperative for industries to embrace sustainable approaches that minimize their ecological footprint.One of the cornerstones of sustainable manufacturing is the efficient use of resources. This involves optimizing production processes to reduce waste generation, energy consumption, and water usage. Implementing techniques like lean manufacturing, which focuses on eliminating waste and maximizing efficiency, can significantly reduce resource consumption while improving productivity.Additionally, recycling and reuse play vital roles in resource conservation. Industries can adopt closed-loop systems where materials are recycled and reused within the production process, minimizing the need for virgin resources. By implementing comprehensive recycling programs and designing products for easy disassembly and recycling, manufacturers can reduce the demand for raw materials and decrease the amount of waste sent to landfills.

3.7 Opportunities ahead

The carpet market presents numerous significant opportunities for growth and advancement. Here are some key areas of opportunity:

- Diversification of Product Offerings: Manufacturers can explore opportunities to diversify their product range by venturing into luxury carpets, eco-friendly options, and customized solutions tailored for both commercial and residential applications.

- Technological Innovation: Continuous investment in research and development to introduce innovative carpets with enhanced performance and eco-friendly features can help manufacturers gain a competitive edge in the market.

- Partnerships and Collaborations: Collaborations among carpet manufacturers, architects, designers, and contractors can stimulate demand for carpets in construction and renovation projects, driving growth opportunities.

- Sustainability: With an increasing demand for sustainable products, there is an opportunity for manufacturers to invest in environmentally friendly production methods and materials, and market their carpets as eco-friendly solutions.

- Online Sales and Marketing: Leveraging the growing trend of online sales and marketing, manufacturers can expand their reach and increase sales through e-commerce platforms and social media channels.

- The carpet market is confronted with several significant threats that may jeopardize its growth and profitability.

3.8 Key concerns of the Carpet Industry

- Competition from Alternative Flooring Options: Carpets encounter competition from various other flooring alternatives, such as hardwood, vinyl, and tile, which may offer similar or superior performance at comparable prices as their producres are also in the process of R & D to fight the competition.

- Economic Downturns: Economic downturns have the potential to impact consumer spending on carpets, particularly within the residential sector, where purchases are often discretionary and subject to economic fluctuations.

- Environmental Concerns: Increasing awareness regarding the environmental impact of carpets, including non-biodegradable materials and chemicals used in production and disposal, may lead to heightened regulations and consumer preferences shifting towards more eco-friendly flooring options.

- Disruptive Technologies: The emergence of disruptive technologies like 3D printing and digital printing could revolutionize carpet manufacturing methods, potentially altering consumer preferences and favoring newer, more innovative products.

- Raw Material Price Fluctuations: Fluctuations in the prices of raw materials, such as synthetic fibers and natural fibers like wool, can significantly impact the production costs of carpets, thereby affecting profit margins within the industry.

- Changing Consumer Preferences: Shifting consumer preferences in flooring materials and designs, influenced by evolving trends in interior design and lifestyle choices, have the potential to disrupt demand for carpets and reshape market dynamics.

- Market Saturation: Some regions may experience market saturation with numerous existing carpet installations, limiting new sales and growth opportunities, particularly in mature markets.

- Competition from Alternative Flooring: Carpets face competition from alternative flooring options such as hardwood, laminate, vinyl, and tiles. Consumer preferences for these alternatives, driven by ease of maintenance and changing design trends, pose a challenge to the carpet market.

3.9 Opportunities ahead in the Indian Carpet Industry

- Surge in Demand for Sustainable Products: Increasing environmental awareness creates opportunities for the carpet market to develop and promote sustainable, eco-friendly products. Manufacturers can focus on utilizing recycled materials, reducing carbon footprints, and adopting environmentally friendly production processes. India has a rich heritage and history in sustainability.

- Innovation in Materials and Technology: Investments in research and development can lead to innovations in carpet materials and technology. This includes the development of stain-resistant, durable, and low-maintenance carpets that align with evolving consumer preferences.

- Customization and Personalization Trends: Consumer demand for personalized flooring options presents an opportunity for the carpet market to offer customizable products. This includes a variety of colors, textures, and designs that cater to individual preferences and interior design trends.

3.10 Challenges for Indian Carpet Industry

- Maintenance and Cleanliness Concerns: Carpets require regular maintenance, and concerns about cleanliness, allergens, and the accumulation of dust and debris can deter some consumers. Addressing these challenges involves developing and promoting easy-to-maintain and hygienic carpet solutions.

- Global Trade Uncertainties: Trade tensions, tariffs, and uncertainties in global trade relations can impact the carpet market. Changes in trade policies may disrupt supply chains, influence production costs, and affect the competitiveness of carpet products in the international market.

- Strong Global competition from USA

4. Conclusion

To bolster the global market share of carpets, particularly hand-knotted varieties, it is essential to optimize pertinent processes. This enhancement will not only benefit the industry's socio-economic standing but also uplift the artisan community. To achieve this objective, it is imperative to engage in Public-Private-Partnership (PPP) initiatives and/or receive interventions from the national government. As per report by Freedonia, The global demand for carpets and rugs is projected to grow at a rate of 2.3% annually, reaching 5.4 billion square meters by 2027, with a total market value of $63.7 billion [17]. This growth will be fueled by several factors, including:

1. Increased construction activity in both residential and nonpresidential sectors, particularly in regions such as Asia/Pacific and Africa/Mideast.

2. The increasing popularity of carpet tiles in non-residential buildings is driven by their convenient installation and replacement.

4.1 Future trends in Global Carpet & Rug Demand

Through 2027, global demand for carpets and rugs is forecast to increase 2.3% annually to 5.4 billion square meters as per report by Freedonia [19]. Growth in the rug market is projected to greatly outpace that of the carpet market, primarily due to continued market inroads made by luxury vinyl tile in the US and Europe, which is taking substantial share away from wall-to-wall carpeting in the world's largest markets for carpet hard surface flooring gaining market share worldwide, which increases the likelihood of accent and decorative rugs to cover portions of the existing floor covering product

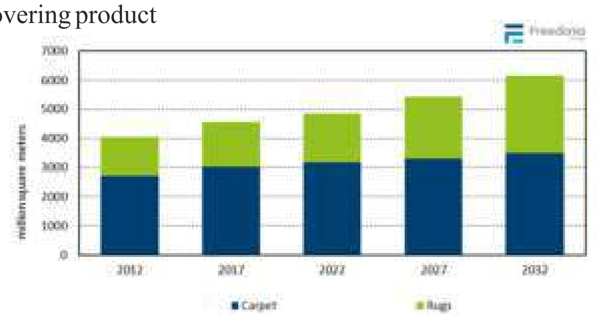

Figure 4. Global carpet & Rug Demand by Product 2000-32 (million Sq. Mtrs.) as per report by Freedonia [20]

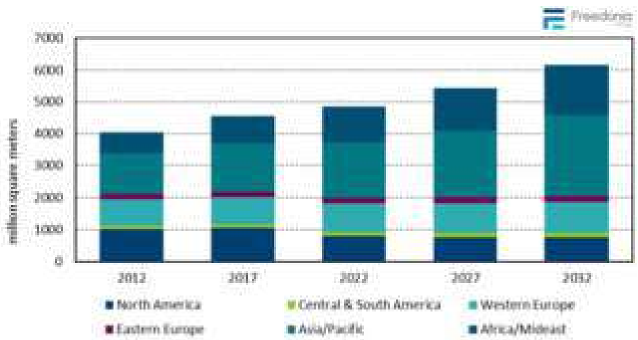

Figure 5. Global carpet & Rug Demand by Region 2000-32 (million Sq. Mtrs.) as per report by Freedonia [21]

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A Study on Comfort Properties of Handloom Fabric using Cotton and Bamboo Yarn

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Abstract:

Clothing comfort plays a vital role for human being thatdirectly affects their performance, comfort and state of mind. Nowadays, people have started giving consideration to comfortalong with aesthetic while making purchase decisions.Cotton is considered as the most comfortable fiber but harmful to the environment due to extensive use of chemicals while harvesting it. Hence, alternate fibers preferably from other natural resources,which are eco-friendly, are gaining importance. Bamboo fiber is a natural fiber that doesn't need a huge amount of water, insecticides, or pesticidesto grow. It has some excellent properties in comparison to cotton fiber, such as high dry tenacity, low density, a lustrous feel, etc. Handloom weaving is also another sector which can add value to a product being sustainable way of producing fabric. In this study, an attempt has been made to use bamboo yarn along with cotton to produce sustainable bamboo/cotton fabric on handloom. Six samples are prepared with different blend ration and weave. Comfort properties such as air permeability, moisture vapor transmission rate, wicking have been tested to see the effect of blend ratio along with the weave structure. Result indicates that plain weave samples exhibit higher air permeability and moisture vapor transmission rates in comparison to twill weave. Twill weave fabric shows higher moisture wicking in comparison to plain weave. Fabric made from more bamboo fiber content exhibits higher moisture absorbency. Overall the use of bamboo fiber in enhancing fabric comfort properties cannot be ignored apart from adding environmental sustainability.

Keywords: *Bamboo, Cotton, Comfort, Handloom, Sustainability*

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1. Introduction :

Clothing comfort plays a very important role in human life and refers to the"perception of pleasant state of physiological, psychological and physical harmony between a human being and the environment". Thermal insulation, air and moisture vapor transmission is considered most significant factor for clothing comfort. In the modern era of fast lifestyle, people would prefer comfortable clothing in daily use. Nowadays clothing comfort is considered as an important factor which is non-negotiable by affluent and elite class [1, 2, 3]. The main factor that directly affects clothing comfort properties is the raw material such as fiber and yarn type that have influence on the textile clothing before fabric constructions [4].

According to a study, cotton is a natural fiber that has essential comfort properties, that is why it is considered as most widely used raw material for clothing. Due to the extensive use of cotton fiber, farmers use fertilizers and pesticides to increase the productivity that have a negative impact on the environment including water pollution, soil degradation and harm to non-target organisms such as bees and other pollinators. Even the textile processing units involve a lot of water usage and the wastewater generated can contain harmful chemicals such as dyes, heavy metals, and other pollutants that can end up in waterways. The chemicals used in textile production can be harmful to both the environment and human health, as many are known to be carcinogenic or have other negative health effects. Conventional cotton farming often involves huge amount of consumption of water. This can place a burden on local water resources, especially in areas where water is already limited [5].

Synthetic fibers are made from petroleum-based chemicals, which are non-renewable resources that contribute to greenhouse gas emissions and climate change. Synthetic fiber production also necessitates a significant amount of energy, much of which is derived from nonrenewable sources such as coal or natural gas. They are not biodegradable and can take hundreds of years to break down in landfills, contributing to the growing problem of textile waste.

Additionally, reducing overall consumption and increasing the use of natural fibers can also help mitigate the negative environmental impact of synthetic fiber production. To address environmental issues, there are a number of sustainable practices that the textile industry can adopt, such as using organic and recycled materials, reducing water usage and pollution, minimizing waste, and using renewable energy sources or sustainable alternatives such as recycled polyester or bio-based fibers made from renewable resources like corn or bamboo [6]. The most significant feature of sustainable fibers is their renewability and biodegradability [5]. Some of the important fibres which are now gaining momentum in various applications are bamboo, aloe-vera,

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hemp, corn, soya, milk, banana, jute, eucalyptus, groundnut shell, areca nut, lyocell etc. [6]. Bamboo is a highly sustainable material that can be used in clothing in a number of ways. It is fast-growing plant that requires very little water and no pesticides or fertilizers to grow. This means that bamboo can be cultivated sustainably, without putting a strain on natural resources or contributing to pollution. It also has a lower carbon footprint throughout its growth due to its ability to absorb huge amounts of CO2 from the atmosphere [7]. However the extraction of bamboo fiber and processing of yarn uses mainly two method- mechanical and chemical treatment. Chemical treatment of fiber and yarn involves the use of caustic chemicals, such as sodium hydroxide (NaOH), sodium triphosphate (Na5P3O10), sodium sulfate (Na2SO4), sodium carbonate (Na2CO3), sodium hydrogen phosphate (Na2HPO4), sodium silicate (Na2SiO3), and sodium citrate (C6H5Na3O7). Due to the inexpensive equipment and low energy usage, it is an economical method to extract fiber, although it is not a sustainable way. Moreover, the fiber of this fast growing plant has excellent characteristics- like strength, UV protection, and antibacterial properties. Mechanical treatment of fiber extraction involves steam explosion and it is very labor intensive method as well as lesser harmful for environment [8].

Bamboo clothing is also biodegradable, which means that it can be broken down naturally in the environment without leaving behind harmful pollutants or micro plastics. It inhibits antibacterial and moisture-wicking properties, which can help to reduce odor and keep the wearer cool and comfortable [6, 9].

An attempt has been made to study fabric made from bamboo and cotton yarnproduced on handloom to promote environmental sustainability. It has the potential to enhance the existing properties of the textile materials. The handloom industry offers several sustainable solutions in the textile sector which has low-impact, labor-friendly process that requires minimal use of electricity, water, and other resources. It has much lower carbon footprint than those produced by industrial processes. By supporting the handloom industry, consumers can help to preserve these traditions and support local artisans and communities [10, 11, and 12].

2. Materials and Methods

2.1. Sample preparation

In this study, six woven fabric samples with different specifications using bamboo and cotton yarn were prepared on a handloommachine at the weaver service centre, Panipat, Haryana.

Single warp beam using 100 % cotton yarn of 2/20s was prepared and in weft direction, samples were prepared using three different yarns; 100 % cotton, 50:50 bamboo: cotton and 100 % bamboo. Three samples with plain weave and three samples with twill weave were produced with different blend ratio. Different properties as per standards have been evaluated to investigate the comfortability of fabrics, the details of fabric specification is given below:

Table 1: Specification of plain and twill weave samples

Sample ID	Weave structure	Warp yarns	Weft yarns	Count of yarns	EPI	PPI	GSM
S1	Plain	100% C	100% C	2/20's	46	32	200
S2	Plain	100% C	50/50 (B/C)	2/20's	46	35	210
S3	Plain	100% C	100% B	2/20's	46	36	216
S4	Twill	100% C	100% C	2/20's	46	46	237
S5	Twill	100% C	50/50 (B/C	2/20's	46	48	248
S6	Twill	100% C	100% B	2/20's	46	49	256

2.2 Methods used to measure comfort properties

2.2.1 Air permeability:

The air permeability of plain and twill fabrics was determined using an air permeability tester as per ASTM D737-96 standard. Five readings were taken for all samples.

2.2.2 Water vapor permeability:

The water vapor permeability of plain and twill fabrics was determined according to the ASTM E96 standard. Five readings were taken for all samples.

2.2.3 Vertical wicking:

The vertical wicking of all samples was measured in accordance with the AATCC TM197-2011 standard. Five readings of each sample were recorded.

2.2.4 Water Absorbency:

Water absorption of all samples recorded in accordance with AATCC TM97-2019 using an embroidery hoop; woven textiles were fixed at a 60o angle. A drop of water was released onto the fabric's surface from a predetermined height, and the time of absorption was recorded. Five readings of each sample were taken.

Table 2: Properties of Bamboo and Cotton Fiber [13, 14, 15]

Fiber properties	Fiber length (mm)	Fiber fineness (dtex)	Density (g/cm^3)	Moisture regain(%)	Dry tenacity (cN/dtex)	Wet tenacity (cN/dtex)
Bamboo	38-76	1.3-5.6	0.8-1.32	13.03	2.33	1.37
Cotton	25-45	1.2-2.8	1.5-1.54	8.5	1.9-3.1	2.2-3.1

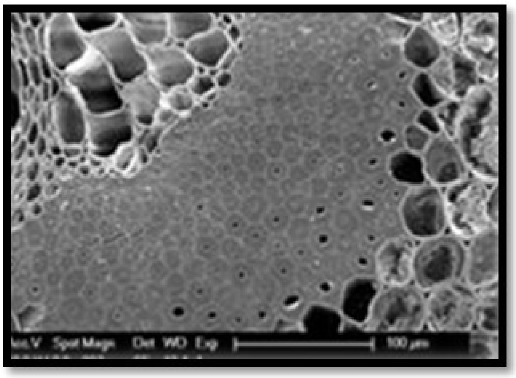

Figure 1: Cross sectional view of bamboo fiber [15]

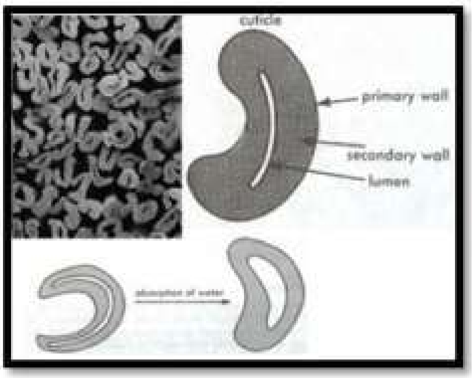

Figure 2: Cross sectional view of cotton fiber [16]

3. Result & discussion

The aim of the study was to produce samples of same constructional parameters other than weave and different blend ratio but due to manual control on handloom weaving which lead to the variation in picks per inch, which may have influenced various physical properties as shown in below:

Fabric properties of different specimen as measured are resulted in Table 3:

Table 3: Fabric Properties

Sample ID	Yarn blend ratio in weft	Cover factor (%)	Air Permeability ($m^3/m^2/min$)	WVP	Vertical Wicking (in cm.)		Water absorption (Time - in sec.)
					Warp	Weft	
S1	100% C	10.11	218.79	851.935	5	5.1	7
S2	50:50 (C:B)	11.07	137.11	866.075	6.2	7	4
S3	100% B	11.38	140.36	887.285	6.5	7.2	2
S4	100%C	14.54	145.27	788.305	6.2	6.2	6
S5	50:50 (C:B)	15.17	129.12	837.795	7.8	8.8	2
S6	100% B	15.49	138.52	859.005	8.2	9	1

a. Air Permeability

The air permeability depends upon the pore size and weaves structure of woven fabric, which is connected to the structural properties of woven fabric [17]. Based on the literature review, Plain weave fabrics inhibit airflow due to their shorter float length and compact structure, resulting in lower air permeability than twill weave fabrics [18].

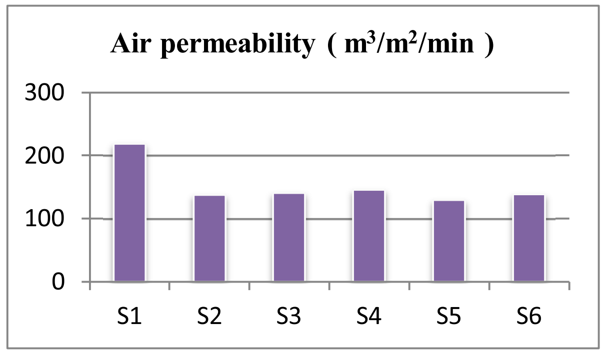

Figure 3:- Air Permeability

Experimental results are shown in Table 3 & Fig.3, air permeability of twill weave is less than that of plain weave. This may be due to the increase in thread density in weft yarns due to handloom weaving, which hinders air flow. Air-permeability is found maximum in 100 % cotton plain woven fabric due to least PPI.

3.1 Water vapor permeability

The results of water vapor permeability (WVP) depends upon the pore size and weaves structure of woven fabric, which is connected to the structural properties of woven fabrics [17]. Based on a literature review, Plain weave fabrics inhibit water vapor transmission due to their shorter float length and compact structure, resulting in lesser water vapor transmission than twill weave fabrics [18]. But the results in Table 3 & Fig. 4 indicated that twill weave has lower WVP than plain weave, which may be due to increasing pick density of twill weave samples.

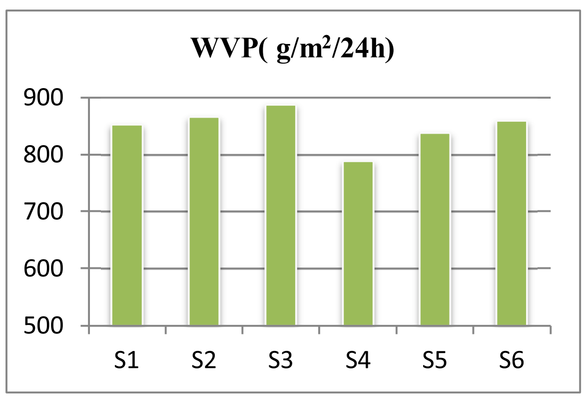

Figure 4: -Water vapor permeability

Overall, WVP increases with increasing bamboo content in plain and twill weave samples, this may be due to the higher tendency of moisture absorption [19] or regain of bamboo fibres. This can be attributed due to presence of macro channels in bamboo fibers as compared to cotton fiber which represents no hindrance to moisture transfer in hydrophilic system [20].

b. Vertical wicking

The vertical wicking of fabrics depends upon weave structure and type of fiber content used in fabrics. The results are shown in Table 3 & Figure 5 in warp direction, which indicates that vertical wicking becomes faster in twill weave when compared with plain weave. This may be due to higher float length in twill weave fabrics. Sample S6 shows faster vertical wicking than other samples, which can be attributed to higher bamboo fiber content which have micro gaps [19] and twill weave structure with longer float length and open structure of twill.

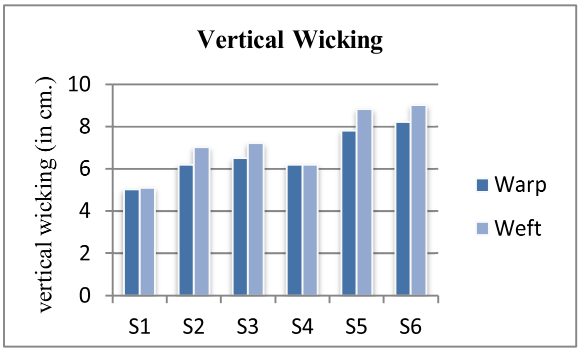

Figure 5: Vertical wicking

When compared the results in weft directions among S1, S2, and S3 of plain weave and S4, S5 and S6 of twill weave samples; Sample S3 and S6 indicate better wicking tendency in weft direction than warp direction for both in plain and twill weave samples with the increase of bamboo content. This may be due to 100 % bamboo yarn used in weft direction and twill weave structure which has higher water transfer tendency due to capillary rise and maximum no. of floats in construction which provide more spaces to accommodate water [13, 21]. Higher wicking in bamboo fiber may be attributed to the presence of more amorphous region as compared to cotton fiber [19]. Moisture regain in bamboo fiber generally ranges from 12-13 %, while in cotton; it is generally 8 % at 65 % RH.

c. Water Absorbency Test

The water absorbency depends upon the weave structure and type of fiber content used in fabrics. The results are shown in Table 3 & Fig.6, which indicate that water absorbency becomes faster in twill weave when compared with plain weave due to presence of longer float length.

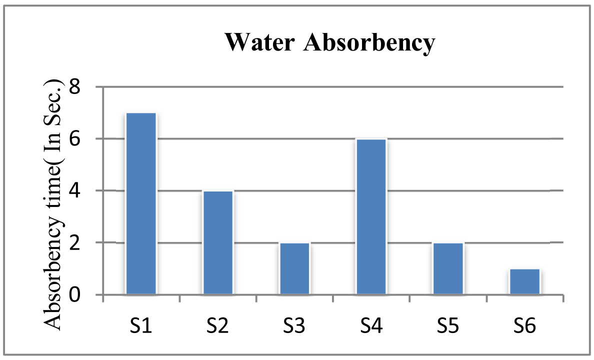

Figure 6:- Water Absorbency

Sample S6 shows faster water absorbency than other samples, which attributes on higher bamboo fiber content due to micro gaps present in bamboo fiber [19] and twill weave structure, which may be due to float length and open structure of twill [22].

4. Conclusion

Increased consumer's awareness towards environmental sustainability is gaining momentum and leading the manufacturing industry to adopt sustainable materials, processes, production technology and even supply chain. Handloom sector is reviving again and producing fabric on handloom is being seen as added value addition in terms of social, economic and environmental sustainability. The use of bamboo in the current study has indicated results in favor of enhanced comfort properties. Along with suitable constructional parameters like weave, fabric produced from bamboo rich fibres has proven to improved air-permeability, moisture vapor transfer, wicking and moisture absorbency. Apart from it, bamboo inherently has some excellent properties like biodegradability, antibacterial properties, UV resistance, high dry tenacity, low density, lustrous feel etc. in comparison to cotton fiber. Overall, use of bamboo fiber along with handloom industry could be seen as promising scope for consumers and entrepreneurs who are environmental conscious.

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Application of Nanotechnology in Textile Industry: A Review

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Abstract:

Nanotechnology is considered as one of the most promising and emerging technologies for the 21st century. Nano Science along with the nanotechnology encompasses the study and application of very small and tiny things which can be used across all the other science fields such as physics, chemistry, biology, material-science and engineering. This technology overcomes the drawbacks of applying traditional methods to impart certain properties to textile materials. Nanotechnology applied in smart textiles has modernized the textile world. Fabric touch pads, bullet free jumpsuits, invisible coating and advance fibers turned the basic textiles into smart textiles. The use of nanomaterial and nanotechnology-based processes are growing at a tremendous rate in all fields of science and technology. In this context, the use of nanotechnology in textile industry has also increased rapidly due to its unique and valuable properties. Nanotechnology has versatile applications in textile chemical industry in manufacturing garments with stain resistance, wrinkle resistance, finishes, antibacterial qualities, UV Protection etc. The future success of nanotechnology in textile applications lies in area where new principles will be combined into durable, multifunctional textile systems without compromising the inherent textile properties. In this present review paper, the present applications, principles and future scopes of the nanotechnology in the field of textile and apparel manufacturing have been discussed as a complete overview.

Keywords: *Anti-static, E-textiles, Nano-composite, Nanomaterials, Nanotechnology, UV-Protection*

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1. Introduction :

Nanotechnology (NT) is the specific field of technology which deals with particles of the length of 1-100 nm. At the molecular level, nanotechnology can be applied for imparting the required textile features, like self-cleaning, antimicrobial characteristics, fire retardancy, hydrophobicity, durability, soft and smooth surface-feel, remarkable surface texture, high tenacity etc. [1].

Nanoparticles, nanofluids, nanowires and nanofilms all have incredible potential for the applications in the different domains of science and technology i.e. microbiology, optics, electronics, textiles, biomedical, coatings, aerospace, materials science, energy, plastics and mechanics etc. It is established that the ordinary conventional materials treated with nanoparticles show significant improvements in certain physical, mechanical and chemical properties owing to large surface area of nanoparticles. A remarkable improvement in desired properties has been reported while moving from microscopic to nanoscopic. Nanoparticles contributes in upgradation of some unique properties by precise and controlled arrangements of molecules and atoms [2].

Advances in nanotechnology for the textile industry have initiated the special and emerging field which paved the way for several potential and opportunities for the textile industry. All of these are highlighted in brief in this review paper. This paper's main focus is on summarization and consolidation of nanotechnology's recent applications as they relate to textile and apparel products.

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In this context, it can be stated that beyond just fulfilling the basic human needs of protecting and covering the body, the textile-fabric now can be developed with some specific characteristics for some special and unique applications in our daily life. For example, static protection, self-cleaning, shrink resistance, stain resistance, fire - resistance, electrical conductivity, fragrance release, UV protection, water repellent (hydrophobic), moisture management, high strength, antimicrobial and wrinkle resistance by the controlled application of nanotechnology [3]. The salient advantages of nanotechnology is based on the nanostructure, nanoscale additives, nanoscale thin membranes, engineered nanomaterials and nanoscale transistors etc. Materials that can engineered by nanotechnology is reported to be more durable, sieve like, lighter in weight, conductive, stronger and may possess many other uniqueness [3].

Nanotechnology is used in the process of imparting certain functional characteristics to the textiles, which includes self-cleaning fabrics, dye capability enhancement, flame retardation, UV and anti-static protection. The latest nanotechnology-based wrinkle free treatment is launched by Nano-Tex which provides enhanced performance while preserving the integrity and strength of the fabric, offering an alternative to the harsh traditional process. Nanotechnology makes the current applications work more efficiently and effectively as it is an enabling technology. A great Scope in the future is possessed by the nanomaterial due to their potential of being used for various advanced applications in numerous sectors [1]. Nano fabrics are textiles engineered with small particles that imparts advantageous properties such as super-hydrophobicity, odor moisture elimination, increased elasticity, bacterial resistance to the ordinary textile materials. Depending upon the desired property, a nano-fabric is either constructed from nanoscopic fibers called nanofibers or ordinary textile fabric treated with nano-particles [4]. The most common nanomaterials in clothing are nano-silver and nano-titanium-dioxide. Nano-silver is woven into fabric to give it anti-bacterial properties, to repel the bacteria that make those clothes smell badly after sweat. Nano–Titanium dioxide also adds sun protection to clothing just as it does in sunscreen creams. It can be said strongly that, Nanotechnology is increasingly attracting worldwide attention because it is widely perceived as an option offering huge potential in a wide range of end uses. The unique and new properties of nano-materials have attracted not only scientists or researchers but also business personnels, due to its huge economic potential [5]. The use of nanotechnology in textiles can allow for the control of crystal structure, improved mechanical properties, improved resistance to adverse external factors, electrical properties and self-cleaning features of clothing [6]. Furthermore, textiles can be nano-engineered to have specific functions including hydrophobicity, antistatic behavior etc. And most importantly, using nanotechnology these properties can be achieved without compromising with breathability, wear comfort and tactile comfort of textile materials [7].

Apart from imparting certain specific properties to the apparel fabric, the nanotechnology has a great role to play in the fields of smart-textile as well. Smart textiles are a type of sensitive and responsive materials that can sense and respond to the change in physical and mechanical properties of the surroundings, i.e. they can respond to change in magnetic, mechanical, electrical, thermal or chemical parameters. In modern days, the smart textiles are being used in various fields i.e. health care, IOT-based health-monitoring, environment, military and hygiene etc. [8]. Smart textiles are manufactured as composites and coatings that result in sensor materials or wireless data transmission. It is possible to impart smartness in textile materials to be used as sensors or auto-responsive elements by treating with of nanoparticles, nanofilms and nano-coatings. Moreover, it is very much possible to achieve improved electrical conductivity, high mechanical strength and thermo-stability by the application of nano-particles [8, 9].

2. Review of Literatures

Available review paper of Ali K Yestisen et.al. [10] provides a fair understanding about the nanoparticle and its application in imparting some significant properties like stain repellence, wrinkle resistance, static elimination, electrical conductivity to fibers without compromising their comfort and flexibility. Also, the available papers are very much insightful about the application of smart garments that can sense and respond to external stimuli via electrical, color or physiological signals. Moreover, this review paper provides a fair understanding about the electronic and photonic nanotechnology that are integrated with textiles and shows their applications in displays, sensing, drug release within the context of performance, durability and conductivity. Also, it throws some light regarding some risk factors including nanotoxicity, nano material release during washing, environmental impact of nanotextiles based on life cycle assessments. Furthermore, this available article reports an analysis of nanotechnology consolidation in the textiles market to evaluate global trends including some insight about the present limitations of nanotechnology in the textile industry [10].

In this context, another article reports the application of nanotechnology with the materials of 1 to 100 mm in length [11]. This paper provides a fair understanding about the physical, chemical and biological properties of the nano particles. The Figure 1 represents a pictorial comparison of different categories of fibers in terms of diameter-range along with corresponding technologies.

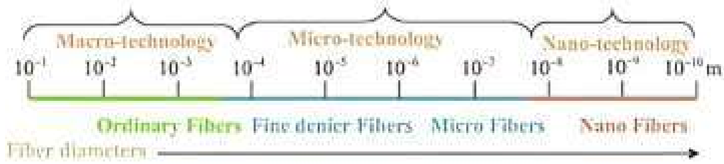

Figure 1: Fiber size and associated Manufacturing process [11]

In addition to that, this paper is very much insightful about the high tensile strength of nano particles, unique surface structure, soft-hand, durability, water repellency, fire retardancy and antimicrobial properties. [11]. The Figure 2 represents a consolidated pictorial view of different functional applications of nano finish for textile fabrics.

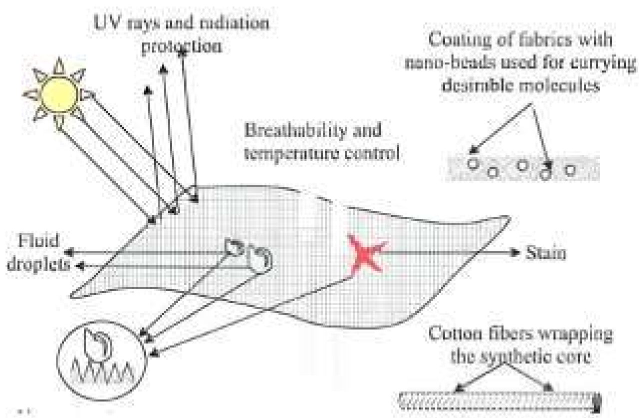

Figure 2: Fabric finishing for enhanced properties and performances [11]

Furthermore, another very relevant paper [2] reports about the application of nano-particles in medical textiles, which includes the development of artificial muscles which are used to match biological muscles. This paper is very much insightful about the use of fabrics treated with silver nano-particles (AgNPs), for the development of most effective antiseptic bandages or dressings. This paper provides a fair understanding about the encapsulation and piezoelectric properties of the nano particles. Also, it enlightens about the deformation-detection, light transmission, sensing and data transmission device for smart applications in the field of Internet of Things (IOT). In addition to that, it provides a fair understanding about the phase change material (PCM) and the features of thermostat. The application of nano technology in case of military purpose to monitor the stress and failure in human body during combat conditions is also reported. Also, it is insightful about the application of nylon nano particles which are utilized as protective clothing for the filtration applications and the application of fiberglass and carbon nano tubes which are widely used in the air filtration industry. The application of nano technology in smart textile and sportswear is also highlighted [2].

The applications of nano-finishes for medical purposes is also reported by the researchers. In this context, silver is very crucial element in biological point of view. It has been used in bio-treatment since ancient past. It is evident that the Silver has natural anti-fungal and anti-bacterial features. The nanotechnology has a great role to play in this domain as well. Polyester non-woven and colloids treated with nano-silver particles possess enhanced anti-bacterial properties. Resistance to bacterial growth in nano-silver particles makes it suitable to be applied in some special apparels like socks. Also, these nanoparticles are widely used in gauge or bandage materials for the purpose of wound, scald and burn dressings. Electrostatic, thermal and padding methods are utilized to apply nano-finishes on textiles. Textiles are generally treated with silver nanoparticles through padding technique. Also, antimicrobial filters are produced by manipulation of antimicrobial agents (Ag with nanofibers). Many nanofiber membranes like cellulose, PAN, (polyacrylonitrile) and PVC (polyvinyl chloride) containing Ag nanoparticles are found to be possessing antimicrobial properties. Engineered nanomaterials containing Ag and Ag^+ nanoparticles are used as antimicrobial filters with sufficient transport properties [2, 12].

Apart from Ag nanoparticles, titanium oxide and magnesium oxide nanoparticles are also utilized as biological protective agents. Also it is reported that, nanoparticle finishes can convert a material into sensor based material. Such sensors can be effectively used for IOT-based health monitoring systems. For instance, piezoceramic particles that are incorporated into the textiles can sense the pulse and heart beat by conversion of mechanical force into electrical signals. It is further reported by the researchers that Zinc oxide and titanium oxide nanoparticles are used for oxidative catalysis, UV protection and fiber protection. And also, the Silicon dioxide and aluminum oxide nanoparticles with polypropylene or polyethylene coatings are utilized as super water repellent purposes. It is further evident from the available researches that the ceramic nanoparticles are also being developed for enhanced abrasion resistance. Nanoparticles of indium tin oxide are used as infra-red protective clothing. Applications of Nylon fiber containing zinc oxide particles are found to enhance the antistatic and shielding effect [2].

Also, another article [13] reports the application of nano technology in the manufacture of the multi-functional textiles with sustainable durability which can be integrated into smart textiles. This paper provides a fair understanding about the use of interactive textiles which can perceive and response to external stimuli to align themselves with changes in the surrounding environment. This paper is very much insightful about the self-cleaning and self-healing ability of the nano particles. Moreover, it focuses on the application of the adjunctive garments that can response to the external stimuli. This review addresses the broad highlights of modern textile in the realm of smart application of nano technology to improve our daily life efficiency [13].

Furthermore, the article [14] in this context conveys that the use of nano materials and nano technology-based process are growing at a tremendous rate in all fields of science and technology. This paper is very much insightful about the application of nano technology in the textile industry that has increased rapidly due to its unique and valuable properties. Also, it provides a very clear and fair understanding about the use of nano technology in the apparel industry in manufacturing of garments with special functional properties like stem resistance, wrinkle resistance, wrinkle-free finishes etc. This paper is very much insightful about the anti-bacterial properties of nano particles and UV protection [14].

It is evident from available researches that metal-oxide nanoparticles can be effectively used for protection of skin form UV radiations. In this category, Titanium oxide, magnesium oxide, zinc oxide and aluminum oxide are the commonly used metal oxides that possess the potential of UV absorption, photocatalytic, electrical conductivity and photo- oxidizing capability [2, 15, and 16]. Also, nanotechnology can be used for protection against toxicity. Nanoparticles of above-mentioned metal oxides work against the biological and chemical toxic agents. It is evident that zinc oxide and titanium oxide nanoparticles are most popularly used as UV resistance elements [2, 17-20].

Regarding the application procedures, the Silver-nanoparticles coated on cotton fibers through pad dry cure method exhibited high laundering durability, retaining the antibacterial properties and anti-fungal properties against many pathogens even after several washing cycles. Such durability of silver-nanoparticles has made it a very effective and popular choice for the application on textile materials [2, 21].

Moreover, the Organic or inorganic titanium-oxide and titanium-dioxide have significant impacts on certain special features of textiles i.e. photo stabilizing wool, super-hydrophobic, photo- catalyst, co-catalyst for cotton crosslinking, antibacterial, gas sensor, self-cleaning, hydrophilic, dye degradation and solar cell. Also, the carbon nanotubes are utilized as chemical absorbers, electrically conductive device, antistatic, antimicrobial, and fire retardant. Furthermore, in this category, clay nano-particles used as UV absorber, antibacterial and flame retardant. In this context, it is also reported that the gold nanoparticles are electrically conductive and effective antibacterial agents [2, 21-24].

It is further reported by the researchers that the nylon nanofibers coated with silver has excellent antibacterial properties against gram negative E.coli and staphylococcus aureus bacteria. Also, the Electrospun nylon 6 nanofibers coated on cotton/nylon woven fabrics has effective filtration property. By using nylon-6 nanofibers, it is reported that around 99.5% efficiency is achieved without any surrendering in pressure drop and loss in air permeability [2, 25, and 26]. It is also found that Nylon fabric treated with electrospun nanofibers using the nanoparticles of ZnO, $SrTiO_3$ and TiO_2 exhibits significant self-cleaning features. It has been proved by characterization techniques that fabrics treated with such nylon (polyamide66) nanofibers retaining high photo activity after repeated wash and dye degradation [2, 12, 27, 28].

In this domain, another report [29] conveys the application of nano-science and nano-technology which encompasses the study and application of very small things and which is popularly used in the other science fields such as physics, chemistry, biology, Material science and Engineering. This paper provides an effective understanding about multifunctional textile structures, breathability and flexibility of nano particles. Also, it enlightens about the drawbacks of traditional process to impart certain properties to textile materials [29].

Another research paper [30] in this context, presents the use of nano dimensional silicon dioxide which may be used for final treatment of cotton and polyester textile materials in the process of industrial and household washing of the textile products. Furthermore, the insightful knowledge is available about the application of nano-materials on hygroscopicity, moisture yielding capacity, humidity, anti-soiling property and permeability. In addition to that it is very much insightful about the properties of textile materials with different fiber compositions after the nano-treatment [30].

Also, critical review is available [31] regarding the influence of the various types of the nano-finishes on the functional properties of the fabrics. This paper is very much insightful about multifunctional properties of the nano particles. In this context, Figure 3 represents the SEM (Scanning Electron Microscope) images of Zinc-Oxide (Zno)nano-particles on different textile materials.

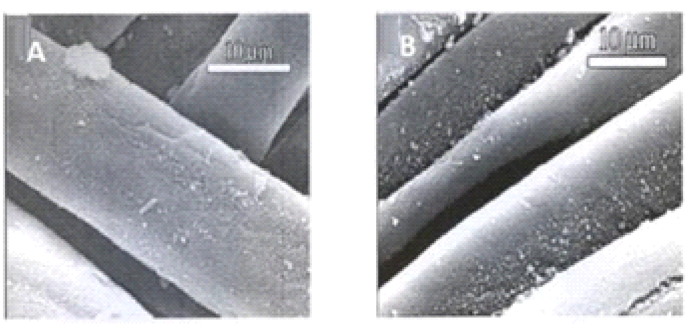

Figure 3: SEM Images of ZnO nano particles on A-Polyester before washing and B-Cotton after washing [31]

This article [31] conveys clearly about the application of Titanium di-Oxide nano particles which have been applied on the cotton fabrics to improve their wrinkle resistance. Silver-Oxide nano particles have been found to be best suited for imparting antimicrobial resistance and also in the treatment of wounds resulting from burns. This paper provides a significant insight about the use of polymer nano composites. Also, this paper is very insightful about the application of zinc oxide nano particles which have been used in stain elimination of textiles [31].

In this context, Figure 4 represents cross-sections of different nano-finished fabrics.

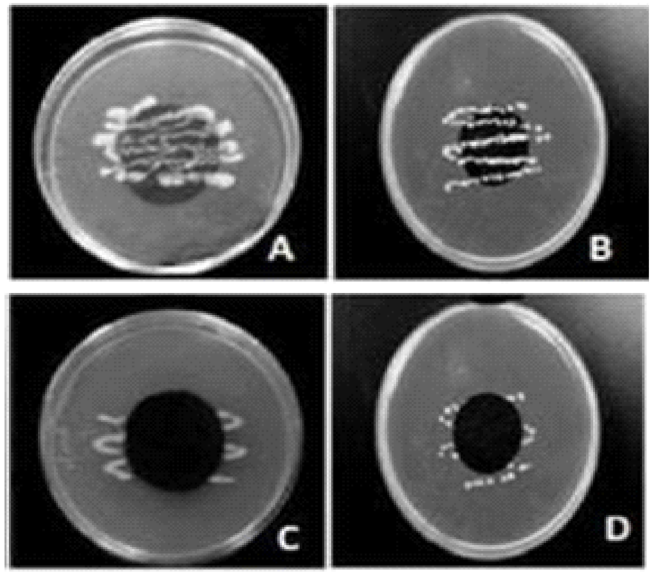

Figure 4 : A and C: Fabric cross-section with Anti-bacterial nano-treatment
B and D : fabric samples finished with mixed nano-particles TiO_2/nano-Ag (2.0 wt%/125ppm) [31]

In this regard, reports are obtained [32] about the application of nano technology for multiple purposes of the textile industry. This paper is very much insightful about the nano-treatment for water repellency, wrinkle resistance, UV-protection, anti-bacterial properties without alternating the other mechanical properties. This paper is insightful about the stability of application of nano materials on textile which has a key role in determining the success of nano textiles economically and sustainability for environmental safety [32].

The Table-1 represents different types of nano-materials for different types of functional-finishes of the textile substances, as obtained from different research papers and review papers.

Also, another article [39] reports about the unique and new properties of nano materials. This paper mainly focuses on the improvement of the nano-applications. This paper effectively throws some light in the domain of the application of nano-particles in the fields of color change, UV radiation, textile heating etc. In this context, Figure 5 represents the

Table-1: Different nano-materials for different functional finishes on textile

End-use requirement	Suitable nan0materials	References
Protection from UV	ZnO, TiO_2	2, 17-20
Improved staining and fade reduction	Nanoporous hydrocarbon, Carbon black, SiO2 matrix	2, 18, 33
Moisture absorbency	TiO_2	2, 17
Self-cleaning properties and water repellency	TiO_2, Fluoroacrylate, CNT, SiO_2 matrix	2, 34-35
medicinal products or fragrances	Montmorillonite (nano clay), SiO_2 (as matrix)	2, 36
Antistatic and conductive	Carbon nanotubes (CNT), Carbon black, Copper, Polypyrrole, Polyaniline	2, 37-38
Durability	Metal oxides like Al_2O_3, SiO_2, ,ZnO, CNT, Polybutylacrylate	2, 17
Antibacterial	Chitosan, Ag, SiO_2 matrix, ZnO and TiO_2	2, 17-18
Fire proofing	Boroxosiloxane, CNT, Montmorillonite (nano clay), Sb_3O_2	2, 35

schematic diagram of a very special technique of treating synthetic fiber with nano-touch wrap.

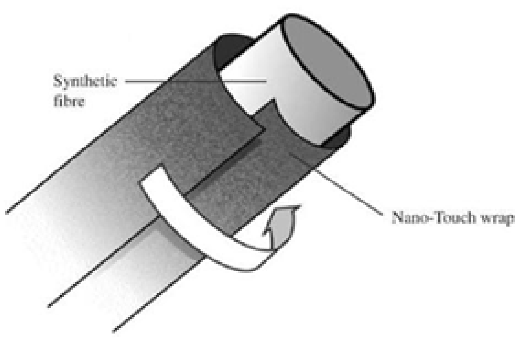

Figure 5: Schematic representation of a Nano-Touch treated fiber [39]

Likewise, the Figure 6 represents the 3D simulation of the application of nano-set of nano-dry on synthetic fibers.

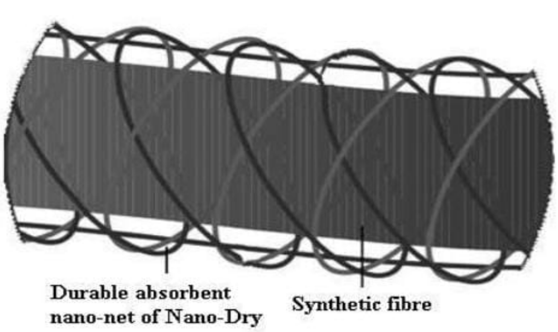

Figure 6: The Schematic representation of the 3D Molecular nano-net of nano dry [39]

Also, this paper is very much insightful about the economic potential of the nano particles. Moreover, it conveys effective information about the applications of nano-technology in the fields of high-tech fibers, stay-clean textiles and antistatic textiles [39]. Also, this paper provides a very vivid and effective pictorial representation of the change of surface with the change of the particle size at nano-scale, which is self-explanatory (Figure 7).

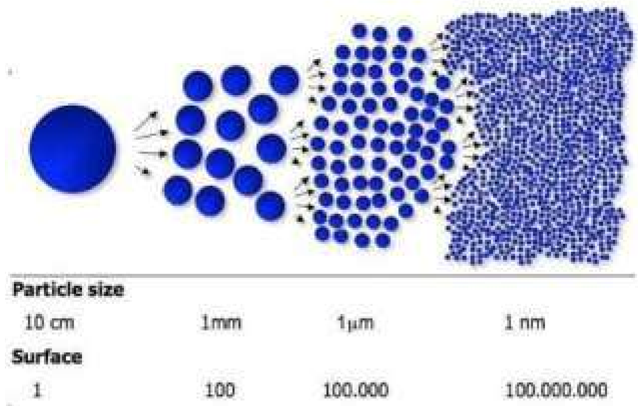

Figure 7: Schematic representation of particle size and surface at nano scale [39] .

There is a specific and special need of protection and comfort in adverse and extreme environments. Increased performance efficacy and unique functionality are the prime and crucial objectives to tackle the emergency and adverse situations, specifically in case of defense and security purposes. Nano-materials can be used to design special jumpsuits that can be used as low GSM bullet-proof textiles. These jumpsuits can be used in battlefields to detect and monitor injuries, health issues and pulse rate. Also, the conductive polymers that are embedded onto woven textile fabrics, worked as chemical sensors. These are engineered to monitor and detect health-hazards like toxic gases etc.

Application of Carbon nanotubes (CNT) as fillers in different polymers for imparting and enhancing different mechanical, heating and chemical properties of polymers are discussed by researchers. Also, Carbon-nanotube based polymer-composites are used as sensors of different external factors like pH, gasses, temperature, pressure, chemical vapors, light, strain and liquid. Also, the carbon doped polymers are used as piezoelectric materials, which can be effectively used as stretch actuators [40]. For high performance textiles, sensing apparels are made by the combination of carbon black powder and silicone. In case of modern-day electric-blankets, carbon-doped polymers can be used as reported by the researchers. Now it is possible to produce conductive textiles by incorporating the carbon-based fabrics [2, 40].

Coatings on the textiles are mainly used to obtain high performance and enhanced functionality. On the other hand, CNTs coatings are used presently on textiles for sensing applications. For example general cotton yarns are converted into e-textiles by coating of carbon nanotubes. Basically, polyelectrolyte-based coating of carbon nanotubes is carried out on the cotton yarns. Presently, it is possible to detect the blood protein (albumin) with the help of CNTs coated cotton yarns. Not only on the threads/ yarns, but carbon nanotubes can be coated on the fabrics and polymers as well. They may be utilized as lithium-ion battery [2, 41]. Development of self-powering energy textile was also reported that transforms solar energy into electrical energy using CNTs [42]. Another report was found which studied carbon-activated cotton threads on textile also for energy generation [2, 43].

Nanotechnology is an emerging and fast-growing interdisciplinary technology often seen as an element of industry 4.0. Nanotechnology (NT) involves the dealings with particles of 1 to 100 nm in length. The fundamentals of nanotechnology are based upon the fact that the basic properties of materials drastically alter when their dimensions are reduced to nanometer scale. In recent time the textile industry has adapted nano-technology, in different domains of applications, in both research level and commercial level. So, it can be stated that nanotechnology in textile is the realization, manipulation, and control of matter at the nano-length, such that the physical, chemical, and biological properties of the materials (individual atoms, molecules, and bulk matter) can be engineered, synthesized and altered to develop the next generation of upgraded materials, devices, structures and systems. It is used to develop desired textile features such as high tenacity, high tearing strength, durability, engineered surface structure, soft and smooth hand-feel, water repellency, fire retardancy, antimicrobial properties, self-cleaning, medical applications, thermoregulation properties etc.,

The application of nanotechnology makes the current processing work more efficient and effective. A great opportunity and potential of nanotechnology in the future can be forecasted due to their potential of being used for various advanced applications in a number of sectors. Also, it has gained commercial success as the companies are focused on the production of the nano-textile products, including conventional characteristics and meeting international safety, health, and environmental standards too. It can be said with a lot of affirmation that this technology is steadily finding its way into textiles for a long time now.

Moreover, textile-based nano-sensors are also being developed by the companies, thus opening numerous options for the nano-textile, including the creation of smart-clothes that easily adapts and responds accordingly to the weather changes, and also real-time monitoring of the vital physiological signs of the wearers, and customized healthcare systems. It can be of a huge interest in the field of IOT-enabled smart apparels also,

On the other hand, so far as the limitations or challenges are concerned, it is reported by the researchers that nanotechnology failed after the first trial for health care application, due to its poor medical consistency at reasonable price range. So, presently, the main focus of the commercial application of nanotechnology is presently on life style-regulation. Major thrust is towards the sportswear applications [2]

It is further reported that the textile and apparel companies and research organizations are presently working in collaborations to find out and formulate the unique ways of evaluating, sharing and tracking the athletic performance of the sportspersons using nanotechnology enabled sensors. However, it is obvious that aesthetic is the prime focus in the fashion industry. Therefore, commercial application of smart textiles are quite difficult [2].

Another drawback related to nano-finish and nanomaterials is the threat of toxicity. To evaluate the toxicity of engineered nanomaterials different methods are formulated. Also, the evaluation standards like IEC/TC113 and ISO/TC229 etc. have been prepared to measure the toxicity of nanomaterials. However, no distinct or defined resource is presently available to know about specific adverse effects of nanotechnology in textiles, or how it can be minimized. Some risks associated to engineered nanomaterials have been reported in the literature [2].

Some of the present researches reported the risks and potential hazards associated with the engineered nanomaterials that are used for facial cosmetics and textiles. The toxicity and other characteristics of engineered nanomaterials as projected through mathematical modelling are available in different literatures. However, at the same time, it is also reported that almost 90 % of nanoparticles of silver and other engineered nanomaterials can be eliminated by waste water treatment [2, 44-46].

But it must be noted that there is always a risk while using engineered nano materials like silver and zinc compounds. As, there is always a chance that engineered nanomaterials may be coupled with the large sized particles and then released into the atmosphere. For example, the Nano Titanium dioxide is the part of engineered magnetic materials that may cause harm to the organic cellular structures like lungs, brains etc. Nanoparticles can enter more easily into the lungs and may cause tissue damages [2, 44-46].

Although, more researches are needed to be carried out to gather more precise understandings about the potential adverse effects of the engineered nanomaterials. However, it is remarkable that some researchers have examined the sustained toxicity of engineered nanomaterials [2, 47].

Presently, there are a lot of uncertainties to assess the hazardous impacts of engineered nanomaterials on human health. As per the available researches it is found that there are quite a different types of engineered nanomaterials which have not caused any serious effects after exposure with skin. The bottom-line is that it is essential to have thorough and detailed investigations about the risk factors associated with nanomaterials, before its commercial and mass-scale applications. As it is highly recommended by all the world community of researchers [2][44-46].

Finally, Inspite of all these shortcomings, it can be said that there is a paradigm shift of textile and apparel industry towards technological upgradation and modernization by the application of nanotechnology , even though it has some drawbacks and sustainability issues at present [2, 48-50].

3. Conclusion

There are lots of functional advantages of the application of engineered nanomaterials on textile fabrics. The particle sizes of certain materials like silver, zinc, titanium compounds etc. when reduced to the nano-level, possess remarkable characteristics and potential, which can be capitalized for enhancement of some functional and surface properties of textile materials. Wrinkle resistance, UV protection, water resistance, antimicrobial property, anti-static property, surface smoothness, thermo-regulation, self-cleaning property, durability etc. can be improved by the application of nano-finish. Also, application of engineered nano-materials in the fields of smart-textiles, e-textile, medical textile and technical textile are remarkable.

However, at the same time, it is associated with some drawbacks and threats as well, as the toxic influences of the nanoparticles on the environment and human health are of serious concern and still vast researches are to be carried out to have more precise guidelines for most optimized and favorable usage of Nano-materials. In addition to that, the high expenditures that are associated with the nanotechnology-based textile finishes is one of the biggest hurdles in the expansion of nano-textiles. For instance, In the apparel market, a common domain of interest is thermos-regulated or temperature-regulated clothing, however, customers stay away due to the hefty prices.

In-spite-of these temporary drawbacks and challenges, it is very loud and clear that a broad number of qualities are possessed by nanomaterials despite some cons, making the textile products extremely durable, lighter and stronger, and also giving them special end-use properties. The researches project a very promising and commercially successful future of nanotechnology in the textile industry, as it is evident that the quality and service must overcome the cost-barrier in the consumer market.

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Best Predictor for Fiber - Yarn Relationship using Hybrid Neuro - Fuzzy Logic

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Abstract:

A crucial process in the textile industry is spinning. There is a distinct relationship between the provided fibers and the yarn that is created during the process of spinning. The relationship between the input and output quality is not linear. Several approaches, such as the Artificial Neural Network framework and multiple regressions method, were used in an attempt to establish the aforementioned relationship. This study uses Hybrid Neuro Fuzzy Logic (HNFL) to anticipate multi-property fibers based on yarn characteristics. This work describes the development of an ANFIS-based yarn-quality forecasting system that can predict five qualities of cotton yarns by entering nine fiber parameters into the framework. Furthermore, it has been demonstrated that the predictive model performed well in accurately forecasting yarn qualities with a relative error of less than 0.00356266 percent. The outcomes reveal that the Takasi Sugeno Kang Fuzzy Inference System based ANFIS model produces more precise and reliable predictions. The proposed model serves as an excellent foundation for the creation of comparable applications designed for intricate models that need prediction and multi-objective optimization.

Keywords: *Artificial Neural Network, ANFIS, Hybrid Neuro-Fuzzy Logic, Predictions, Takasi Sugeno Kang fuzzy Inference System*

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1. Introduction :

Yarn quality is significantly influenced by fiber characteristics, spinning technique, spinning equipment, mill temperature and humidity, and other variables. The most crucial of these variables for yarn quality is fiber properties. The quality of any cotton yarn is primarily determined by fiber qualities such as strength (STR), yellowness (+B), span length (SL), micronaire (MIC), degrees of reflectance (RD), color grade (CG), trash (TR), short fiber index (SFI), and uniformity index (UNF). As a result, choosing the right cotton is critical for producing a high-quality yarn. Yarn quality is measured by features such as coefficient of mass variation (CV %), count strength product (CSP), twists per inch (TIP), irregularity (U %), thinness (-50%), thickness (+50%), neps (+280%), imperfection index (TOTAL IPI), hair, and elongation. Several models have been devised by researchers to ascertain the relationship between fiber and yarn. The multiple regression approach, which calculates coefficients that are frequently only applicable to a given population and operating circumstances, is the main component of the statistical methodology. The empirical method makes the unfounded assumption that yarn qualities are only influenced by fiber characteristics, which is not necessarily the case [1- 4]. By using the neural network, yarn characteristics may be predicted based on fiber properties. There is no universal Artificial Neural Network (ANN) model since various sectors use different metrics for predicting yarn characteristics. All spinners aren't going to use an identical set of input qualities to produce the desired yarn. Span length, tenacity, the fiber quality index (FQI), and so on are a few examples. As a result, the ANN architecture varies for each spinner [5-14].

Two forms of artificial intelligence, ANN and fuzzy systems, are becoming more well-known in the field of learning. This is mostly because to their innate parallelism, their capacity for learning and adaptation, and, to a lesser extent, their improved error tolerance. As mentioned above, fuzzy logic and neural networks offer numerous benefits. However, one disadvantage of fuzzy control is that, once control laws and membership functions are created, they must be updated whenever a new kind of system arises. A further drawback of the neural network is that it takes a long time to train as many neurons as the system's complexity, and during the learning process it is prone to focusing on the local minimum instead of the global minimum. Research on HNFL, the fusion of neural networks with fuzzy logic, is underway in an effort to compensate for the flaws. A proposed HNFL system combines qualitative knowledge of symbolic fuzzy rules and neural networks' capacity for learning. ANFIS integrates the advantages of ANN and fuzzy systems. The ANFIS generates input-output linkages and may serve as a basis for fuzzy rules with appropriate membership functions. With proper training, the produced fuzzy inference system (FIS) can predict every spun yarn.

2. Materials and Methods

2.1 Selection of Yarn Parameters

Selecting the appropriate yarn properties is essential in different spinning technology. The quality of the fiber

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determines the quality of yarn spun from cotton. The choice of yarn parameters is essential to guaranteeing the effectiveness, durability, and affordability of textile products. Selected characteristics are in accordance with the production process, client preferences, and the functional needs of the final product. Studies are conducted using artificial intelligence methods like neural networks, fuzzy logic, and their hybrid combinations, using the vast amounts of data that are accessible from a reputable spinning companies. The potential to lower costs by offering the chance to replace more costly cotton in blending without compromising quality or processing efficiency is what gives blending its economic impact. It's critical that yarn parameters remain consistent. In this paper we use the important yarn parameters which are used to define the quality of yarn are CV%, CSP, TPI, Total IPI, hairiness and elongations.

2.2 ANFIS Predictor Modelization

An ANFIS is a kind of adaptive network Fig. 1 that consists of many layers with a feed-forward architecture. In ANFIS, each node has a specific node function, which it applies to incoming signals. In addition, each node has a set of parameters connected with it. The intended input–output mapping is attained by updating these parameters in accordance with the provided hybrid learning rule and data. The hybrid learning method involves two iterations: one in the forward direction and one in the backward direction. In the forward pass, the input information undergoes functional transformations and advances to the output layer 5, where parameters are found using the least square equation and the error measure is computed. The gradient approach is used in the backward pass to adjust the layer parameters as the error rates travel from the output side towards the input end [15-18].

2.2.1 Elements of ANFIS Architecture

Fig. 1 illustrates the architecture of the ANFIS, with square nodes representing functions requiring parameter learning and circular nodes representing fixed operations.

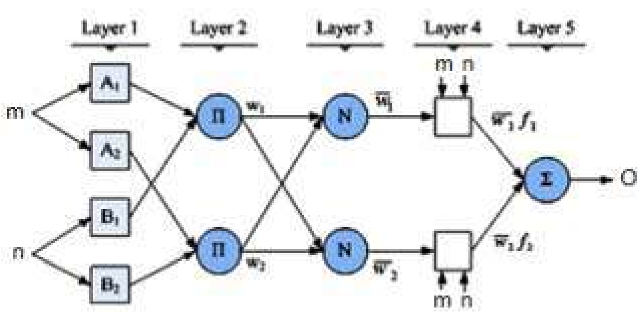

Figure 1: Architecture of ANFIS

Let m and n be two inputs that construct two fuzzy rules.

Rule No 1: If m is A1 and n is B1, then f1 = a1m + b1n + c1;
Rule No 2: If m is A2 and n is B2, then f2 = a2m + b2n + c2 (1)

The fuzzy rule's premise variables are represented by the inputs m and n. The premise parameters are indicated by A1 and B1. a1, b1, and c1 make up the consequences parameter. Equation (2) uses the weight values of w1 and w2, the f1 and f2 functions, and the total output function

$$O = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2} = \overline{w_1} f_1 + \overline{w_2} f_2 \quad (2)$$

With reference to Fig. 1 five layers are present in the ANFIS architecture [19-21].

Layer No. 1: All nodes in this layer are adaptable. Here the fuzzification process occurs. Outputs are the membership values of the premise portion. The output of each node is represented by equation (3).

$$\begin{aligned} Out_{1,i} &= \mu_{A_i}(m) \quad for\ i = 1,2 \\ Out_{1,i} &= \mu_{B_{i-2}}(m) \quad for\ i = 3,4 \end{aligned} \quad (3)$$

For inputs m and n, the membership grade is thus $Out_{1,i}(m)$. Any shape, including bell, trapezoidal, triangular, and others, might be used for the membership purposes. The function with a triangular form is provided by

$$Tri_i(m) = \begin{cases} 0 & if\ m \le x_i \\ \dfrac{m - x_i}{y_i - x_i} = \dfrac{1}{y_i - x_i} m - \dfrac{x_i}{y_i - x_i} & if\ x_i \le m \le y_i \\ \dfrac{z_i - m}{z_i - y_i} = \dfrac{-1}{z_i - y_i} m + \dfrac{z_i}{z_i - y_i} & if\ y_i \le m \le z_i \\ 0 & if\ z_i \le m \end{cases}$$

Layer No.2: Equation (4), which represents the weight of the rule, determines the output of each fixed node in this layer.

$$Out_{2,i} = w_i = \mu_{A_i}(m)\mu_{B_i}(n) \quad for\ i = 1,2 \quad (4)$$

Layer No. 3: Once again, the nodes in this layer are fixed. Equation (5) gives the calculated ratio of the firing weight of the i^{th} rule to the total weights of all the rules.

$$Out_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2} \quad (5)$$

Layer No.4: The nodes work as a function block, with adaptive parameters and variables representing input values. Equation (6) Produces TSK outputs.

$$Out_{4,i} = \overline{w_i} f_i = \overline{w_i}(a_i x + b_i y + c_i) \quad (6)$$

Here the resultant parameters that need to be found are ai, bi, and ci.

Layer No.5: The sum of all incoming signals is this layer's output. Equation (7) represents the whole output.

$$Out_{5,i} = \sum_i \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \quad (7)$$

To map the input-output dataset, the ANFIS associates the parameters with a specific membership function. Fig. 1 shows that the Takagi-Sugeno model's output membership functions are linear but its input membership functions are non-linear. In order to optimize the parameters based on an input-output dataset, the hybrid learning algorithm which incorporates the error back-propagation technique with the least squares method, is the most efficient approach. The error back propagation (BP) technique is an appropriate optimization procedure as the input functions are non-linear. Since the output functions are linear, the least squares estimate approach works very well.

In summary, the advantages of the ANFIS algorithm over the ANN model lie in its fuzzy logic-based paradigm, which leverages the ANN's learning capabilities to improve the performance of intelligent systems by using past information. The ANFIS builds a FIS from a given input-output dataset, and then uses the least squares approach together with the back-propagation technique to tune (change) the membership function parameters. By using these strategies, the fuzzy modelling process may acquire knowledge about the dataset and use that knowledge to calculate the membership function parameters that will enable the associated FIS to monitor the input-output data most effectively. An input layer, hidden layers, and an output layer make up the structure of the ANN model. These layers have fixed nodes, and the error back-propagation approach is employed to alter the synaptic weights. Since there are two methods of learning in the ANFIS—gradient descent is used employed for backward learning and the least square estimate technique is used employed for forward learning—it is clear that flexibility in parameters is related to nodes and that this will improve non-linear mapping. The ANFIS has a quick convergence rate and requires minimal training data. Here, we provide an ANFIS-based modelling approach that leverages the neural network at the front end to maximize system efficiency while preserving all the benefits of fuzzy systems.

2.2.2 Training ANFIS Predictor

Matlab's Neuro-Fuzzy toolbox was used to train the ANFIS predictor. An input-output data set is used by the ANFIS to construct a TSKFIS. It enables the fuzzy system to acquire knowledge from the modelled system's data collection. Gradient vector ensures membership parameter calculation.

3. Result and Discussion

For the purpose of this research, various cotton varieties were selected to encompass all staple length categories of cotton cultivated in India. A grand total of 20 cottons varieties were examined H1098, RS 875, NHH 44, F 846BRAHMA, LH 1556, J34, PHULE 492, G Cot 16, DHH11,G Cot HY 10, F414, MCU 5, DCH 32, Shankar-4, BUNNY, Shankar-6, Gujarat -17, Hybrid 4and H777 were among the varieties that were examined. After conditioning the cottons for moisture equilibrium, they were evaluated in a controlled environment of 64.9% relative humidity with a temperature maintained at 27.5°C using a High Volume Instrument. The HVI system measures SL, SFI, MIC, STR, TR, RD, +B, CG, and UNF.

For the experiment, the average values of the fiber qualities were taken into account. The fiber length range that was examined ranged from 21.8 to 30.5 mm. The BRAHMA variety of cotton has the lowest SL of all the varieties under study, measuring 21.8 mm. The greatest fiber length measured for MCU 5 was determined to be 30.5 mm. RS. 875 have the lowest MIC value. In this investigation, it was discovered that NHH 44 and Phule 492 contained the lowest SFI. DCH32 revealed the least TR values, whereas BUNNY showed the highest. The results also showed that F 414 had the highest elongation value of 6.7%, while LH 1556 had the least amount of elongation of 6.4%. We analyzed the yarn samples for CV %, CSP, TIP, TOTAL IPI, Hair and Elongation.

There are 300 distinct textile industry samples in this collection, representing 20 distinct kinds. Two groups were created using the information that was gathered from the spinning industry. Two sets were utilized: one for testing and the other for learning. There are 250 samples in the training dataset and 50 samples in the testing dataset. The ANFIS block needs to learn from the dataset, as Fig. 1 illustrates. Six inputs and one output make up the used ANFIS. By changing the kind, quantity, and structure of the input membership functions as well as the output membership function type, several strategies were examined. Table 1 provides a full summary of the learning phase's outcomes.

Table 1: Results of the Learning Phase

Input Membership: Type	Input Membership: No.	Training Method	Output Membership Type	Error CV%	Error CSP	Error TPI	Error TOTAL IPI	Error Hair	Error Elongation	Epoch
Triangle	2	Hybrid	Const	36.2217	0.044018	4.1764	38.1145	0.37626	0.14577	50
			Linear	0.26066	0.00019477	0.011818	0.069013	0.00062476	0.00073541	50
		BP	Const	86.8244	1.1645	23.9382	109.2304	4.3031	5.1567	50
			Linear	75.4152	0.07682	11.8228	97.6133	0.39703	0.16792	50
	3	Hybrid	Const	0.0010304	1.2265 x10^{-05}	0.00036745	0.0041306	4.0193 x10^{-05}	3.67 x 10^{-05}	50
			Linear	4.241 x 10^{-05}	4.8064 x10^{-07}	6.8422 x10^{-06}	4.3752 x10^{-05}	1.3486 x10^{-06}	1.99 x 10^{-06}	50
		BP	Const	86.8754	1.2189	23.9921	109.2813	4.3575	5.2109	50
			Linear	2.3588	0.041313	16.6874	102.3448	0.33725	0.3942	50

Input Membership Type	Input Membership No.	Training Method	Output Membership Type	Error CV%	Error CSP	Error TPI	Error TOTAL IPI	Error Hair	Error Elongation	Epoch
Trapeze	2	Hybrid	Const	34.8789	0.041999	4.0566	33.38	0.35483	0.13477	50
			Linear	0.0026274	3.5261×10^{-06}	0.00036354	0.0028844	3.0673×10^{-05}	1.99×10^{-05}	50
		BP	Const	86.8158	1.1544	23.9278	109.225	4.2933	5.146	50
			Linear	74.7952	0.097391	11.2462	97.173	0.37711	0.17766	50
	3	Hybrid	Const	0.00081286	7.2951×10^{-06}	0.00015019	0.00047274	2.9781×10^{-05}	5.51×10^{-05}	50
			Linear	4.5452×10^{-5}	6.6042×10^{-07}	1.2718×10^{-05}	6.1163×10^{-05}	2.266×10^{-06}	2.76×10^{-06}	50
		BP	Const	86.8775	1.2274	24.0001	109.2873	4.3654	5.2213	50
			Linear	80.1874	0.047503	17.5214	102.8822	0.30294	0.32522	50
Bell Shape	2	Hybrid	Const	34.3232	0.041469	3.968	34.66	0.35432	0.13842	50
			Linear	0.016278	1.5452×10^{-05}	0.0017723	0.013597	0.00011152	8.21×10^{-05}	50
		BP	Const	86.8092	1.143	23.9174	109.2122	4.2817	5.1352	50
			Linear	74.0619	0.076506	9.9794	95.9465	0.39035	0.18495	50
	3	Hybrid	Const	0.0022973	1.2324×10^{-05}	0.00033941	0.0031114	3.7278×10^{-05}	3.73×10^{-05}	50
			Linear	0.00020619	2.7601×10^{-06}	4.4254×10^{-05}	0.00023797	9.7336×10^{-05}	1.1×10^{-05}	50
		BP	Const	86.8293	1.1667	23.9392	109.237	4.3054	5.2902	50
			Linear	75.979	0.055151	12.5297	98.3459	0.33113	0.22165	50
Gauss	2	Hybrid	Const	34.4908	0.042466	4.0232	34.8579	0.37134	0.1397	50
			Linear	0.022138	3.0658×10^{-05}	0.0041324	0.025864	0.00025913	0.00017538	50
		BP	Const	86.8077	1.1413	23.9159	109.2107	4.2799	5.1335	50
			Linear	73.9251	0.075801	9.8428	95.8102	0.39893	0.18134	50
	3	Hybrid	Const	0.002426	1.2784×10^{-05}	0.00032939	0.0036689	4.4209×10^{-05}	3.84×10^{-05}	50
			Linear	0.00012438	1.2567×10^{-06}	3.2232×10^{-05}	0.00012522	5.3798×10^{-06}	7.21×10^{-06}	50
		BP	Const	86.8012	1.1382	23.9114	109.2127	4.2767	5.1297	50
			Linear	73.5191	0.063827	10.5355	96.166	0.37247	0.22308	50
Gauss2	2	Hybrid	Const	36.7239	0.042978	4.0353	33.2257	0.34241	0.14024	50
			Linear	0.064929	4.9543×10^{-06}	0.00036309	0.0039281	3.3329×10^{-05}	2.50×10^{-05}	50
		BP	Const	86.8072	1.1432	23.917	109.2104	4.2804	5.1348	50
			Linear	73.9274	0.094745	10.3764	95.7571	0.40339	0.17989	50
	3	Hybrid	Const	0.0010779	8.5547×10^{-06}	0.00016299	0.0012288	2.9542×10^{-05}	5.69×10^{-05}	50
			Linear	0.00018244	2.8895×10^{-06}	5.9483×10^{-05}	0.0002546	1.3274×10^{-05}	1.22×10^{-05}	50
		BP	Const	86.8731	1.1898	23.9814	109.0131	4.3259	5.1799	50
			Linear	79.9767	0.053063	16.1161	104.165	0.3039	0.33992	50
Pi	2	Hybrid	Const	38.4341	0.042209	4.043	34.0061	0.34317	0.13608	50
			Linear	0.71628	4.1089×10^{-06}	0.00026401	0.0023974	2.1237×10^{-05}	1.31×10^{-05}	50
		BP	Const	86.815	1.1571	23.9319	109.2268	4.2957	5.1494	50
			Linear	74.5964	0.097422	11.605	97.3184	0.384	0.18513	50
	3	Hybrid	Const	0.071121	7.9074×10^{-05}	0.00015105	0.00077832	2.7953×10^{-05}	8.69×10^{-05}	50
			Linear	6.3544×10^{-5}	9.8685×10^{-07}	1.7826×10^{-05}	9.2547×10^{-05}	3.2252×10^{-06}	4.03×10^{-06}	50
		BP	Const	86.8733	1.2251	23.9963	109.2832	4.363	5.217	50
			Linear	79.8096	0.063557	17.155	102.4882	0.22385	0.13615	50
Psig	2	Hybrid	Const	33.4995	0.041545	4.0431	33.2041	0.34045	0.13675	50
			Linear	0.0034485	4.9162×10^{-05}	0.00031777	0.0030707	2.6504×10^{-05}	2.32×10^{-05}	50
		BP	Const	86.8087	1.1474	23.9219	109.2208	4.2861	5.1396	50
			Linear	74.0274	0.097111	10.6752	96.8228	0.38617	0.1712	50
	3	Hybrid	Const	0.001005	1.0525×10^{-05}	0.00019513	0.0010337	3.2379×10^{-05}	6.01×10^{-05}	50
			Linear	0.001655	4.2761×10^{-06}	8.5219×10^{-05}	0.00045455	1.5042×10^{-05}	1.73×10^{-05}	50
		BP	Const	4.5366	1.2158	23.9905	109.2868	4.3542	5.2078	50
			Linear	7907822	0.058971	17.0124	102.3828	0.28348	0.26744	50

Input Membership Type	Input Membership No.	Training Method	Output Membership Type	Error CV%	Error CSP	Error TPI	Error TOTAL IPI	Error Hair	Error Elongation	Epoch
Dsig	2	Hybrid	Const	33.4995	0.041545	4.0431	33.204	0.34045	0.13675	50
			Linear	0.003421	5.5833 x10^{-06}	0.0003109	0.0030844	2.6392 x10^{-05}	1.85 x 10^{-05}	50
		BP	Const	86.8087	1.1474	23.9219	109.2208	4.2861	5.1396	50
			Linear	74.0274	0.097111	10.6752	96.8228	0.38617	0.1712	50
	3	Hybrid	Const	0.001005	1.0525 x10^{-05}	0.00019513	0.0010337	3.2379 x10^{-05}	6.01 x 10^{-05}	50
			Linear	0.00032278	4.2568 x10^{-06}	8.4107 x10^{-05}	0.00046465	1.5078 x10^{-05}	1.73 x 10^{-05}	50
		BP	Const	86.8719	1.2158	23.9905	109.2868	4.3542	5.2078	50
			Linear	79.7821	0.058971	17.0123	102.2857	0.28339	0.26744	50

After both systems were trained, an evaluation was conducted on the remaining 100 samples. Qualities of the projected yarn were CV %, CSP, TIP, TOTAL IPI, hair and Elongation. Training aims to accurately generalize the correlation between input and output datasets. Based on a review of the facts in Table 1, the strategy indicated in input membership type-triangle, number-3, training method-hybrid and output membership type-linear should be selected for the most accurate prediction.

4. Conclusion

To anticipate yarn quality, it is necessary to predict yarn quality more accurately throughout the spinning process. In this article, a best predictor for fiber - yarn relationship was evaluated using Hybrid Neuro - Fuzzy Logic, to predict six yarn properties such as CV %, CSP, TIP, TOTAL IPI, Hair and Elongation. Accuracy can satisfy the demands of spinning factories, therefore anticipating outcomes would be valuable for directing spinning practice.

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Compact System to Determine Single Yarn Strength and Elongation

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Abstract:

The two main properties of the majority of raw materials—whether they be metals or non-metals like foam, textiles , leather ,paper, rubber, or completed goods like ropes, yarns etc which are tensile strength and elongation. These two characteristics frequently have a significant impact on whether any raw material is appropriate for a certain use [2]. Determining these attributes in a timely, easy, and accurate manner is therefore crucial.

A reasonably priced method for figuring out the tensile strength and elongation of cotton, jute, and silk yarn in a single strand is offered by the proposed model. They are based on the constant rate of traverse principle, which uses a motor, gear box, and screw arrangement to move the test specimen's opposite end at a predetermined speed while keeping the stationary end in a grasp. A load cell and a digital indicator are used to measure the load applied to the stationary grip. The digital indicator features a tare feature for employing different grips and a peak hold feature to indicate breaking load. The tester's frame is equipped with a linear scale that measures the elongation of the test specimen and marks the distance between the grips. The suggested approach is less expensive and more accurate.

Keywords: *Count lea strength product (CLSP), Constant Rate of Extension (CRE), Constant Rate of Loading (CRL), Constant Rate of Traverse (CRT), Gramm force (gf)*

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1. Introduction :

The majority of basic materials, which may be metals or non-metals like plastic, foam, paper, rubber, textiles, leather or completed goods like rods, ropes, yarns, belts, etc., have tensile strength and elongation as their two main properties. When assessing whether any raw material is appropriate for a given application, these two characteristics frequently come into play [1]. Consequently, it is critical to quickly, easily, and properly ascertain these parameters.

The importance of yarn strength is to be studied from several aspects depending on its end use.The textile materials show marked differences in strength among themselves. There are many factors that are to be considered while estimating the yarn strength [3]. Yarns are used for manufacturing sewing threads and tough industrial fabrics. The end use of yarns depends upon the most important property, namely strength. The greatest force or load needed to break the material is known as the tensile property of a yarn. Because it directly affects the developed materials' strength, it is a metric that is crucial to the yarn-making process. Yarn strength is measured in a variety of ways.

The single yarn strength is measured in Newton (N) and centi-Newtons (cN) units. One Newton force is the amount of force needed by an object with a mass of one kilogram to accelerate it to one meter per Second Square. Information regarding the warping machine and loom efficiency can be obtained from the strength of a single yarn. The count lea strength product (CLSP) of the yarn is computed in order to determine its combined strength effect [4]. Using the wrapping reel, a Lea of 120 yards is formed, and the weight of the lea is computed to get the yarn count.

i. Types of Tensile Strength Testing Machines:On the basis of the working principle, tensile strength testing machines can be categorized into three major categories.

ii. Constant Rate of Extension (CRE): Here, the rate of elongation of the test specimen is kept constant and the load is applied accordingly. A constant rate of elongation is the basis for the Tensorapid-4's operation, which assesses a single yarn's tensile strength [4].

iii. Constant Rate of Loading (CRL):The test sample is subjected to a load applied by the machines that increases with time. The specimen can freely extend, and for any given applied load, its extension will depend on its properties. This is the category in which the Lea Strength Machine operates [5].

iv. Constant Rate of Traverse (CRT):This kind of apparatus uses two pulling clamps to measure the sample's tensile strength. A load measuring mechanism is activated by the second clamp, which applies the load while the first clamp travels at a constant speed.

Tensile strength is a crucial mechanical property of yarn that measures the maximum tensile or pulling force that a yarn can withstand without breaking [6]. It is a main parameter in determining the suitability of a yarn for various applications, such as textiles, sewing, knitting, or industrial uses. Tensile testing is a technique used to evaluate a yarn's toughness, elongation, and breaking force. So proposed technique use to obtain correct tensile strength in real time application in short time.

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2. Yarn Strength and Elongation

The greatest force a yarn under tension may withstand before breaking is known as its yarn strength. This is dependent upon the fiber's resistance to slippage and strength. Yarn strength is particularly dependent on the fiber's properties (length, strength, and crimp), the yarn's evenness, particularly the presence of thin areas, and the yarn's construction parameters (count and twist) [5]. A yarn's extension, also known as its elongation, is the maximum length it can stretch before breaking. Frequently, it is stated as a percentage of the initial, or outstretched, length.There is a relationship between yarn strength and extension, which in spun yarns is mostly dictated by (a) the number of fibers in the yarn's cross-section, (b) the mean length of the fibers, and (c) the degree of twist that keeps the fibers together in the yarn. Extension and strength will increase in tandem with the degree of twist, until the yarn's strength actually begins to decline [6].

3. Methodology

The basic mechanism to measure yarn strength and elongation is shown in figure1. As shown in figure1 mechanism consists of load cell, upper jaw, lower jaw and helical drives from motor. Upper jaw is stationary where as lower jaw moves with motor. To measure yarn strength, lengths of yarn are broken by stretching yarn with lower jaw. Both the maximum breaking elongation and the maximum load are noted. The highest load expressed in gramme force (gf) or centiNewtons (cN). The % elongation at break is used to assess the maximum breaking extension.

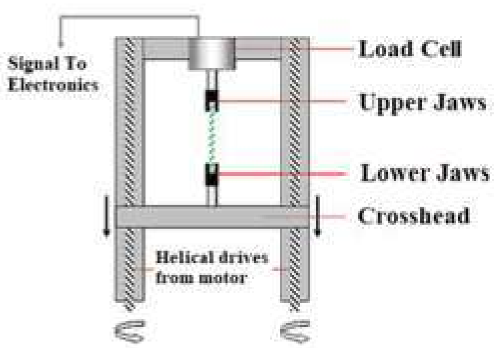

Figure 1 - Basic mechanism [7]

With this mechanism proposed model provide a relatively inexpensive and compact model for estimate the elongation and tensile strength of cotton, jute, silk yarn in single strand [8].

Proposed method is based on the fixed rate of traverse concept, which involves holding first end of the specimen which we have to test in a stationary grip and using a motor, screw arrangement and gear box to move the other end at a predetermined speed.

As shown in block diagram proposed system is mainly consisting of load cell, servo motor, and rotary encoder. Rotary encoder is mainly used to measure elongation.

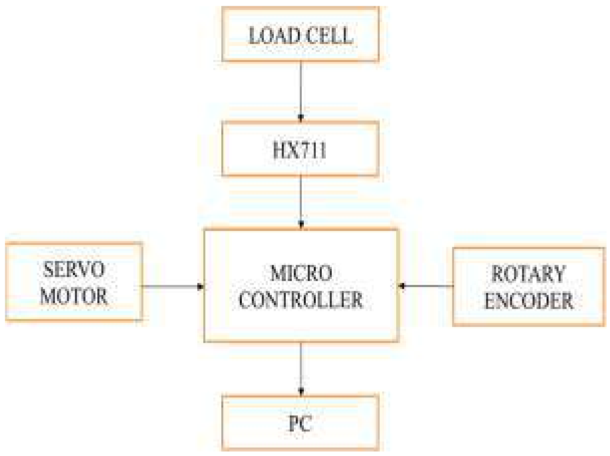

Figure 2 - Block Diagram [9]

3.1 Load Cell and HX711

A device that measures force or weight is called a load cell which is shown in figure 3. Load cell basically consist of strain gauge, which are tiny sensors that alter in electrical resistance in response to mechanical strain, are important to the operation of a load cell. One or more strain gauges are strategically positioned within the load cell to measure the deformation brought on by the applied force. It is frequently utilized in many commercial and industrial applications, including force measurement devices, material testing apparatuses, and weighing scales. The exerted force is transformed into a measurable and interpretable electrical signal by the load cell. Piezo-resistivity is the basis for the operation of resistive load cells [10].The resistance of the sensor changes as a load is applied to it. When an input voltage is applied, this resistance change causes an output voltage change. An elastic component with several strain gauges attached is used to create a load cell. As can be seen in Figure 3, the load cell is made up of four strain gauges in total, which are attached to both the upper and bottom surfaces.

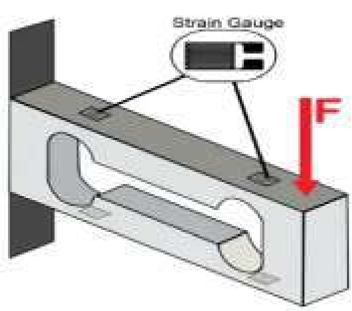

Figure 3 - Load Cell

The elastic portion of a resistive load cell deflects as indicated and produces strain at those areas as a result of the stress exerted when the load is applied to the cell's body as shown below. Consequently, as figure 4 illustrates, two strain gauges are in compression and the remaining two are in tension.

Elastic deformation occurs in the load cell due to weight acting on its metal spring element during a measurement. Strain gauges (SG), fixed to the spring element, and

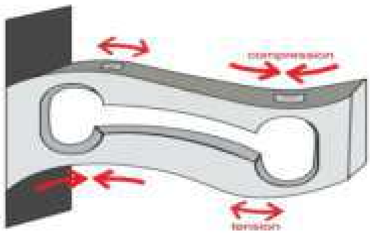

Figure 4 - Load Cell with elastic deformation

transform this strain positive or negative into an electrical output. This change in strain or resistance is converted into voltage that is proportionate to the load using a Wheatstone bridge circuit [11]. An electrical part that is frequently used with load cells to interface them with microcontrollers is the HX711 module shown in figure 5. It functions as an analog-to-digital converter made especially for load cell uses.

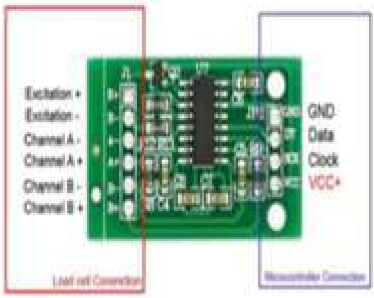

Figure 5 - HX711 Pin out

As per specification of HX711 is concern output Sensitivity is 1.0 ± 0.1 mV / V, two selectable differential input Channels, On-chip power-on-reset, measurement Resolution is 24 bit and on-chip active low noise PGA with the selectable gain of 32, 64 and 128. Load cell is connected to the HX711 module's input terminals and the module is connected to a microcontroller using standard communication protocols such as I2C. Because load cells are small, it is simple to incorporate them into various structures or systems. They can be applied in a number of sectors, including agriculture, industry, transportation, and healthcare. The purpose of load cells is to endure severe conditions and frequent loading [12]. Usually composed of sturdy materials like aluminum or stainless steel, they are long-lasting and durable. Installing and connecting load cells to measurement systems is simple. They can be easily integrated into pre-existing systems because they frequently feature standardized mounting holes or connectors.

3.2 Microcontroller

In proposed model we use ATmega328P microcontroller. The ATmega328P is an 8-bit AVR microcontroller with great performance and low power consumption. It has advanced RISC architecture. ATmega328P has program memory size 32KB.SRAM with 2KB. It has CPU speed of 20MIPS. ATmega328P has data EPROM with 1KB.This microcontroller also has 3 timer with capture, compare and PWM model. Atmega328 support different communication protocol like UART,SPI and I2C. This controller has two SPI port.

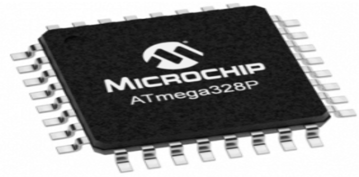

Figure 6 - ATmega 328 microcontroller

3.3 Rotary Encoder

A rotary encoder, also called a shaft encoder, is an electro-mechanical device that converts the angular position or motion of a shaft or axle into analog or digital output signals. It is depicted in figure 7. There are two main types of rotary encoders: absolute and incremental. An absolute encoder serves as an angle transducer since its output shows the shaft's present position [13]. Information about the motion of the shaft is obtained from the incremental encoder's output and is usually processed into position, speed, and distance data. The rotary encoder has five pins. The first pin is GND, second is VCC with positive supply voltage, typically between 3.3 and 5 volts. The third pin SW is the output of the push button switch (active low). The fourth and fifth pins are DT (Output B) and CLK (Output A) resp. DT (Output B) is similar to CLK output, but it lags behind CLK by a 90° phase shift. This output is used to determine the direction of rotation.CLK (Output A) is the primary output pulse used to determine the amount of rotation. Each time the knob is turned in either direction by just one detent (click), the 'CLK' output goes through one cycle of going HIGH and then LOW.

Figure 7 - Rotary Encoder

Applications for rotary encoders include industrial controls, robotics, photographic lenses, and computer based devices like op to-mechanical mice, controlled stress rheometers and trackballs and many more. These encoders are used in a wide range of mechanical system monitoring and control applications. As seen in figure 8, the encoder consists of a disk with uniformly spaced contact zones connected to two distinct contact pins, A and B, as well as the common pin C.

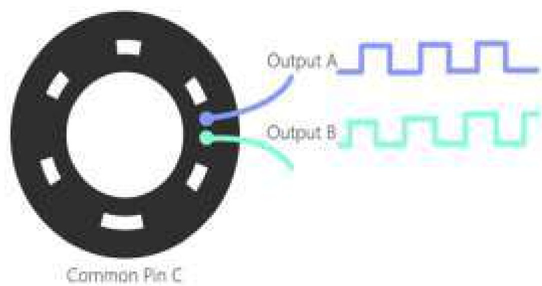

Figure 8 - Encoder Disk Structure

Pins A and B will begin to make contact with the common pin when the disk begins to rotate gradually, at which point the two square wave output signals will be created appropriately. If we simply count the signal's pulses, we may utilize any of the two outputs to get the rotational position. Nonetheless, we must take into account both signals simultaneously if we wish to ascertain the direction of rotation as well.

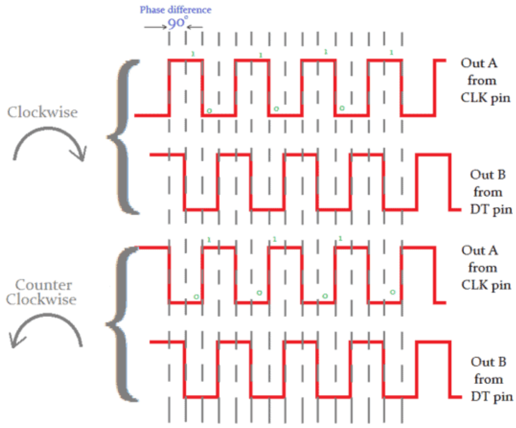

Figure 9 - Output signal from Pin A and B

Figure 10 - Schematic of Proposed Model

Two output signals are 90 degrees out of phase from one another, as seen in figure 9.When the encoder rotates in a clockwise direction, output A will occur before output B. Thus, we may observe that the two output signals have different values at that point if we count the steps every time the signal changes, either from High to Low or from Low to High. Conversely, when the encoder rotates in a counterclockwise direction, the output signals exhibit identical values. In light of this, we can easily program our controller to read the rotation direction and encoder location. Figure 10 show schematic of proposed model consists of display section and actual mechanism.

4. Result & Analysis

We perform different experiment to find out the single yarn strength and elongation percentage at break of the given sample of cotton single yarn by using proposed model. Strength of single yarn is a ratio of breaking load in gram and count of yarn in Tex. The particular test length of the specimen is fixed in between the two gripper. The length of the specimen is taken as 60cm. The extra material is cut off exactly at the clamp position. When the machine is started the lower grip travels downward and tension develop in the specimen. Microcontroller detects breaking point with the help of load cell. Encoder attached with servo motor to estimate elongation. This process is repeated with 10 of these specimens, to estimate elongation percentage and single yarn strength in gms/Tex shown in table1.The yarn count determined by the beesley balance was known before to the experiment. Mean value of tenacity from table 1 is 11.26 gm/Tex.

Table 1 - Single Yarn Strength with count in Tex =22.28 T

Number of Observation	Test Length	Breaking load in gms	Tenacity in gm/Tex
1	60cm	232	10.41
2	60cm	251	11.26
3	60cm	263	11.80
4	60cm	243	10.91
5	60cm	263	11.80
6	60cm	234	10.50
7	60cm	272	12.21
8	60cm	243	10.91
9	60cm	253	11.36
10	60cm	233	11.46

At the time of conducting above experiment we also estimate elongation. With the help of rotary encoder and circumference of lower jaw microcontroller estimated elongation which is shown in table 2. Table2 also shows elongation in percentages. Mean elongation percentages is 3.72.

Table2 - Single Yarn Elongation with count in Tex=22.28 T

Number of Observation	Test Length	Elongation in cm	Elongation Percentage
1	60cm	2.2	3.67
2	60cm	2.1	3.50
3	60cm	1.8	3.00
4	60cm	1.9	3.17
5	60cm	2.7	4.50
6	60cm	2.5	4.17
7	60cm	2.2	3.67
8	60cm	2.1	3.50
9	60cm	2.5	4.17
10	60cm	2.3	3.83

5. Conclusion

Proposed model is simple in design. This model has high efficiency and accuracy. Also this system provides smooth performance. Textile professionals can test any type of roving made up of varying percentages of fibers using the developed model. As previously said, the experts can use the offered model to determine the yarn strength without having to physically handle the data. The parameters in the proposed model are those that technicians typically measure before beginning the spinning process. They can thus test a lot of ravings quickly till they find the ideal desired strength attribute.

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Development of Antimicrobial Textiles using Neem Seed Extract - A Sustainable Approach

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Abstract:

This study focused on the extraction of natural antimicrobial agent from neem seed (Azadirachta indica) to apply it on cotton, polyester and linen fabrics. Aqueous neem-seed extract had been prepared by decoction method and major compounds were identified by phytochemical analysis. The neem seed extract of optimized concentration with cross-linking agent was applied on to fabrics by pad-dry-cure method. The finished fabrics were analyzed for antimicrobial activity against gram-positive and gram-negative bacteria. The results show that the neem treated linen fabric has the best antimicrobial activity when compared to neem-treated cotton and polyester fabrics. FTIR spectrum of the treated fabric samples confirmed the presence of bioactive compounds in the finished fabric. The study suggests that neem seed extract could be a less expensive, non-toxic and effective alternative to traditional antimicrobial agents for fabric treatment.

Keywords: *antimicrobial agent, cotton, decoction method, linen, neem seed extract, phytochemical analysis, polyester*

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1. Introduction :

Antimicrobial textiles are gaining popularity due to the increasing demand for products that offer protection against bacteria and other microorganisms. The use of natural antimicrobial agents in the textile industry is a sustainable approach that can offer an eco-friendly alternative to traditional chemical-based treatments. The antimicrobial qualities of Neem oil, when combined with other herbal oils like Clove, Tulsi, and Karanga, have been harnessed to apply an antimicrobial finish to cotton textiles.

The Neem tree (Azadirachta indica), belonging to the Meliaceae (Mahogany) family, stands out as one of the most abundant sources of bioactive compounds in the Indian subcontinent. Indian farmers extensively utilize Neem leaf extract to safeguard their crops against pests and fungi, owing to its reputed antibacterial properties. Earlier studies reveal that neem seed or bark extract with a crosslinking agent was applied on to cotton fabric by conventional or microwave-curing methods . The use of natural products for imparting antibacterial properties to textiles is gaining importance due to concerns over the environmental impact and potential health hazards associated with synthetic chemical. Attempts are being made to develop effective and long lasting antimicrobial finishes on textiles as textiles can harbor harmful bacteria causing skin infections and other illnesses , 3].

The traditional chemical treatments can have negative environmental impacts and may not be suitable for certain applications and thus making natural extracts as a promising alternative. Many studies reported the effectiveness of plant extracts in preventing bacterial growth on fabrics . It was claimed that the bioactive constituents in neem are less toxic to warm-blooded animals like human [5]. In the recent years, neem extract has gained attention for its potential use in textile applications due to its antimicrobial, antiviral, and antifungal properties [6-'– .

The natural fabric treated with neem, combined with citric acid, exhibits superior antimicrobial activity compared to the fabric treated with acetic acid. Increasing the concentration of the neem leaf extracted solution enhances the effectiveness of the antimicrobial activity on the cotton fabric. Among the various concentrations of the extracted solution, the treatment using a 7g/l concentration, along with citric acid, yields the highest level of antimicrobial activity on the treated natural fabric . Earlier studies disclose the use of neem for the functional finishing of textile materials , . Phytochemical analysis is used to identify and quantify the chemical compounds in plants, providing insights into their medicinal and nutritional value, and guiding the development of drugs and natural products. Neem leaf extracts comprise organic compounds such as nimbidin, nimbolide, mahmoodin, margolone, margolonone, and isomargolonon, all of which exhibit notable antibiotic properties . Research investigating the antimicrobial efficacy of flax reveals impressive zones of inhibition against both gram-positive (S. pyogenes) and gram-negative (K. aerogenes) bacteria surrounding the treated fabric . Neem essential oil nanoparticles were formulated using nano-emulsion and ionic gelation technique and applied to cotton and polyester fabric to give them antibacterial properties [14].

2. Materials and Methods

The woven textile materials selected for the study included 100% cotton, 100% polyester and 100% linen fabrics. These natural and synthetic fabrics were used in various applications such as clothing, home textiles, and upholstery.

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The specifications of fabrics sourced from local market given below in Table1.

Table 1: Fabrics specifications

Property	Cotton	Polyester	Linen
Weave	Plain	Plain	Plain
EPI	117	150	90
PPI	98	130	75
GSM	140	140	140
Thickness (mm)	0.32	0.28	0.32
Warp Count	60s Ne	45 denier	25 Nm
Weft Count	60s Ne	45 denier	25 Nm

The active ingredient used in the antimicrobial finishing is the kernel with the coat of the neem seed. It has already been well documented that the extract of the neem seeds has antimicrobial properties. In addition, neem extract is also known to repel insects, making it a popular natural insecticide.

Flow Chart for the Methodology

Selection of Textile Materials

↓

Preparation of Neem Seed Extract

↓

Phytochemical Testing of Neem Seed Extract

↓

Application of Antibacterial Finish on Fabrics

↓

Testing and Analysis

2.1 Preparation of Neem Seed Extract

The fresh neem seeds were obtained by squeezing out the skin of the neem fruits collected from neem trees of southern India. Neem seeds were washed thoroughly two to three times with distilled water. Then the seeds were shadow dried at room temperature (~30^{0}C) for five to seven days. After complete drying, the seeds were crushed into a coarse powder by using the grinder.

Figure 1 - Neem seed Powder

The active compounds from dried neem seeds were extracted using an aqueous extraction method known as the Decoction Method. To prepare the aqueous neem seed extract, 50 grams of neem seed powder was mixed with 500 milliliters of distilled water, maintaining a ratio of 1:10 (weight/volume). The mixture was brought to a boil and then simmered at varying temperatures (60, 70, 80, and 90°C) for different durations (5, 10, 15, and 20 minutes) to determine the optimal extraction time. The extract was then cooled and filtered through Whatman No. 1 filter paper. The filtered extract was further analyzed to identify the bioactive compounds present.

2.2 Phytochemical Testing of Aqueous Neem Seed Extract

Qualitative phytochemical tests were performed to identify the bioactive compounds present in the neem seed extract. The analysis confirmed the presence of Azadirachtin, the major active component along with other compounds like Nimbolinin, Nimbin, Teraponids, and Tannins etc.

Analyzing plant extracts to spot and describe the presence of different bioactive compounds is known as phytochemical screening. These substances, also referred to as phytochemicals, are essential to plants' metabolic and defense mechanisms. Phytochemical screening of plant extracts revealed the presence of terpenoids, flavonoids, saponins, tannins etc. [12]. The presence of such phytochemicals protects the plant from harmful agents such as insects and microbes as well as a stressful event such as ultraviolet (UV) irradiation and extreme temperature.

2.2.1 Flavonoids and testing

Flavonoids, also known as Vitamin P, encompass iso-flavonoids and neo-flavonoids, depicted in Fig. 2 and Fig. 3 respectively. These compounds, which contain ketones, include canthaxanthins (such as flavones and flavanols) and are crucial plant pigments. Functioning as chemical messengers, physiological regulators, and inhibitors of the cell cycle, flavonoids have been implicated in cancer prevention according to several clinical studies. Additionally, they exhibit direct antimicrobial activity.

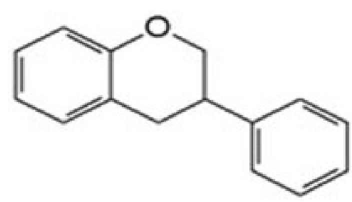

Figure 2 - Structure of Iso-flavone

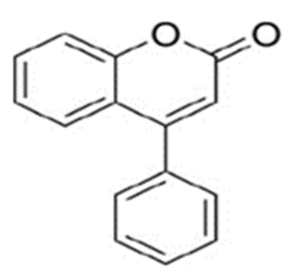

Figure 3 Structure of Neo Flavonoids

The aqueous extract of neem seed of 1 ml was taken in a test tube. The extract has a natural colour of yellow. Ethanol (95% conc.) of 1ml was added to the extract followed by adding few drops of 2% sodium hydroxide and dilute (20% conc.) hydrochloric acid. Gradually the yellow color of the solution disappeared and turns to milky white. This is an indication for the presence of flavonoid in the extract.

2.2.2 Terpenoids and Testing

Isoprenoids, also known as isoprenes, are naturally existing organic compounds with similarities to terpenes. Plant-derived terpenoids are prized for their aromatic attributes and are frequently employed in herbal therapies. Azadirachtin, a prominent terpenoid, is found in the neem plant. Its molecular structure is depicted in Fig. 4.

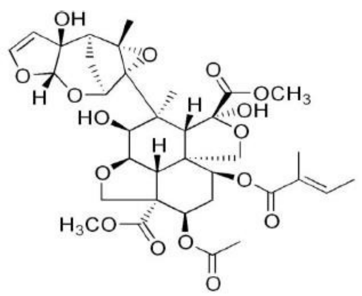

Figure 4 - Structure of Azardiractin

The aqueous extract of neem seed of 1 ml which has a natural yellow colour was taken in a test tube. With continuous stirring, ethanol (95% conc.) of 1 ml was added in drops followed by adding few drops of chloroform and concentrated (98%) sulphuric acid. The solution gradually turns to reddish brown which is an indication for the presence of terpenoids.

2.2.3 Saponins and Testing

Saponins are glycosides that exhibit amphipathic properties. When agitated in aqueous solutions, they produce foams. Within plants, saponins function as antifeedants to deter ants and provide protection against microbes and fungi. Additionally, they may facilitate nutrient absorption and support animal digestion. However, saponins can be toxic to cold-blooded organisms and insects at certain concentrations. They typically possess a bitter taste and readily dissolve in water.

The aqueous extract (1 ml) was taken in a test tube. Ethanol (95% conc.) of 1 ml was added to the extract and the test tube was shaken well. The reaction generates foam which is an indication for the presence of saponins.

2.2.4 Tannin and Testing

Tannin, a bitter and astringent polyphenolic compound found in plants, has the ability to bind to and precipitate proteins, as well as compounds such as amino acids and alkaloids. It serves various functions in plants, including regulating growth, protecting against predation, and acting as a pesticide. Tannins are present in tissues such as leaves, seeds, roots, and stems. Depending on their chemical structure and concentration, tannins can be deemed as anti-nutritional.

The extract solution (1 ml) was taken in a test tube. Ethanol (95% conc.) of 1 ml and 10% alcoholic ferric chloride were added to the solution. The reaction produced a brownish yellow color of the solution. This colour change validates the presence of tannins in the solution.

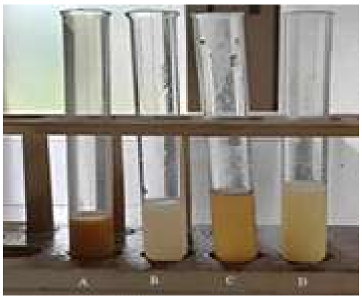

Figure 5 - Phytochemical test, A-Terpenoids, B-Flavonoids, C- Tannin, D- Saponins

2.3 Antibacterial Finishing of Fabrics

Pad-Dry-Cure method was adopted to apply the antimicrobial finish on fabrics. The laboratory model padding mangle was used for the study. The fabrics were first immersed in the decocted neem seed extract of concentration 7g/l for thirty minutes. Acetic acid was added to maintain the pH level of 5.5. Material to liquor ratio of the bath was maintained at 1:30. To achieve better wash fastness of the finish, citric acid of 10% w/w of fabric sample was also added to the bath as cross-linking agent. The fabric samples were then allowed to pass through the vertically arranged bowls of padding mangle to squeeze out excessive solution. All the fabric samples were then dried at 80° C for five minutes followed by curing at 120° C for three minutes in the curing chamber.

2.3.1 Antibacterial Test

Antibiotics represent a major class of antimicrobial agents. By definition, antibiotics are biochemical produced by microorganisms that inhibit the growth of, or kill pathogenic microorganisms. The ISO 20645 agar diffusion test method was employed to qualitatively evaluate the antimicrobial properties of textile material. A clear zone of inhibition is formed around the test specimen if there is antibacterial activity.

2.3.2 Durability Testing of Antibacterial Finish

In addition to evaluating the initial antibacterial properties of neem extract-treated fabrics, it is crucial to assess the durability of these properties after repeated laundering. The durability of the antibacterial finish on linen, cotton, and polyester fabrics tested after 10, 20, and 30 laundry cycles. The laundering tests were conducted following the AATCC 61-2013 standard using a Launder-Ometer.

2.3.3 Fourier Transform Infrared Spectroscopy

Infrared spectroscopy is a valuable technique for categorizing the functional groups within a molecule. By utilizing the distinctive array of absorption bands, one can authenticate the identity of a pure compound or detect the presence of particular impurities. This analytical method relies on the principle that molecules exhibit characteristic frequencies of internal vibrations. These frequencies manifest within the infrared region of the electromagnetic spectrum, spanning from 4000 cm−1 to 200 cm−1 [13].

3. Results and Discussion

The results obtained from the various tests conducted on treated and untreated fabric samples are discussed herein.

3.1 Heat and Time Effect of Extract Concentration

The decoction method of extracting active ingredients involves heating an aqueous solution containing neem seed powder to a boil. As the duration of heating increases, the concentration of the extract also increases up to 20 minutes of heating, after which it stabilizes at a constant level. Similarly, as the temperature increases, the concentration of the extract also increases, reaching its maximum at 90°C. The decocted extract was visually examined and subjectively graded for concentration. The details were provided in Table 2 & 3.

Table 2: Extract Concentration based on duration of heating

Sample No.	Heating time (minutes)	Concentration (subjective assessment)
1	5	Very low
2	10	Low
3	15	Average
4	20	High

Table 3: Extract Concentration Based on Heating Temperature

Sample No	Temperature (°C)	Concentration (subjective assessment)
1	60	Very low
2	70	Low
3	80	Average
4	90	High

3.2 Antimicrobial performance

The possible mechanism of antimicrobial activity is either by preventing microbial growth or potential cell wall breakdown of bacteria. Fabric samples treated with neem seed extract displayed antibacterial properties against both gram-positive (S. aureus) and gram-negative (E. coli) bacteria. Fig.7 shows the effect of antimicrobial activity (zone of inhibition) of untreated and treated samples of three different fabrics. Referring to Fig.7 (a), treated linen sample exhibits the highest level of antimicrobial activity against E-Coli as seen from the larger zone of inhibition measuring 24 mm followed by cotton and polyester with 20 mm and 16 mm respectively. No antimicrobial activity is observed in all the untreated fabric samples. The larger zone of inhibition of linen fabric sample is attributed to the high lignin content of flax fibre since lignin is a natural antibacterial. Lignin content in its chemical composition causes products made of this fibre to efficiently protect the user from UV radiation [15]. Higher moisture content of flax also could help in leaching out of the active compounds resulting in a larger zone of inhibition. Low level of antimicrobial activity of polyester fabric is attributable to the absence of reactive groups for bond formation with the active factors of extract.

Figure 6 - Disk with fabric samples, (a) linen, (b) cotton and © polyester

3.3 FTIR (Fourier Transform Infrared Spectroscopy) characteristics

FTIR spectroscopy was conducted on all treated and untreated fabric samples and shown in Fig.7, 8 and 9. Fig.8 is a comparison of treated and untreated cotton fabrics.

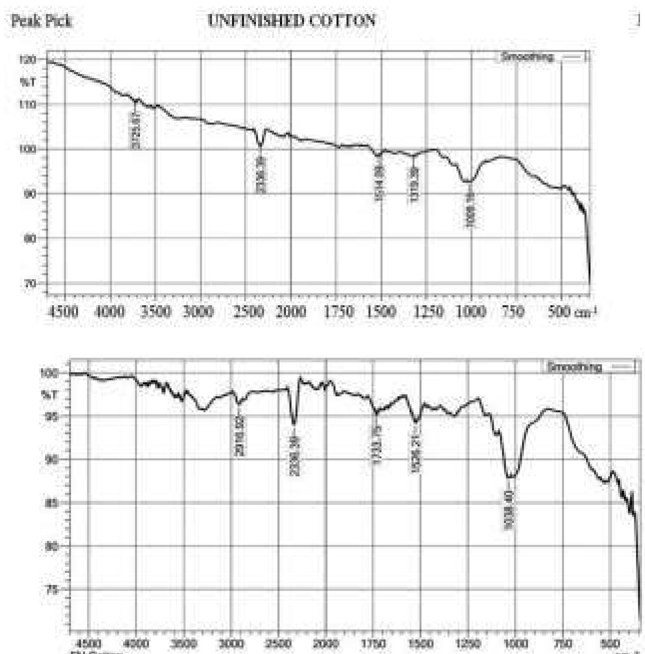

Figure 7 - FTIR Spectra of treated and untreated cotton fabric

As seen from Fig.7, some of the intense peaks are identical for both untreated and fabrics. The peak of 2336 cm-1 corresponds to C=C stretch vibration of aromatic cellulose of cotton. Similarly the peaks at 1009 cm-1 and 1038 cm-1 due to C-H stretching and peaks of 1514 cm-1 and 1526 cm-1 of C-O stretching refers to cotton cellulose. The unique peak of treated fabric at 2916 cm-1 corresponds to carboxylic acid O–H stretch and a peak at 1734 cm-1 is characteristic of C=O (Esters, Carboxylic acids, Ketones, Aldehydes) which are the functional groups present in the active compounds of neem seed extract.

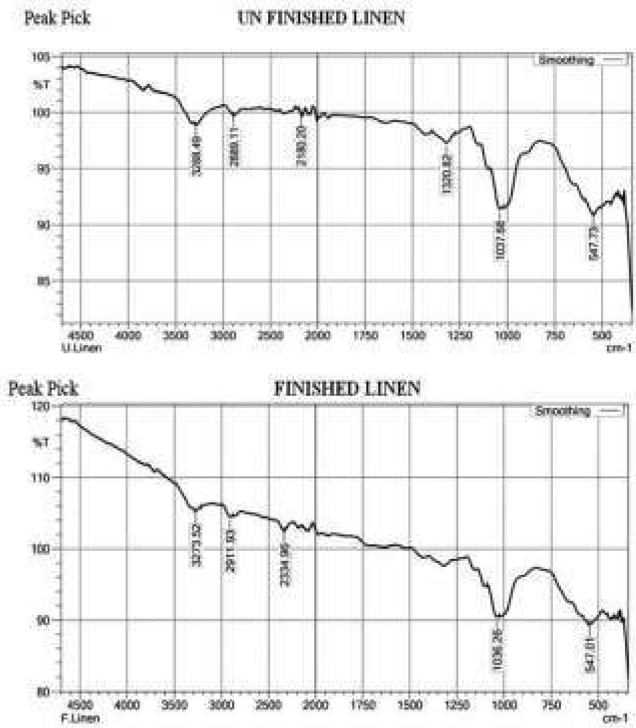

Figure 8 - FTIR Spectra of unfinished and finished linen fabric

From Fig.8, identical peaks are observed at wave numbers 3288, 3274, 1038, 1036, 548, 547 in both untreated and treated linen fabric which are functional groups present in the polymer structure of flax fibre. The unique peak at 2335 cm-1 corresponds to N-H stretching of amines and amides present in the active principles of neem seed extract.

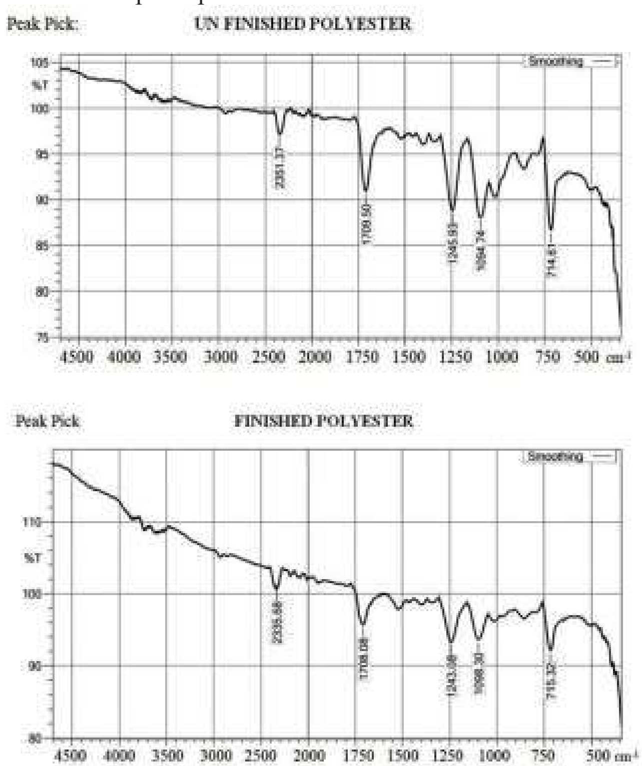

Figure 9 - FTIR Spectra of unfinished and finished Polyester fabric

The peaks in the IR spectra of treated and untreated polyester fabric are shown in Fig.9. The peak at 1709 cm-1 shows C=O vibration which indicates the presence of ester group in the polymer of polyester. The other peaks of the spectra of polyester fabric might be the impurities present in the polymer structure. No specific difference between the spectra of treated and untreated samples could be traced. Unlike cotton and linen, polyester has no reactive groups like OH and there is no likely formation of hydrogen bonds with bioactive compounds.

3.4 Neem Extract-Treated Fabric Durability against Laundry

The initial antibacterial activity of neem extract-treated fabrics showed different zone of inhibition sizes: 24 mm for linen, 20 mm for cotton, and 16 mm for polyester. After 10 laundry cycles, all fabrics slightly decreased to 22 mm for linen, 18 mm for cotton, and 14 mm for polyester. This decrease continued after 20 cycles to 20 mm for linen, 16 mm for cotton, and 12 mm for polyester. Even after 30 cycles, the trend persisted with linen maintaining 18 mm, cotton dropping to 14 mm, and polyester to 10 mm. This suggests varying durability, with linen being the most durable, followed by cotton, and polyester being the least. The decrease in antibacterial activity was due to the washing out of active compounds, chemical breakdown, and wear. Linen's higher lignin content, moisture handling, and strong structure make it more durable than cotton and polyester. These findings stress the importance of fabric choice for long-term antibacterial effectiveness.

3.5 Predicting Antimicrobial Effectiveness Based on Treatment Conditions

To predict how effective a fabric treatment was in inhibiting bacterial growth, a multiple linear regression model was used. The model considered treatment time, concentration of the treatment, temperature, and GSM (grams per square meter of the fabric). First, data was collected that included these variables and the resulting zone of inhibition (a measure of antimicrobial activity). Using Python and the statsmodels library, a DataFrame was created with this data. A regression model was defined where the zone of inhibition was the dependent variable. Time, concentration, temperature, and GSM were the independent variables. The model was fitted to get the regression equation.

$$Z=\beta 0+\beta 1\cdot \text{Time}+\beta 2\cdot \text{Concentration}+\beta 3\cdot \text{Temperature}+\beta 4\cdot \text{GSM}$$

If the coefficients were: intercept (β0) = 5, time (β1) = 0.3, concentration (β2) = 0.5, temperature (β3) = 0.1, and GSM (β4) = 0.01. The equation became:

$$Z=5+0.3\cdot \text{Time}+0.5\cdot \text{Concentration}+0.1\cdot \text{Temperature}+0.01\cdot \text{GSM}$$

This equation helped predict the zone of inhibition for any given set of treatment conditions.

3.6 ANOVA Analysis on the Impact of Fabric Type, Concentration, and Treatment Time on Antimicrobial Efficacy

The data was collected and structured. This data contained information on fabric type, concentration of extract, treatment time, and the corresponding zone of inhibition. This formed the basis for an ANOVA analysis. The ANOVA model regressed the zone of inhibition on fabric type, concentration, and time. Statistical software, Python's statsmodels, was used to get the results.

Table 4: ANOVA Results

Source	Sum of Squares	df	Mean Square	F-value	p-value
Fabric	78.720	2	39.360	75.15	0.00002
Concentration	3.565	1	3.565	6.81	0.031
Time	59.610	1	59.610	113.98	0.00001
Residual	2.096	7	0.299		
Total	143.991	11			

The ANOVA table showcased significant effects. Fabric type had a p-value of 0.00002. Concentration had a p-value of 0.031. Time had a p-value of 0.00001. All three significantly influenced the zone of inhibition. A low p-value (< 0.05) for each factor suggested their substantial impact. Specifically, varying fabric types, concentrations, and treatment times resulted in notably different mean zone of inhibition values. These findings underlined the importance of fabric choice, concentration, and treatment duration in determining antimicrobial efficacy.

To achieve maximum antimicrobial efficacy, the optimal conditions based on the ANOVA analysis were using Linen fabric, with a concentration of 4, and a treatment time of 20 minutes. These conditions yielded the highest zone of inhibition, indicating superior antimicrobial activity.

4. Conclusion

The study reveals that bioactive compounds are present in aqueous seed extract obtained by decoction method as tested by qualitative phytochemical analysis. Azadiractin is a major constituent of tannins which is an effective antimicrobial agent. Decoction method is a simple and easy process of extracting bioactive compounds from plants, however, at elevated temperatures it is likely that some of the compounds may be dissociated.

All fabric samples finished with aqueous neem seed extract exhibit antibacterial activity as seen from the zone of inhibition. It is observed that among three fabric samples of linen, cotton and polyester, the linen fabric showed larger zone of inhibition which could be attributed to the higher lignin content of flax fibre. The neem extract-treated fabrics show a reduction in antibacterial activity with increased laundering due to the loss of active compounds and degradation. However, linen retains higher antibacterial efficacy due to its inherent properties, making it a more durable option for long-term antibacterial applications. FTIR spectra of finished fabric samples establish the constituent functional groups of bioactive compounds present in the neem seed extract as well as the polymer composition of fibres. The combined use of ANOVA and regression analysis enabled to determine the optimal conditions for achieving maximum antimicrobial efficacy. The best results were obtained using Linen fabric, with a concentration of 4, and a treatment time of 20 minutes. These conditions yielded the highest zone of inhibition, indicating superior antimicrobial activity.

Selective use of bioactive compounds of plant extracts is a sustainable way for textile finishing. Plant varieties are renewable and also abundantly available thus cost-effective methods can be devised for various types of textile finishes. Neem based textile materials seems to be promising alternative to chemically synthesized finishing agents. Neem treated textile materials have the potential to replace the traditional materials used in home textiles, healthcare and hygiene textiles.

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Enhancing Agronomic Efficiency: Investigating the Water Retention Properties of Coir/Kenaf Blended Non-Woven Mats

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Abstract:

The use of natural fibers as sustainable materials is gaining popularity due to their biodegradability. This study delves into the potential of two natural fibers, namely coir and kenaf, to be used in needle-punched nonwoven samples for various applications. The study involves developing nonwoven samples with varying blend ratios of coir and kenaf fibers, followed by testing them for specific properties such as porosity and water retention capacity. The experiment reveals that a blend of 25% coir and 75% kenaf fibers exhibits noteworthy water retention capacity, with a recorded 97.2% water-holding capacity due to its small pore size as compared to other samples. These results suggest that coir and kenaf fibers can be blended to produce nonwoven samples with desirable properties for various applications.

Keywords: *biodegradability, coir, non-woven, needle punching, porosity, water retention*

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1. Introduction

The agricultural sector faces issues such as climate change, water shortage, and modernization, making textiles an appropriate answer. Textiles, with their enormous surface area, lightweight, and superior water retention qualities, provide eco-friendly and biocompatible options. Agrotech is a key branch of technical textiles that uses textile structures to regulate environmental conditions. Natural biodegradable textile fibers derived from agricultural plants are widely utilized in ropes, carpet backings, and purses. The research project intends to design and manufacture biodegradable non-woven mats made from coir/kenaf and coir/recycled cotton materials for agricultural water irrigation. This seeks to provide environmentally friendly alternatives to traditional synthetic carpets. A thorough evaluation will be carried out to confirm the mats' efficacy, practicality, and overall quality.

2. Objective

To produce a non -woven mat using coir/kenaf blends with water retention properties for reducing the scarcity of water in agriculture. To reduce the water usage in the irrigation process.

3. Literature

The agricultural sector faces many threats due to climate change, water scarcity, and modernization. Water scarcity and management are serious problems, and textile is one of the suitable sectors that can offer a better solution to this. Natural biodegradable textile fibers like coir, kenaf, and cotton are eco-friendly and can be used in agriculture. Needle-punched nonwoven samples were developed with coir/cotton and coir/kenaf fibers, which have water-retention properties. Kenaf mats processed using needle-punching technology have shown potential mechanical and physical attributes for diverse applications. Coir is a biodegradable organic fibre that can retain moisture for a longer period and can be used for various agricultural applications [1, 2 & 5]. The article talks about the need to replace synthetic fibers with natural fibers in Agro-textile products, and how coir is a suitable alternative due to its moisture retention, high wet strength, and ability to improve soil fertility. The usage of organic coir mulch sheet in agricultural lands increases the quality and yield of crops in a faster way. The objective of the work was to develop an environmentally friendly method for the effective utilization of coir fibre by adopting steam pre-treatment, which increases the cellulose content in the fibre and removes lignin and hemicelluloses. Steam explosion has been proved to be a green method to expand the application areas of coir fibre. The processing of kenaf bast fibre, a renewable, biodegradable, and ecologically beneficial fibre bundle, was investigated in this work. It was discovered that although decreasing fibre bundle strength, modified chemical degumming and alkaline sulphide treatments enhanced tensile properties, fineness, length, and softnes [6-8]. Research was conducted in Tunisia to develop seed production practices of high-yielding kenaf cultivars. Kenaf is a renewable bast fibre that is environmentally safe and biodegradable. Water is retained by various particles in different ways. Larger particles are less able to retain moisture than smaller ones over extended periods of time. This is because water is easily able to escape through the larger pores in the larger particles, whereas the smaller holes in the smaller particles hold water. The number and size of a particle's holes as well as its surface area determine how much water it can hold. Because their pores better retain moisture, smaller particles absorb water more readily than bigger ones. Thus, the coir pith grades' holes are crucial for retaining water in them [3, 4 & 9].

3.1 Conclusion from the Literature Review

This text investigates the uses and qualities of natural fibers,

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particularly coir and kenaf, in agriculture, textiles, and environmental sustainability. These fibers, which are biodegradable and moisture-retaining, are employed in a variety of applications. Their characteristics are enhanced through processing procedures such as needle-punching, steam pre-treatment, and chemical retting. They have environmental benefits like as renewability and low impact as compared to synthetics. They also have useful qualities, such as preventing fungal.

4. Materials and Methods

4.1 Fibres

Coir and Kenaf fibres are used as a raw material in this research work. Coir is a long staple fibre and kenaf fibre is cut up to 40mm for the manufacturing process. Non-woven mat was produced on 28th march, 2024 using needle punching method and testing were done on 30th march, 2024.

The production of a non-woven mat involves the utilization of two fibers, namely coir and kenaf. Coir is a natural fibre extracted from the husk of a coconut, while kenaf is a fibre obtained from the bast of the plant. These fibers are carefully blended to create a strong, durable, and eco-friendly material that is widely used in various industries such as automotive, construction, and agriculture.

4.1.1 Coir

Coir, also called coconut fibre, is a natural fibre extracted from the outer husk of coconut, and used in products such as floor mats, doormats, brushes, and mattresses. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. Other uses of brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture.

Coir must not be confused with coir pith, which is the powdery and spongy material resulting from the processing of the coir fibre. Coir fibre is locally named 'coprah' in some countries, adding to confusion. Pith is chemically like coir, but contains much shorter fibers.

4.1.2 Structure of Coir

Coir fibres are found between the hard, internal shell and the outer coat of a coconut. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature, but later become hardened and yellowed as a layer of lignin is deposited on their walls. Each cell is about 1 mm (0.04 in) long and 10 to 20 µm (0.0004 to 0.0008 in) in diameter. Fibres are typically 10 to 30 centimetres (4 to 12 in) long. The two varieties of coir are brown and white. Brown coir harvested from fully ripened coconuts is thick, strong and has high abrasion resistance. It is typically used in mats, brushes, and sacking. Mature brown coir fibres contain more lignin and less cellulose than fibres such as flax and cotton, so are stronger but less flexible. White coir fibres harvested from coconuts before they are ripe are white or light brown in colour and are smoother and finer, but also weaker. They are generally spun to make yarn used in mats or rope.

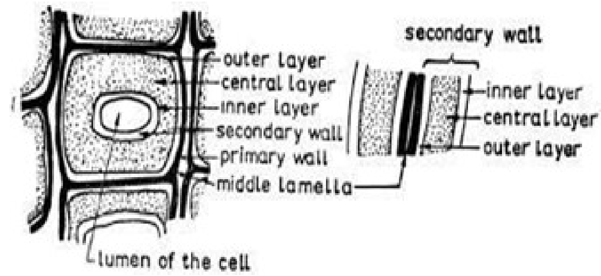

Figure 1: Structure of Coir

4.1.3 Kenaf

Kenaf, Hibiscus cannabinus, is a plant in the family Malvaceae also called Deccan hemp and Java jute. Hibiscus cannabinus is in the genus Hibiscus and is native to Africa, though its exact origin is unknown. The name also applies to the fibre obtained from this plant. Kenaf is one of the allied fibres of jute and shows similar characteristics.

Kenaf is cultivated of its fibre in India, United States of America, Indonesia, Malaysia, South Africa, Viet Nam, Thailand, parts of Africa, and to a small extent in southeast Europe. The stems produce two types of fibre: a coarser fibre in the outer layer (bast fibre), and a finer fibre in the core. The bast fibres are used to make ropes. Kenaf matures in 100 to 200 days.

4.1.4 Structure of Kenaf

The fibres in kenaf are found in the bast (bark) and core (wood). The bast constitutes 40% of the plant. "Crude fibre" separated from the bast is multi-cellular, consisting of several individual cells stuck together. The individual fibre cells are about 2–6 mm long and slender. The cell wall is thick (6.3 µm). Kenaf fibre from bast could be gained as long as 2 meters and it becomes more widespread in polymer composite and concrete industry. The kenaf fibre needs to be treated properly to remove the lignin. The tensile strength of the kenaf fibre is about 800 MPa, which makes it suitable natural fibre in engineering applications. The core is about 60% of the plant and has fibre cells that are thick (≈38 µm) but short (0.5 mm) and thin-walled (3 µm).

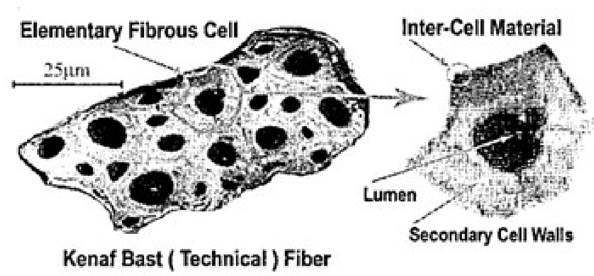

Figure 2: Structure of Kenaf

4.2 Methods

4.2.1 Procedure of Needle Punching

Fiber Preparation: Preparing the fibers used to make the fabric is the first stage in the production process for needle-punched nonwoven fabrics. This can entail separating the various fibre kinds into individual strands or combining them.

Web Formation: After that, the fibers are arranged into a web arrangement, the fibre pattern that will be utilized to make the fabric. Typically, a carding machine or other similar device creates this web shape by combing the fibers into the appropriate pattern.

Needle Punching: After the web formation is finished, the fibers are punched with needles to increase the strength of the fabric by interlocking the fibers together.

Finishing: Once the needle punching process is finished, the fabric undergoes a finishing process. This process can include the addition of a backing, like a scrim, or applying a coating to enhance the fabric's durability.

4.2.2 Sample Manufacturing Process

During the preparation process, two types of fibers are utilized: coir and kenaf. Coir is known for its dense structure, which can make it challenging to form a web during the manufacturing process. This can lead to complications such as needle breakages and increased time consumption. To address this issue, coir is treated with a 30% concentration of caustic soda for 24 hours, then washed and dried for further processing. To enhance the mat's water retention properties, kenaf fibers are blended with the coir fibers.

The non-woven mat is carefully crafted using a combination of 1.5 kilograms of coir and 1.5 kilograms of kenaf, with utmost precision and attention to detail. The kenaf fibre is expertly cut into 40mm lengths before the manufacturing process to ensure seamless blending with the coir and a smooth production process.

The fibers are then processed using a carding machine, a sophisticated tool that individualizes and aligns the fibers to form a web. The web is then subjected to a needle punching process with a density of 250 punches per inch, a technique that ensures the mat's durability and strength. The variables are mentioned in Table 1.

Overall, the production process involves the use of high-quality raw materials, with the total weight of the materials used amounting to approximately 3 kilograms. The result is a non-woven mat that is visually appealing but also resilient and long-lasting.

Table 1: The blend ratio variables in the non- woven mat manufacturing process

S. No.	Non -woven Blends (Coir/Kenaf)	Needle Punching (density/inch)	No. of Variables
1	50/50	250	1
2	75/25	250	1
3	25/75	250	1

5. Testing of Samples

- Water absorption (ISO 20158:2018)
- Water Retention (IHTM:55)
- Porosity (IHTM:77)

5.1 Water Absorption and Water Retention Procedure

Cut or prepare the sample material into standardized shapes or sizes, ensuring they are clean and free from any contaminants. Weigh the samples individually and record their initial dry weights. Submerge the prepared samples completely in water at a specified temperature (usually room temperature, unless otherwise specified). Ensure that the samples are fully submerged and not touching each other to prevent interference with water absorption. Start the timer or note the time when the immersion begins. Weigh each sample individually after removing surface water to determine its wet weight. Record the wet weight of each sample. Calculate the water absorption for each sample using the formula:

$$\text{Water absorption} = \frac{w2 - w1}{w1} \times 100$$

Record the water absorption percentage for each sample

5.2 Porosity Procedure

Weigh the dry sample accurately using a balance. Record the initial weight (W1) of the sample. Determine the bulk volume of the sample by measuring its dimensions (length, width, and height) and calculating the volume. Alternatively, measure the volume displaced by immersing the sample in water in a measuring cylinder and recording the volume change. Submerge the sample completely in water or another suitable liquid. Allow the sample to saturate in the liquid for a specified duration. This could range from a few minutes to several hours depending on the material and testing requirements. Ensure the sample remains fully immersed during this period. Weigh the sample again after saturation, recording the saturated weight (W2). Calculate the porosity using the formula:

$$\text{Porosity \%} = \frac{W2 - W1}{\text{volume of sample}} \times 100$$

Higher porosity values may indicate greater void space within the material, which can affect properties such as strength, permeability, and thermal conductivity.

6. Result and Discussion

The experiment involved testing three different samples to evaluate their water retention ability and porosity level. Figure 3 shows the three different samples.

A)

Figure 3: A) 50/50- Coir/Kenaf,

B)

Figure 3: B) 75/25- Coir/Kenaf,

C)

Figure 3: C) 25/75- Coir/Kenaf

6.1 Water Retention and Water Absorption

To ensure their water retention capabilities, the non-woven mats undergo rigorous testing. This involves submerging the sample mats in water for several minutes and measuring the results using a specific formula. This testing process allows us to determine the effectiveness of the mats and ensure that they will perform well in real-world situations.

$$\text{Water absorption} = \frac{w2 - w1}{w1} \times 100$$

Table 3: Water Absorption and Retention Properties of Non-Woven Coir/Kenaf Mats with Different Composition Ratios

Non-woven mats (Coir/Kenaf)	Water absorption (minutes)	Water Retention %
50/50	6 minutes	97.4%
75/25	6 minutes 58 seconds	97.8%
25/75	6 minutes 45 seconds	97.2%

6.2 Porosity

Our non-woven mats undergo a rigorous testing process to evaluate their porosity properties. This includes a thorough pore size analysis to detect any possible water seepage and determine the retention capability of the mats. This guarantees that the mats meet the most stringent standards of quality and performance. Table 4 shows the pore size or porosity of the different non- woven mats.

Table 4: Porosity of non-woven mats with different compositions

S. No.	Non-Woven Mats (coir/Kenaf)	Pore Size %
1	50/50	0.60
2	75/25	0.50
3	25/75	0.48

6.3 Water absorption time and Porosity of the non-woven mats

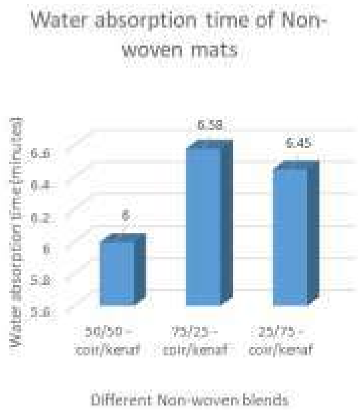

Figure 4: Water Absorption Time of the Non-woven Mats

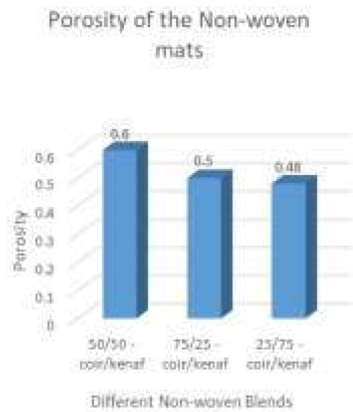

Figure 5: Porosity of the Non- woven Mats

The data presented in Figure 3 indicate the water absorption time for various non-woven mats. Notably, the 50/50 coir/kenaf mat, possessing a pore size of 0.6 (as depicted in Figure 4), absorbs water in a mere 6 minutes. On the other hand, the 75/25 coir/kenaf mat, having a pore size of 0.5 (also shown in Figure 4), absorbs water in 6 minutes and 58 seconds. The 25/75 coir/kenaf mat, with a pore size 0.48, takes 6 minutes and 45 seconds to absorb water. Although the pore size difference between the 75/25 and 25/75 coir/kenaf blended mats is marginal, the irregular blend ratio causes a discrepancy in water absorption time. It is worth noting that the 50/50 coir/kenaf blended mat displays a significantly larger pore size, resulting in faster water absorption compared to other samples.

6.3 Water Retention Percentage of the Non-woven mats

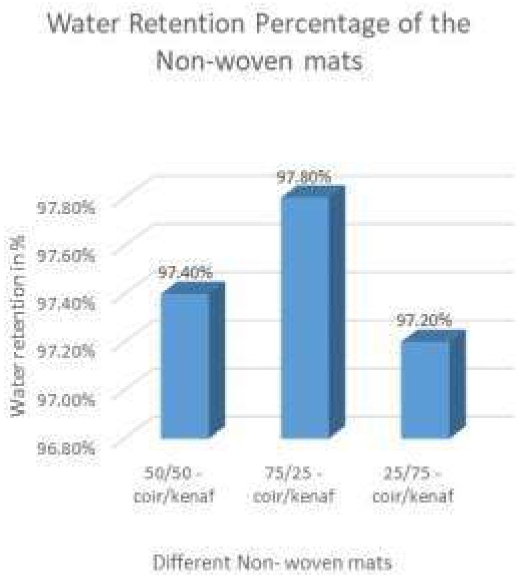

Figure 6: Water Retention % of Non-woven Mats

Figure 5 presents data on the water retention percentage of non-woven mats. This retention is directly related to the mats' porosity, as shown in Figure 4. Specifically, the 25/75 coir/kenaf blended mat has a much smaller pore size than the other non-woven mats, resulting in a higher water retention capacity that is water seepage is less after absorption.

7. Conclusion

Through careful experimentation and analysis of various non-woven mat samples incorporating different ratios of coir and kenaf fibers, we have discovered a remarkable finding. Our research indicates that Sample 3, which comprises 75% kenaf and 25% coir, exhibits superior water retention properties compared to other samples. With its dense and compact structure, coupled with a smaller pore size, it was able to retain a remarkable 97.2% of water within just 6 minutes and 45 seconds. This breakthrough discovery suggests that the blend of 75% kenaf and 25% coir is exceptionally effective in water retention, offering tremendous potential for addressing water scarcity issues in agriculture. With further optimization of this blend ratio and manufacturing process, we can achieve significant advancements in sustainable irrigation practices, thereby contributing to the conservation of water resources in agricultural settings.

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Stitching the Future – A TOL Model Analysis of 3D Modelling Tools in Fashion Design

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Abstract:

The fashion industry, a major player in the global economy, faces the critical challenge of generating extensive waste and pollution, primarily attributed to traditional sampling methods. The conventional approach involves creating physical prototypes through cutting and sewing, resulting in significant fabric waste.

To address the challenges associated with waste generation and environmental impact in the fashion industry, our study pursued a comprehensive three-step approach. Firstly, we conducted a literature review to identify 3D modelling tools used in clothing design, emphasizing their role in expediting sample and pattern creation. Subsequently, through surveys, a critical analysis of these 3D modelling tools was conducted using the Technological, Organizational, and Learning (TOL) framework to evaluate their effectiveness in prototype and sampling processes within fashion production houses. Lastly, we conducted in-depth interviews with seven experts from manufacturing companies to gain insights into design practices and challenges in the fashion industry.

This multi-faceted approach allowed us to gather comprehensive data and perspectives to inform our study's findings and recommendations for advancing sustainability and efficiency in fashion design and manufacturing. This study's conclusions have important ramifications for both academia and businesses. Fashion designers, producers, and policymakers may choose to use and integrate this cutting-edge technology into their practices after learning more about the advantages of 3D modelling tools. This study provides a roadmap to a more sustainable and technologically advanced future for the garment industry with its thorough analysis and useful recommendations.

Keywords: *3D Modelling, Artificial Intelligence, Fashion Industry, Prototyping, Smart Factories*

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1. Introduction :

According to the McKinsey Global Fashion Index, the global fashion industry was valued at approximately $2.5 trillion in 2020, accounting for approximately 2% of global GDP [1]. The traditional approach of the design process in the fashion industry involves numerous steps, each contributing to the fabrication of tangible samples and generating trash [2, 3]. One area of concern is the traditional method of creating physical samples in the fashion industry. This process involves cutting and sewing materials to create prototypes, which often leads to substantial fabric waste. Fashion designers would cut and sew fabrics to make physical samples, wasting a lot of material in the process [4]. According to Fletcher, K., & Tham [2], studies show that fashion brands and manufacturers discard around 15-20% of fabric waste during the sample-making stage. The problem of textile waste and the short lifespan of clothing further exacerbate the negative environmental effects of the fashion industry [5]. The goal of fast fashion is to create affordable, trendy clothing, which has resulted in a disposable fashion culture where clothing is frequently bought and quickly discarded. Globally, 92 million tonnes of textile waste are reportedly produced each year [6]. However, by incorporating technology, these procedures can be shortened, resulting in appreciable increases in both time and cost-effectiveness [7-10]. In a recent study by Mancewicz [11], digital sampling in fashion production was found to significantly improve time and cost efficiency. The research highlights the transformative role of 3D modelling software, enabling the creation of virtual garment representations. Utilizing 3D modelling software, designers can create virtual garment representations, deviating from traditional physical sampling. These virtual samples capture style nuances, allowing for digital adjustments and eliminating the resource-intensive need for physical prototypes. 3D modelling for clothing design is the creation of digital three-dimensional models, allowing pattern makers to preview and evaluate patterns before physical prototyping. This digital process involves simulating clothing fit on various body types, improving accuracy, and saving resources in production. The digital nature of 3D modelling enables quick pattern creation and modification, streamlining the entire production cycle, from Mold creation to mass production. The adoption of 3D modelling optimizes production timelines, promoting efficient garment piece creation [12].

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1.1 Role of Technology in Production Process

Technology plays a crucial part in the production process of the fashion business, revolutionising established methods and encouraging innovation. From design to distribution, different technological breakthroughs have dramatically altered the way fashion products are created and brought to market. One significant area where technology has made a profound impact is in the design process [13]. Digital design and virtual prototyping have brought substantial breakthroughs to the fashion industry's design process through the integration of technology. This technology provides greater precision, accuracy, and control in the design process compared to traditional manual methods. Working digitally enables designers to create, modify, and refine designs more efficiently [14]. Virtual prototype technologies further enrich the design process by replicating and visualising clothing in a virtual environment. Designers can generate 3D models of their designs, enabling them to assess the fit, drape, and overall aesthetic of the garment before physically making it. This removes the need for many physical prototypes, saving time and costs. By virtually testing new materials, colours, and patterns, designers can explore a wider range of design options and make more educated selections [8, 9, 15]. Brands can significantly lower their carbon footprint related to transportation by reducing their reliance on physical samples and in-person fittings [16]. The customary process of producing physical samples in fashion production houses is one of the major factors causing this waste. Cutting and sewing materials to make prototypes frequently generates a significant amount of fabric waste, which not only has a negative impact on the environment but also drives up production costs [17-19]. These advancements offer precise design development, minimizing the need for physical samples and reducing fabric waste [19, 20] and [21].

2. Literature Review

In our search for existing systematic reviews and mapping studies on 3D modelling tools in the fashion industry context, the Google Scholar database returned 30 peer-reviewed articles published between 2012 and 2022. These articles included search terms such as 'digital technology' and 'fashion industry' in their titles or abstracts and linked to Fashion, Manufacturing, Production, or Production house. An in-depth literature review is essential to assess the prevalence and effectiveness of various 3D modelling tools in the fashion industry, specifically those used for sample production. The study found 30 articles that provided valuable insights into 3D modelling technology and shed light on its applications in optimizing processes related to fashion design and production. The extensive literature review reveals multiple 3D modeling tools that assist designers and pattern makers in digitally crafting clothing prototypes, offering superior accuracy compared to traditional paper or fabric patterns. The findings of the literature review revealed that, to reduce waste and improve the efficiency of sample production, fashion designers and stakeholders are utilizing various 3D modelling tools in the fashion industry. Among these, some of the most popular tools include CLO3D, Browzwear, Marvelous Designer, Blender, Optitex 3D, and Tuka 3D [22-27]. Another challenge faced by fashion designers is the availability of many options for 3D simulations. The technology is new and costly. This requires a critical evaluation among these popular 3D tools, namely CLO3D, Browzwear, Marvelous Designer, Blender, Optitex 3D, and Tuka3D, using the Technological, Organizational, and Learning (TOL) framework [28] to assess their effectiveness in prototype and sampling processes within fashion production houses.

3. Methodology

3.1 Survey for 3D modelling Tools in Fashion Production Houses

Following the literature review, a survey involving 30 professionals actively involved in fashion production houses and fashion design was conducted. This survey was designed to elicit information about how these individuals employ 3D modelling tools within their industry. Careful consideration was given to including participants with diverse roles within the sector, ensuring a detailed understanding of varied perspectives on the application and challenges associated with these tools. For this study, we opted for the Technology, Organisation, and Learner (TOL) evaluation model to scrutinize the existing 3D modelling tools used in fashion production houses. This section introduces the TOL evaluation model, presenting a set of assessment criteria for evaluating 3D Modelling tool, considering the perspectives of technology, organization, and learners.

3.1.1 Technology Criteria: This section scrutinizes the technical facets of the platform, encompassing architecture, optimizations, ease of installation, and adaptability. Additionally, it assesses the system's capability to comprehensively manage and monitor students within a unified platform.

3.1.2 Learner Criteria: Here, we investigate empowering users throughout their learning journey, emphasizing user-friendliness, ease of use, and personalization. We also acknowledge the collaborative nature of learning, highlighting the community aspect among learners.

3.1.3 Organization Criteria: This dimension examines the managerial capabilities of the system, including the establishment of a robust and tailored infrastructure setup, as well as the support and assistance provided to users.

3.2 In-depth Interviews with Industry Experts

Furthermore, to identify shortcomings, pros, and cons of these tools in the context of digital design and virtual prototyping processes within the domain of fashion manufacturing, we conducted in-depth interviews with seven experts possessing substantial expertise in utilizing 3D modelling tools in their design processes. The selection criteria for experts were based on their current roles in the industry and active engagement with 3D modelling tools. Specifically chosen for their software experience of more than one or two years, experts were strategically selected to ensure a diverse range of perspectives, providing valuable insights into the evolving landscape of technology adoption in the fashion industry. The interview questions aimed to extract detailed insights about their experiential domain, challenges encountered, and the consequential impact of 3D modelling tools on their design workflows. Through the employment of a mixed-methods strategy, this research strives to deliver an in-depth and refined comprehension of the prevailing state, challenges, and potential solutions associated with the integration of 3D modelling tools within the intricate domain of the fashion industry.

4. Results & Findings

In the examination of 3D modelling tools within the context of fashion production houses, the Technology, Organization, and Learner (TOL) evaluation model has been employed. This well-structured framework is tailored to offer a thorough analysis, highlighting key aspects related to technology, organization, and learners.

4.1 Evaluation Results of 3D Modelling Tools

In evaluating 3D modelling tools using the TOL evaluation model, a complete understanding of the current state of 3D learning environments emerges from a combination of interviews and surveys involving 30 participants and 7 interviews. Notably, CLO3D and Browzwear exhibit more robust 3D technology, while Marvellous and Blender integrate a mix, and Optitex and Tukatech are grounded in specialized infrastructures. Disparities in performance optimizations, scalability, adaptability, and integration capabilities highlight inherent constraints shaped by individual technologies.

4.1.1 Technology Perspective - Architecture and Implementation

(a) Platform Technology: This assessment unveils the diverse technological foundations employed by different 3D modelling tools. CLO3D, BW (Browzwear), MV (Marvellous), BL (Blender), Opti (Optitex), and Tuka (Tukatech) each adopt unique approaches. CLO3D and BW rely on robust 3D technology, while MV and BL integrate a mix of technologies, and Opti and Tuka are built on specialized infrastructures. The technological landscape highlights stability, robustness, and security in specific tools, accompanied by varying degrees of performance optimizations. However, limitations surface in terms of scalability, adaptability, and integration with other components and platforms. The overall design of these tools is inherently constrained by their technology, featuring limited user registration and authentication capabilities.

(b) Reasonable Performance Optimizations: CLO3D secures the top position with a perfect score of 8, highlighting its exceptional performance optimizations for efficiently handling complex design tasks. Browzwear and Tukatech closely trail with scores of 6, demonstrating commendable capabilities in this aspect. Marvellous and Blender achieve scores of 6 and 4, respectively, while Optitex slightly lags with a score of 4.

(c) Easy Installation: CLO3D excels in easy installation with a score of 8, ensuring a user-friendly setup process. Tukatech closely follows with a score of 5, maintaining a good level of ease in installation. Browzwear and Optitex score 5 and 0, respectively, indicating varying degrees of challenges in installation. Marvellous and Blender face difficulties, scoring 0 and 5, respectively.

(d) Adaptability (Customization): CLO3D once again leads in adaptability with a score of 7, enabling users to customize the tool to suit specific design workflows. Marvellous and Blender score 6, showcasing good adaptability. Browzwear and Tukatech maintain scores of 4 and 4, offering a moderate level of adaptability. Optitex scores 5, demonstrating a reasonable degree of adaptability. This thorough evaluation provides subtle insights into the technological landscape of 3D modelling tools, revealing their strengths and areas for improvement.

4.1.2 Learner Perspective

(a) Learner Interface: The learner's interface plays a pivotal role in determining the widespread acceptance of 3D modelling tools. Different tools exhibit varying levels of ease of use, user-friendliness, and learning curves, influencing their appropriateness for diverse user groups.

(b) Ease of Use (Easy to Navigate and Operate): CLO3D sets a benchmark with an impressive score of 8, reflecting its user-friendly interface that ensures effortless navigation and operation. Tukatech follows closely with a score of 5, maintaining a commendable level of ease. Browzwear and Optitex face challenges, scoring 2 and 0, respectively, indicating varying degrees of usability hurdles. Marvellous and Blender encounter difficulties, scoring 3 and 5, respectively.

(c) Ease of Understanding: CLO3D excels in providing a clear and comprehensible learner interface, earning a top score of 8. Tukatech, with a score of 5, maintains a good level of understanding. Browzwear faces challenges, scoring 0, indicating difficulties in facilitating clear comprehension. Marvellous and Blender score 0 and 5, respectively, reflecting varying degrees of complexity in their interfaces.

(d) Personalization: Effective learning necessitates personalization, allowing control over the learning process, content interaction, and performance monitoring. Tools exhibit varying degrees of support for personalization, with CLO3D and Tuka providing a high degree of adaptability and customization, enabling users to tailor the tool to their specific design workflows.

4.1.3 Organization/Institution Perspective

(a) Organization: The implementation of any 3D modelling system necessitates robust institutional support and a tailored infrastructure setup. Organizational prerequisites vary based on the technological underpinning and distinctive features of each tool. CLO3D and Optitex may require specific infrastructures, while others like Blender offer more adaptable requirements. In terms of providing stability and support, CLO3D and Blender emerge as frontrunners, securing top scores of 5 each. Browzwear and Marvellous maintain moderate scores of 3, suggesting a reasonable level of stability. Tukatech and Optitex, however, score lower with 0, indicating potential challenges in delivering stability and support.

In evaluating the best-performing 3D modelling tools across various perspectives, CLO3D emerges as the top performer in both the technology and learner perspectives. In terms of technology architecture and implementation, CLO3D showcases robustness, stability, and adaptability, setting a benchmark for performance optimizations and ease of installation. Similarly, in the learner perspective, CLO3D excels in user-friendliness, interactive features, and ease of understanding, offering high levels of personalization for users. Additionally, CLO3D demonstrates strong institutional support and stability, making it a top choice among fashion production houses. Thus, CLO3D stands out as the preferred option for its comprehensive features and performance across multiple evaluation criteria. Exhibit varying degrees of performance.

4.2 In-depth Interviews with Industry Experts: Unveiling Key Insights

The interview aimed to assess the types of 3D modelling tools commonly used in the fashion sector. The study provided insights into the software currently used by fashion designers and the challenges faced by production houses in utilizing 3D software for various purposes in the design process, including ideation, prototyping, and sampling.

The majority of participants (4 out of 7) primarily utilize CLO3D, followed by Browzwear (VStitcher) with 2 participants, and one participant mentioned using Tuka 3D modelling tools. For switching 5 prefer CLO3D, while the remaining favoured Browzwear. Participants appreciate this software for their pre-programmed 3D models, time-saving features, efficiency in handling complex design tasks, ease of installation, and modularity to suit specific requirements. They also emphasize advanced simulation capabilities, seamless integration, and fashion-specific features such as pattern design and measurement application.

But most participants suggested that training on 3D modelling software is most, as most participants (6 out of 7) learn independently through experimentation and YouTube tutorials. Only one participant received basic training for three months, highlighting the lack of formal training opportunities. Participants universally acknowledge the initial challenges faced by newcomers in grasping 3D platforms and configuring settings, emphasizing the importance of user-friendly interfaces and accessible training to facilitate seamless adoption of 3D modelling tools in the fashion industry.

All participants recognize the importance of 3D modelling software in the prototyping process for showcasing products, enhancing visualization, streamlining prototyping, and improving buyer understanding. Additionally, the majority (6 out of 7) advocate for a combination of traditional methods and 3D modelling, citing benefits such as enhanced productivity, waste minimization, and optimized work processes. This evaluation highlights the prevalent usage patterns, preferences, and challenges associated with 3D modelling tools in the fashion industry. It underscores the significance of tools like CLO3D and Browzwear, which offer pre-programmed 3D models, efficiency in complex design tasks, and seamless integration, among other features. Additionally, it emphasizes the importance of user-friendly interfaces and accessible training to facilitate the adoption of 3D modelling tools. The evaluation also underscores the role of 3D modelling software in enhancing productivity, minimizing waste, and optimizing work processes, thus contributing to the overall efficiency and sustainability of fashion design and production.

5. Conclusion

In conclusion, this study illuminates the potential advantages and challenges associated with the integration of 3D modelling tools in the fashion industry. The adoption of such tools enhances visualization, expedites decision-making, and reduces reliance on physical prototypes, thereby streamlining product development cycles. Efficient collaboration is facilitated through virtual prototypes, promoting effective communication and alignment among designers, manufacturers, and clients. Clo3D stands out as a commendable tool, offering user-friendly design, robust fabric simulation, and seamless integration, positioning it as a transformative force in fashion design.

Looking forward, the future of the fashion industry hinges on the strategic incorporation of 3D modelling tools, promising streamlined processes, reduced costs, minimized material wastage, and enhanced overall efficiency. To maximize these benefits, companies are urged to implement formal training programs, empowering stakeholders with essential skills. The study advocates for the adoption of user-friendly software tailored to the fashion industry's unique needs, fostering accuracy and quality in virtual prototypes. In essence, embracing 3D modelling software represents a holistic shift towards sustainability, cost-effectiveness, and efficiency in fashion design processes.

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Mediating Role of Green Training in Impact of Green Manufacturing on Performance in Apparel Industry

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Abstract:
Background: The garment export business makes a substantial contribution to both industrial production and export revenues. Implementing environmentally sustainable practices in the production process of garment export-oriented enterprises not only contributes to societal well-being but also enhances competitiveness in the global market and boosts overall company performance.

Methods: This study aims to investigate the impact of Green Manufacturing on Operational Performance, Environmental Performance, and Economic Performance in the apparel manufacturing export industry. Furthermore, the study investigates the role of Green Training as a mediator between Green Manufacturing and types of Performance. A survey method is used to collect data from 123 garment export units, and structural equation modelling (SEM) is used to analyze the results.

Results: This study delivers empirical evidence of the impact of the implementation of Green Manufacturing on Green Training, Operational Performance, Environmental Performance, and Economic Performance. The research provides empirical proof of the partial mediation of Green Training in the implementation of GM and its impact on Environmental Performances. Additionally, it demonstrates that Green Training has no significant mediation on Economic Performance and Operational Performance.

Conclusion: This study is unique as it empirically proves that businesses should include sustainability practices to maximize income through internal resources like green technology and trained manpower. This study suggests that implementing green practices can lead to improved firm operational, economic and environmental performance, which has practical implications for enterprises.

Keywords: *garment, green manufacturing, green training, performance, sustainability*

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1. Introduction :

The apparel market already uses more resources than the earth can sustain [1]. Over time, the garment industry has put more strain on the planet's resources, which has had a detrimental effect on society, the economy, and the environment [2]. India's export share is declining in the apparel, cotton fabric, and carpet sectors compared to Bangladesh, Vietnam, Turkey, and China [3]. According to Mariam [4], the stakeholders and policymakers participating in the recovery plan following Covid 19 should implement sustainable development goals. Businesses can get a competitive marketing edge by earning environmental management system (EMS) accreditations like LEED and WRAP [5]. The sustainability challenges associated with garment manufacturing must be addressed immediately due to the industry's reputation regarding it [6]. To lessen the industry's negative environmental effects, green manufacturing is one ecologically friendly approach that should be adopted.

2. Literature Review

Businesses use greener production methods to lessen the environmental impact of their products and production method [7].

According to Cay [8], adopting more eco-friendly production techniques is necessary for sustainable production. Businesses in the fashion industry that actively support green supply chains can better withstand export restrictions in international commerce and increase their competitiveness in the world market. Fashion firms are working to identify best practices based on economic, social, and environmental considerations by incorporating sustainable strategies within the fashion supply chain and using eco-friendly materials, ethical labor practices, renewable energy, and green manufacturing [9]. A study investigates the impact of Green Supply Chain Management (GSCM) practices on the performance of organizations operating in the garment sector of Sri Lanka [10]. Economic Performance is among the primary drivers behind the adoption of sustainable supply chain techniques. Green training is essential for green teams, claim [11]. Recent research explains how green training affects production plans with greener practices. Corporate training influences the creation of environmentally friendly supply chains.

Although there are several studies on green manufacturing and performance, none of them explicitly address the

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interrelationships within the apparel export industry. The relationship between green manufacturing, three categories of performance, and the mediating role of green training has not been investigated in the specific context of garment manufacturing export enterprises. In addition, quite a few previous research studies on green manufacturing were conceptual, qualitative, literature surveys, or investigations with other variables. As a result, studies based on quantitative data are still required [12]. International customers put more pressure on export-oriented organizations to adopt GMP [13], thus, the study focuses solely on export-oriented units in the garment industry. The research is unique because a gap exists, providing a valuable avenue for future research. It was assumed that green manufacturing is positively correlated to operational performance, environmental performance, and economic performance and that green training either has a direct or mediating effect.

2.1 Theory background

The framework known as the resource-based view (RBV) has been utilized to examine the importance of resources and their capabilities concerning product development and an organization's overall success. Furthermore, resource dependence theory examines the impact of green manufacturing practices on performance. Thus, theoretically speaking, green training is a talent that can be attained through resource utilization. The natural-resource-based approach (NRBV) was introduced by Hart [14] and highlights the skills that support the environment. To test the proposed conceptual research framework and research hypothesis, a survey was conducted in Indian apparel manufacturing companies. The study article is organized into various sections, with Section 3 describing the data collection and the methods utilized. Section 4 focuses on the results and discussion, and section 5 highlights the conclusion.

3. Method

3.1 Data Description

As discussed in the literature review, Green manufacturing has grown increasingly attractive and increased attention to environmental and sustainable development challenges in today's society. Additionally, Green Training considerably modified environmental practices in Spanish businesses, claims Sarkis [15]. Daily [11] asserts that green training is essential for green teams. We contend that green training and green manufacturing in the fashion industry continue to be significantly associated. Therefore, the interconnection between Green Manufacturing (GM) and Green Training (GT) is investigated with the hypothesis.

(H1): Green Manufacturing (GM) has a significant positive impact on Green Training (GT)

Furthermore, manufacturing companies accept sustainable and green production methods primarily to improve performance. A study investigates the impact of Green Supply Chain Management (GSCM) practices on the performance of organizations operating in the garment sector of Sri Lanka [10]. Economic Performance is among the primary drivers behind the adoption of sustainable supply chain techniques. Therefore, based on the existing literature review, the study examines the connections between green manufacturing and three types of performance in the apparel manufacturing export industry: operational performance, environmental performance, and economic performance. The research hypotheses are as follows.

(H2): Green manufacturing has a significant impact on Economic Performance. (H3): Green manufacturing has a significant impact on Environmental Performance. (H4): Green manufacturing has a significant impact on Operational Performance.

Additionally, the study contends that green training plays an important mediating role between green manufacturing and three types of performance in the garment manufacturing export industry, adding to the pool of knowledge on green manufacturing. As a result, the following hypotheses is used to investigate the interconnections between the constructs:

(H5): Green Training has a significant mediating effect on Green manufacturing and Economic Performance. (H6): Green Training has a significant mediating effect on Green manufacturing and Environmental Performance. (H7): Green Training has a significant mediating effect on Green manufacturing and Operational Performance. (H8): Green Training has a significant impact on Economic Performance. (H9): Green Training has a significant impact on Environmental Performance. (H10): Green Training has a significant impact on Operational Performance.

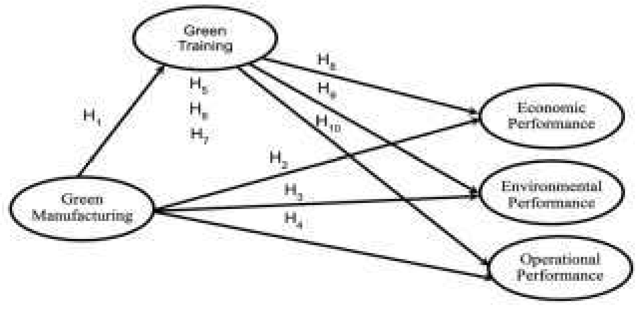

Figure 1: Conceptual framework

The conceptual research framework is presented by the literature review, and the research gap identified (see Figure 1). This exploratory study aims to discover the interconnections among the constructs of Green Manufacturing, Green Training, operational performance, environmental performance, and economic performance of Indian apparel manufacturing export companies. The research employs a deductive approach, quantitative analysis, and a questionnaire survey method for data collection. According to AEPC, there are 246 textile and apparel export companies in Karnataka, out of which 176 medium and large size and medium size apparel manufacturing units are identified as population, and the sample size is 123 [16].

3.2 Variable Measurement and Questionnaire Design

The questionnaire is divided into two sections: demographics and constructs. Five constructs are included in the study: Green Training, Green Manufacturing, and three performances. Shang et al. validated the Green Manufacturing construct, which included 15 items. Sarkis [15] and Daily [11] validated the Green Training construct, which had seven items. Hajmohammad [17] validated the construct of Environmental Performance (6 items), Zhu [18] validated Operational performance (5 items), and Zhu [19] validated Economic Performance (5 items).

The population for the study consists of export-oriented apparel manufacturing companies in the southern Indian state of Karnataka. EOU firm type and garment manufacturing industry type are used to determine the study population. The data is collected from garment manufacturing export houses using random sampling methods. The questionnaire developed was validated was academicians and industry people. The pilot study data analysis included 35 samples. After that constructs reliability, discriminant validity, and convergent validity were checked through preliminary examination of pilot test data. The final questionnaire was shared with the respondents to fill in the company's current GMP adoption status on a seven-point Likert scale. Respondents worked in various departments of the apparel manufacturing unit. For the electronic survey, 159 potential respondents were contacted, and 127 companies returned completed questionnaires. As a result, the return rate is 79.8%. The study used data from July to November 2023. Table 1 summarizes the demographics of the 123 respondents.

Table 1: Demographic characteristics of the companies

Job title	Percent	Valid Percent	Cumulative Percent
Director	9	7.3	7.3
Manager	103	83.7	83.7
Product Developer	3	2.4	2.4
Vice president	8	6.5	6.5
Total	123	100.0	100.0
Age of the company	**Percent**	**Valid Percent**	**Cumulative Percent**
>=21	52	42.3	42.3
0-5 years	16	13.0	13.0
11-20 years	37	30.1	30.1
6-10 years	18	14.6	14.6
Total	123	100.0	100.0

3.3 Data Analysis Procedure

Given the widespread use of PLS-SEM in social science, marketing, and business strategy research, it is being implemented in this study for data analysis [20]. Moreover, it is common research practice to use structural equation modelling with PLS-SEM to demonstrate a theory using actual data [21].

Common Method Bias: It is a measurement source error that can result in inappropriate relationships between measurement items and, in the end, faulty study findings. Common Method Bias can be tested the Harman one-factor test from 1976. According to Podsakoff [22], the single construct's total variance is below the acceptable 50%. The research has a CMB of 42% and the VIF value is less than the recommended level of 3.4 [23]. As a result, the data is free of common method bias and collinearity.

Measurement Model: The validity and reliability of the constructs are evaluated using the measurement model [20] (See Table 2). Indicating that both Cronbach's alpha (CA) and Composite reliability (CR) are greater than the suggested 0.700, CA ranges from 0.881 to 0.956 and CR ranges from 0.907 to 0.957. As a result, all of the data used in the measurement model is reliable [21].

Table 2: Construct Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
EP	0.921	0.926	0.941	0.762
EnP	0.899	0.907	0.922	0.665
GM	0.956	0.957	0.959	0.684
GT	0.953	0.954	0.962	0.782
OP	0.881	0.913	0.911	0.672

Note(s): EP = Economic Performance, OP=Operational Performance, EnP = Environmental Performance, GT = Green Training

The average variance extracted (AVE) values, which range from 0.665 to 0.782 [24], are also used to verify the convergent validity of the constructs [21]. Cross-loading, the Fornell-Larcker criteria, and the Heterotrait-Monotrait ratio (HTMT) are used to assess the discriminant validity. The square root of AVE is used in this work to test the Fornell-Larcker criteria, and its off-diagonal values are lower than the diagonal components [24] (see Table 3).The HTMT is less than 0.9 (see Table 4), indicating a satisfactory HTMT. As a result, constructs have required discriminant validity.

Table 3: Fornell–Larcker criterion

	EP	EnP	GM	GT	OP
EP	0.873				
EnP	0.387	0.815			
GM	0.765	0.543	0.833		
GT	0.574	0.676	0.726	0.884	
OP	0.284	0.574	0.410	0.421	0.820

Note(s): EP = Economic Performance, OP=Operational Performance, EnP = Environmental Performance, GT = Green Training

Table 4: Heterotrait–Monotrait ratio (HTMT)

	EP	EnP	GM	GT	OP
EP					
EnP	0.424				
GM	0.809	0.575			
GT	0.614	0.722	0.753		
OP	0.292	0.634	0.411	0.420	

Note(s): EP = Economic Performance, OP=Operational Performance, EnP = Environmental Performance, GT = Green Training

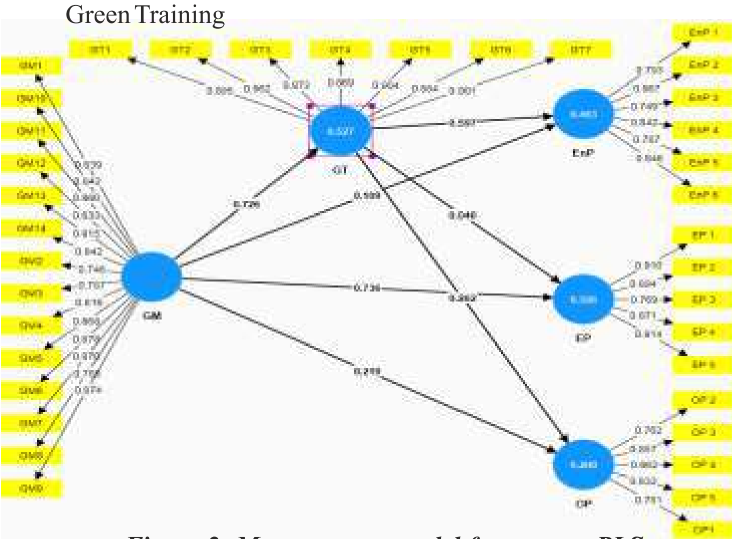

Figure 2: Measurement model from smart PLS

Data analysis reveals the cross-loading matrix values are higher for intended constructs. The measurement model is shown in Figure 2, and it includes the development of a path diagram with constructs to evaluate the reliability, discriminant validity, and convergent validity of all six constructs used in the model.

4. Results and Discussion

Later, a structural equation model was created in smart PLS by bootstrapping with 10000 subsamples to assess statistical fit, check the significance of the impact of the constructs, and test all hypotheses identified during research. Then, the direct path coefficient value and the mediation effects between the construct are investigated. R2 value is determined [25], which measures the ability to explain the dependent variable, is good and significant for the structural equation model. Latan [25] states that the R2 value is less, if it is lower than 0.25, medium if it is lower than 0.50, and large if it is lower than 0.70.

In the structural model, the R2 adjusted value accounts for 52.7% of the Green Training. The value of R2 adjusted for Economic Performance, Operational Performance and Environmental Performance is 58.6%, 20% and 46.3% respectively [20].The P values, path coefficient (β), and t-statistics are used in the research study to assess the interconnections among the constructs. The relationship in H1, GM on GT(t = 16.912, β= 0.726, p< 0.000), successively for all other hypotheses is in Table 5. As a result, research hypotheses H1, H2, H3, H6, H8, H9, and H10 are supported,

Table 5. Path Coefficient

Hypothesis	CP	O	STDEV	TS	*p value*	Results
H1	GM -> GT	0.726	0.043	16.912	0.000	Supported
H4	GT -> EP	0.045	0.095	0.479	0.632	Not Supported
H2	GT -> EnP	0.585	0.077	7.610	0.000	Supported
H3	GT -> OP	0.261	0.131	1.997	0.046	Supported
H8	GM -> EP	0.766	0.043	17.632	0.000	Supported
H9	GM -> EnP	0.536	0.058	9.194	0.000	Supported
H10	GM -> OP	0.408	0.067	6.064	0.000	Supported

Note(s): CP= Construct Path, O = Original sample, STDEV = Standard deviation, TS = T statistics, PV= p Value

while H4, H5 and H7 is not. This signifies that except for Economic performance, Green training constructs directly and considerably impact the economic and operational Performance. Green Manufacturing constructs also directly and considerably impact green training, operational performance, environmental performance, and economic performance.

Table 6: Mediation table

H	Direct Effect Coff.	PV	Specific Indirect Effect	Indirect Coff.	PV	TE	LCL 2.5 %	UCL 97.5%	Mediation
H5	0.73	0.00	GM -> GT -> EP	0.03	0.64	0.77	-0.106	0.165	No mediation
H6	0.13	0.19	GM -> GT -> EnP	0.42	0.00	0.55	0.313	0.563	Partial mediation
H7	0.22	0.13	GM -> GT -> OP	0.19	0.05	0.41	-0.015	0.366	No mediation

Note(s): H = Hypothesis, CP= Construct Path, PV= p Value, TE = Total Effect

As shown by the test results of the Specific Indirect effect (β= 0.033, p = 0.635), there is no significant mediation of GT on GM and EP. There is partial positive significant mediation of GT on GM and EnP (β= 0.424,p< 0.000). Also, there is a no significant mediation of GT on GM as there is zero value in between LCL 2.5% and UCL 97.5%. Therefore, research hypotheses H5 and H7 have no mediation, and H6 have partial mediation.

Finally, the model fit is checked to understand the statistical adequacy of the structural model; the value of SRMR is close to .80, indicating that the research model is valid [25]. The values of LV predictive are mentioned in Table 8, where the predictive power of constructs is good and R2 values are significant.

Green training is thus significantly impacted by green manufacturing. This study signifies that except for Economic performance (PP), Green training construct directly and considerably impacts the economic and operational Performance. This research supports the literature, which

Table 7: LV predictive summary

	Q²predict	R^2
EP	0.581	0.463
EnP	0.279	0.586
GT	0.522	0.527
OP	0.145	0.200

Note(s): RMSE = Root Mean Squared Error, MAE = Mean Absolute Error

emphasizes the importance of green training and its influence on the green economy. This study adds to current research on green manufacturing by showing a strong mediating influence of green training on green manufacturing and performance. The research provides further evidence to back up previous studies on the effects of Green Supply Chain Management (GSCM) strategies on the productivity of companies in Sri Lanka's apparel industry [10].

4.1 Implications

Both academics and researchers will benefit from the study. Garment export companies competing for orders from other nations may utilize green training to adopt green manufacturing and plan business strategies to achieve organizational goals. The study's analysis of the mediating effects between the components significantly expands the pool of knowledge on green manufacturing. The research enables experts in the apparel sector to comprehend the significance of numerous concepts, such as green training and demands for green manufacturing implementation at the firm level, and to reset environmental resources appropriately. Finally, the research will assist garment exporters in growing their apparel export companies by getting certifications like LEED and ISO 14000 after applying green production.

4.2 Limitations

One of the study's limitations is that it was conducted in Karnataka's garment manufacturing export-oriented firms. The generalizability of study is constrained by the fact that the data is gathered from top or middle management at the firm level. There is an impact of knowledge of sustainable manufacturing practices on furthur studies in apparel [26], textiles [27] or textile technology [28]. Therefore, future studies may examine the moderating impact of constructs, including various business stakeholders in the textile and apparel industries.

5. Conclusion

The research provides empirical proof of the partial mediation of Green Training in the implementation of GM and its impact on environmental performances. Additionally, it demonstrates that Green Training has no significant mediation on Economic performance and Operational performance. Also, construct GM have a direct significant positive impact on OP, EnP and EP. Moreover, construct GT have a direct significant positive impact on OP and EnP. This supports the findings of other academics who hypothesize that the high upfront expenses associated with adopting sustainable practices could prevent them from having a beneficial short-term impact on profitability and sales. The garment export companies competing for orders from other nations may utilize green training to adopt green manufacturing and plan business strategies to achieve performance goals. Lastly, the study suggests that adopting green practices should be viewed as a long-term objective because it may not result in increased profitability or sales success.

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Envisioning the Era of 3D Printing in the Textile and Fashion Industry

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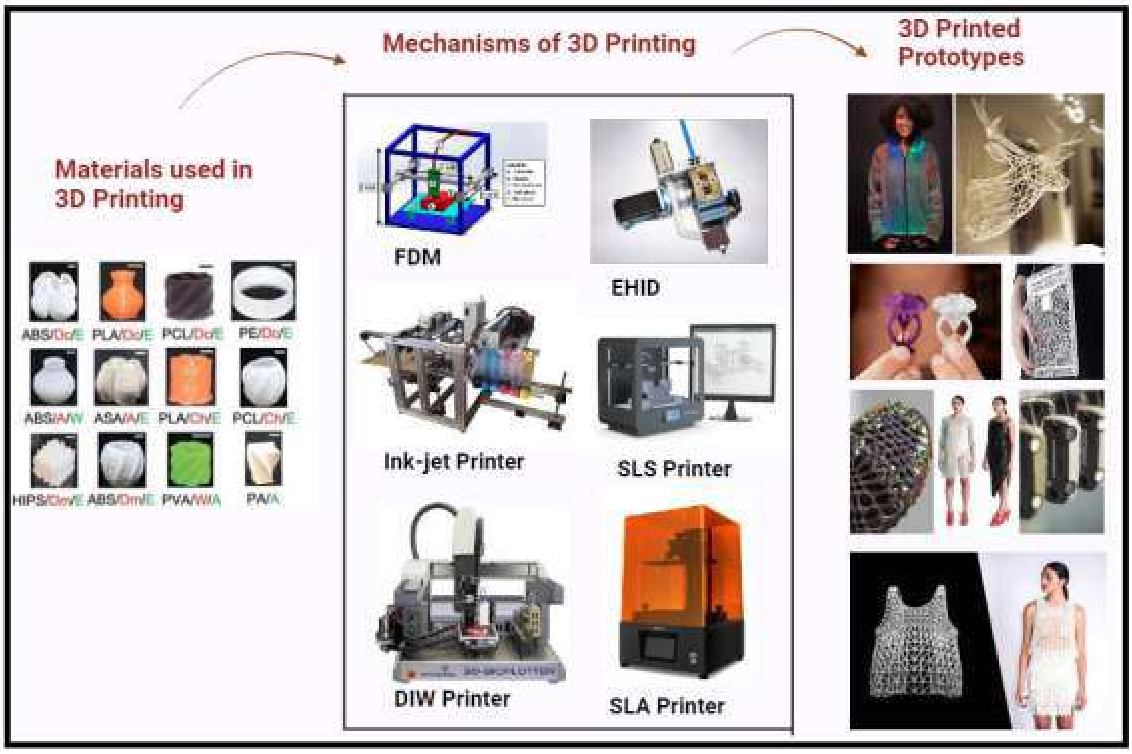
Abstract:

The widespread potential of 3D printing technology has led to it being heralded as a major innovation of the so-called "fourth industrial revolution." Dramatic inventions have been noticed in the last few years in the fashion sector too making use of 3D/ 4D printing. The use of 3D printing in the fashion industry yields excellent outcomes. However, there is a robust connection between the worlds of fashion and 3D printing, and incredible new projects are being revealed on a daily basis. With 3DP, designers and consumers alike can make goods that are both unique and intricate. Designers and manufacturers of clothes have recently come to recognize the significance and benefits of 3D printing technology, which has led to a rise in the use of 3D printers in the textile and fashion industries. Significant curiosity has been sparked, and it appears to have considerable potential for fashion design goods. In this paper, we sought to update a previous evaluation of 3DP technology in the fashion sector to reflect the most up-to-date findings. In this study, the author has covers the review of 3D printing material, the printing process, use of different 3D software, and summarized the advantages and limitations of 3DP in comparison to the traditional manufacturing process. Furthermore, examples of how 3D printing has been used in the fashion industry are provided.



Graphical Abstract

Keywords: *3D Printing, 3D Software, Envisioning, Industry, Manufacturing Process*

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1. Introduction :

Using digital design tools like CAD, CAM, or other electronic design tools, 3D printing (also known as additive manufacturing, or AM) rapidly and efficiently produces 3D objects layer by layer [1]. Compared to more conventional printing technologies, 3DP can produce extensive 3D structures in a shorter time frame and at a lower cost [2]. The 3DP method involves the gradual deposition of material (much like a coating) in order to construct an object [3]. Decoration of the fabric's surface can be done with no adhesives when three-dimensional printing is used on textile

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substrates [4]. While chemical bonding is certainly a part of the attachment of 3DP materials to textiles [5], revealed that the key factor was the real-world "locking" of textiles and printing supplies. Although 3DP can be printed on a variety of materials, controlling its adherence, durability, and stability has proven challenging so far [5]. Furthermore, 3DP has received a lot of interest in the textile and fashion industries in recent years due to its adaptability in terms of size and shape. Unlike the fabrication of conventional textiles, 3DP technology enables the creation of very complex structures and permits personalized customization according to the wearer's body via 3D scanning [6]. Due to raw material constraints, however, it is challenging to manufacture goods with the same flexibility, scalability, and pore structure as conventional textiles; a lot of people are interested in the idea of using 3D printing to create textiles with practical applications these days.

Since Chuck Hull, co-founder of 3D Systems, created the first 3D printer in 1983 [7], there have been significant advancements in additive manufacturing technology. The ability of 3D printing technology to rapidly and accurately produce complicated structures has increased its popularity in recent years. Furthermore, cutting-edge technologies like bioprinting and 4D printing have expanded medical practice's potential [8]. Development in additive manufacturing has reached a pinnacle, making it possible to 3D print with a wide variety of materials, including metals, thermoplastics, hydrogels, extracellular matrix materials, ceramics, fiber-reinforced composites, polymers, concrete materials, and even shape memory alloys & polymers and variety of other smart materials [9].

The fashion industry is also going through the industrial revolution from design to production. The use of computers and other digital technologies to design and create products is known as "digital manufacturing," and it has progressed significantly over the years. The environment created by the Fourth Industrial Revolution is one in which virtual and physical production systems work with one another on a global scale in a highly adaptable fashion. One of the foundations of Industry 4.0 is the incorporation of digital manufacturing, which has been shown to decrease production time, costs, and errors while increasing production efficiency and product quality. In addition to the industry's interest, consumers have a lot riding on the fashion industry's transition to digital.

2. 3D Printing in the Fashion and Textile Industries

a) Fashion Design

Designers have been able to produce a wide range of inventive and intricate clothing that would be hard to produce using more conventional textile manufacturing techniques due to the flexibility provided by 3D printing. For instance, Nervous System Studio [10] used SLS printing nylon to make a petal dress with over 1600 individual components and over 2600 hinges. Inspired by the intricate patterns found on the wings of minuscule butterflies, artist Julia Koerner worked with STRATASYS to experiment with digital pattern design and multi-color 3D printing on cloth. Following this, the butterfly design was 3D-printed directly onto the stretchy fabric without the use of a support structure [11]. They created the "ARID collection," which consisted of 38 separate 3D-printed pieces that could be put together to form a garment. The designers made a point of using 3D-printed joinery for all seems so that no sewing was required at any point in the process [12]. The 3D printing technology allowed Acne Studios to create a bag for the 2019 fall/winter season [13]. Using a 3D printer and TPU filament, Nike [14] created the Nike Flyprint upper. When compared to conventional 2D materials, 3D uppers have improved pliability, weight, and breathability by connecting the warp and weft in new ways.

b) Functional Garments

Another exciting area of study is the application of 3D printing technology to the production of functional clothing. This is possible because the technology may be used to generate fibers or fabric with a unique textile structure or by adding functional components. By combining poly (vinyl alcohol) (PVA) and boron nitride (BN) in a 3D printer [15] were able to create a thermally conductive fiber with improved thermal transport capabilities of textiles for individual cooling. Additionally [16] developed a 3D-printed thermoplastic polyurethane (TPU) mesh fabric with digitally adjusted mechanical characteristics and shape [17] used SLS technology to create a structured fabric with a progressive transition between soft and hard states, with the granular particles in its two layers interlocking with one another.

c) Electronic Textiles

These technologies are widely used in the field of e-textiles because they can swiftly and accurately print intricate functional structures using 3DP [18]. One example is the fabrication, by ink printing with a coaxial spinneret, of a textile substrate bearing a core-sheath fiber-based smart design [19]. Stretchable elastic fibers and smart textiles with a coaxial core-sheath structure using 3DP technology were also developed [20], with graphene serving as the conductive core and PTFE serving as the insulative sheath. Triboelectric nanogenerators (TENGs) were developed [21] using 3D printing to create a three-dimensional, hierarchically porous structure; the TENGs were made from a matrix of poly (glycerol sebacate) (PGS) and electrodes of conductive carbon nanotubes (CNTs).

d) Materials used in 3D printing

Material plays a crucial role in the realm of 3D printing because it influences how the art of 3D Fashion is created and serves as the basis for new developments in 3D printing technology. A multitude of materials, each with special qualities and features, can be utilized to 3D print fashion apparel. Here are some materials that are frequently used in 3D printing for clothing.

e) Thermoplastic Polyurethane (TPU)

TPU is a flexible, elastic substance that is frequently used in 3D printing for apparel. It is ideal for uses like sportswear, activewear, and lingerie because of its outstanding stretchability, toughness, and comfort.

f) Polyamide (Nylon)

Nylon, often known as polyamide, is a versatile material used in 3D printing for apparel. It is renowned for its fortitude, adaptability, and strength. The smooth and fabric-like texture of nylon prints makes them ideal for creating clothing with complicated patterns and challenging geometries.

g) Thermoplastic Elastomer (TPE)

TPE is a flexible, rubber-like substance that is frequently used in 3D printing for accessories for clothing, such as shoes, belts, and jewelry. It enables the development of pleasant and useful fashion products by offering flexibility, impact resistance, and high elasticity.

h) Polyester

Polyester is a synthetic fabric that is frequently used in the fashion industry and may also be utilized as a 3D printing material. Polyester prints are appropriate for a variety of garment applications because they can provide good strength, durability, and colour vibrancy.

i) Polyethylene Terephthalate Glycol (PETG)

PETG, a translucent and strong material, is frequently used in 3D printing to create jewellery, accessories, and other decorative items. It offers strong chemical resistance, impact resistance, and printing simplicity.

j) Thermoplastic Polyurethane Elastomer (TPU-E)

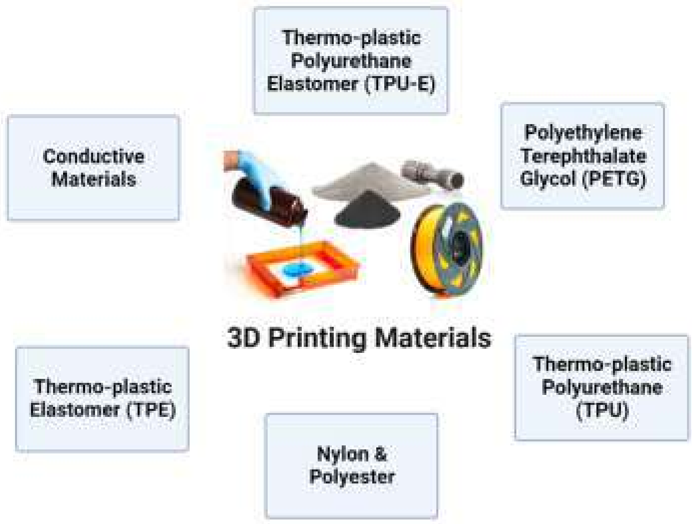
TPU-E is a specific thermoplastic elastomer that combines flexibility, elasticity, and toughness. It is made of polyurethane. Stretchable and form-fitting clothing, such as swimwear, activewear, and compression apparel, are created using in 3D printing.

k) Conductive Materials

Conductive materials, such as conductive filaments or inks, are used in 3D printing to create garments with integrated electronic components or sensors. These materials enable the production of smart clothing with capabilities like sensing, heating, or lighting.

l) Bio-based and Sustainable Materials

With a growing emphasis on sustainability in the fashion industry, bio-based and sustainable materials are gaining popularity in 3D printing. Filaments made from PLA (Polylactic Acid) or PHA (Polyhydroxyalkanoates) are examples of biodegradable and compostable materials. Materials for 3D printing currently consist mostly of novel polymers, resin materials, metals, and composites. The specifics are outlined below.



the Fashion Industry

3. Mechanism of 3D/4D Printing

Pre-processing is the first step in the 3D printing process. During this stage, the model is created using computer-aided design (CAD) programs like AutoCAD, Rhino, 3Ds Max, etc. The model is then told to be sliced horizontally into x and y layers by the software. In order to print the layers at their specified locations, the CAD-controlled digital file communicates with the printer [22]. The information and commands are then transferred to the CAM system, which constructs the final form of the object. Sanding, polishing, and painting the result, as well as trimming off any excess material, all fall under the "final phase" [23]. Replicating the fabric's pattern exactly necessitates a very high resolution, hence the resolution needed to create textile structure is extremely small and precise [22, 24]. Filaments for 3DP are often made from Acrylonitrile Butadiene Styrene (ABS), Poly Lactic Acid (PLA), or Poly Vinyl Alcohol (PVA). Technologies such as stereolithography (SLA), selective laser sintering (SLS), inkjet printing, binder jetting, and fused deposition modelling (FDM) are utilized to create 3D textiles and fashion accessories [22], [23]. Ultraviolet (UV) lasers are used in stereolithography to harden successive layers of photopolymer resin, a liquid plastic, used in the creation of three-dimensional objects [4]. Objects can be printed from a wide variety of powdered materials, including polymers, metals, ceramics, and composites, using a process called selective laser sintering [25]. Fused deposition modelling involves the layer-by-layer extrusion of molten thermoplastic filament from a nozzle onto a printing bed in the form of a wire-shaped, thin production-grade filament [26].

3D printing using glue or binder bonding agents to fuse powder ingredients and then create consecutive layers of powder materials to build the 3D printed goods is called "binder jetting" [22]. The ink droplet in inkjet printing is propelled out of a microscopic aperture in the printing head by heating the liquid ink, causing bubbles to develop in the ink reservoir [27].

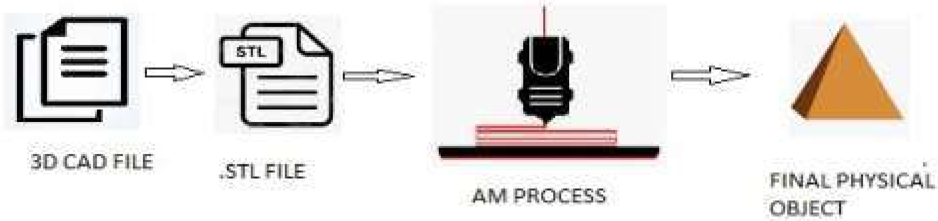


Figure 2 - Steps of 3D printing

4. 3D printing process methods and design & modelling software

Table.1 displays the characteristics of the three most used traditional 3D printing processes: fused deposition modelling (FDM), selective laser sintering (SLS), and stereolithography (SLA).

According to the underlying forming principle of each 3D printing technology, a unique set of materials can be used for printing. To create a solid object, a fused deposition model (FDM) printer melts filaments of thermoplastic material and extrudes the molten material via a nozzle. The filamentary hot-melt materials most commonly employed in the Fused Deposition Modelling (FDM) process have the advantages of a wide variety of forming materials and high strength of produced parts at the expense of low processing accuracy and a rather rough surface. This technique is widely used in today's 3D printing items. One of the raw materials utilised in FDM technology is PLA, which was used to print the clothing displayed at the Asian art museum in San Francisco. Therefore, fused deposition modelling (FDM) was previously the most popular approach to 3D printing [28]. Using a lamination technique for particle sintering, the selective laser sintering (SLS) process builds 3D printed objects by repeatedly irradiating and sintered powder or particles applied to a machine tool. Powders and tiny particles are commonly used in SLS. The crystallisation collection suit by Iris Van Herpen and Daniel Widrig, for instance, is made from polyamide. This approach has the benefits of a straightforward production procedure in addition to a large selection of inexpensive printing raw materials, a high forming speed, and a low material cost. The printer, while effective, is both cumbersome and costly.

In the realm of 3D printing, SLA technology is a mainstay. The liquid resin is deposited in a reservoir, and a programmable laser is scanned over its surface to commence photopolymerization, so completing the photo-hardening process. Chemical crosslinking is the mechanism through which the resin typically solidifies and becomes inflexible after having been a liquid [29]. Iris Van Herpen's Hybrid Holism collection, for instance, was the inspiration for a see-through dress.

At the meso- and micro-scales, Direct-Ink-Writing (DIW) is a popular additive manufacturing technique that relies on extrusion to deposit ink. The DIW process involves layer-by-layer fabrication of 3D structures by dispensing liquid-phase "ink" from small nozzles at controlled flow rates and depositing it along digitally determined routes. 3D printing using inkjet lamination (also known as 3DP). The process involves spraying the raw powder with colored ink and a liquid solidified component through a nozzle [30].

Table 1. Analysis of various process methods

S. No.	Process method	Main materials	Medium	Advantages	Disadvantages	References
1	FDM	ABS plastic PLA plastic	Solid	1. cheap price 2. High utilization 1. Strong support 2. Not easy to deform	1. The surface is rough and requires a framework. Low adaptability; only one texture available	[31]
2	SLS	Plastic powder	Power	1. High processing accuracy 2. No support needed	rough surface	[32]
3	SLA	Photosensitive resin material	Liquid	1. Fast forming speed 2.Smooth surface	Expensive	[33]
4	EHID	PP, PLA, PCL	Solid/liquid	Reasonably priced, user-friendly, flexible, and nanofiber-based	Low mechanical quality, sluggish construction times	[34]

S. No.	Process method	Main materials	Medium	Advantages	Disadvantages	References
5	DIW	Polymers, waxes, ceramics	Liquid	Quick processing times, no filler required	Material constraints	[34,35]
6	Inkjet	PLA, PCL, poly (lactide co - glycolide) (PLGA), ceramics	Liquid	Design complex structures	Slow build speeds, material limitation	[35]

The fashion industry utilizes various software tools for 3D printing to enable the design, optimization, and production of fashion garments and accessories. Here are some of the commonly used software in the 3D printing process within the fashion industry:

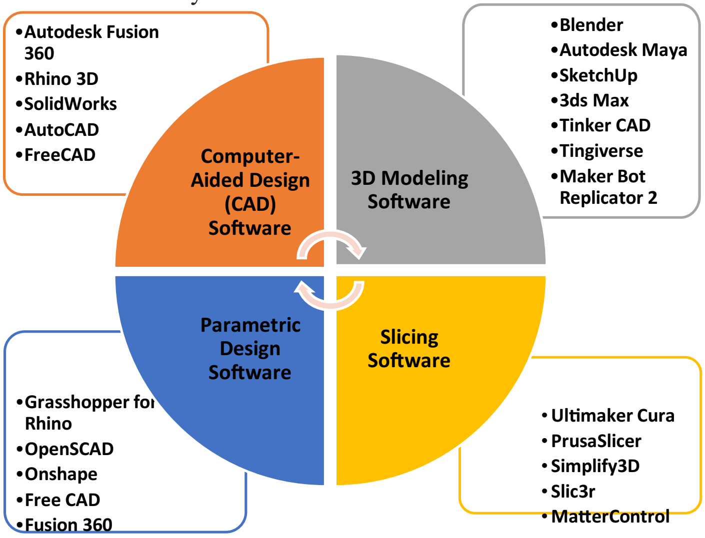


Figure 3. 3D printing Software

In 3D printing of fashion clothing, various software tools are used to create and prepare 3D models for printing. These software tools enable designers to visualize their designs, optimize them for 3D printing, and generate the necessary files for the printing process. The majorly used 3D printing software I fashion industry are Grasshopper for Rhino, OpenSCAD, Onshape FreeCAD, and Fusion 360 (with parametric design capabilities). Table 2. Can be referred for the analysis of the advantages and disadvantages of materials used in additive manufacturing.

Table 2: Analysis of Advantages and Disadvantages of Materials [36]

S. No.	Material Name	Advantages	Disadvantages	References
1	ABS plastic	1. Consistent physical properties and high resistance to wear 2. The colors don't fade easily	1. The optimal temperature range for the platform is between 80 and 120 degrees Celsius. 2. Large-scale production on a mass scale is not simple.	[36]
2	ALS Nylon powder Material	1. High resilience to both heat and wear 2. Very strong tensile properties	1. Reduced sensitivity to colour. 2. Extreme heat is used in manufacturing.	[37]
3	Photosensitive resin	1. High tensile strength and rapid curing time 2. Finished garments have a sleek finish that is well -suited for individualized designs. 3. A lot of resources are reused and recycled	1. Poor heat and wear resistance	[38]
4	Rubber materials	1. Excellent durability and pliability 2. Sufficient adaptability and high levels of comfort	1. Poor environmental safeguards and a low rate of reuse	[39]

5. 3D Printing over conventional methods:

The conventional methods used in fashion industry are giving limited results in terms of accuracy, design constraints, customised designs and productivity. Refer Table. 3 for the major advantages of using 3D printing over the conventional methods.

Table 3. Advantages of using 3D Printing over conventional methods [40,41,42]

Parameters	3D/4D Printing	Conventional method
Flexible Design	When compared to conventional manufacturing techniques, 3D printing facilitates the development and fabrication of more intricate designs. The use of 3D printing eliminates the need to work around the design limitations of more conventional methods.	Production of the complex design is the limitation of the conventional method. Fabrication methods are not very flexible for complex designs.
Rapid Prototyping	With 3DP, parts can be produced in a matter of hours, speeding up the prototyping process and making it simple to change designs. In many cases, a3D-printed component can be ready for use in as little as two hours, making it a more economical and time-efficient option than machining a prototype. Because of this, it takes significantly less time to implement each design change.	Rapid prototyping before 3D printing was expensive and time-consuming.
Restricted Build Size	Despite printing the object in separate pieces because of the restricted build size platform, 3D printing still gives efficient products.	From conventional methods steps of making the separate parts get eliminated and size is not the restriction for making products.
Print on Demand	In 3DP, storing merchandise does not necessitate a sizable warehouse.	Adequate space is required after making the inventory.
Post-Processing	Cleaning up the support material and getting a smooth surface is usually required after 3D printing.	No post-processing is required.
Minimizing Waste	There is no material waste in 3DP manufacturing because just the materials necessary for the part's fabrication are used.	The majority of conventional methods produce waste in some formalmost at every stage of production.
Cost-Effective	Inexpensive when mass -produced. Three - dimensional printing (3DP) eliminates the need for several equipment, reducing both production time and costs.	Conventional methods are not very cost - effective.
Advanced Healthcare	Using 3D printing technology, doctors are able to create human parts including livers, kidneys, and hearts to help save patients' lives.	Although many methods are used to make the fashion products used in the healthcare industry.
Copyright Issues	There is a rising risk of fake and counterfeit goods as 3DP becomes more widely available to the general public.	No such issues are there while using conventional methods.

Table 4. A brief analysis of cases/applications of 3d printing technology in the fashion industry

S. No.	Year	Designer	Product Category	Description	Reference
1	2021	Danit Peleg	Apparel	This lace-like texture was made possible by merging traditional textile features with modern technologies, which influenced the structure of his designs. The outfits are created in layers using desktop 3D printers and a flexible filament.	[43]
2	2022	Iris van Herpen	Apparel/ haute couture dress	The outfit was 3D printed using a vegan organic material derived from cocoa bean shells.	[44]
3	2022	Galerie Dior	garments, handbags, or even shoes	Everything in the manufacturing process is made from renewable sources.	[45]

S. No.	Year	Designer	Product Category	Description	Reference
4	2021	Ronen Samuel-Kornit Digital	Knitwear	Direct-to-yarn printing, which can be done on any type of textile, is one method that Ronen employs in its pursuit of eco-friendly and waste-free clothing. With MAX technology, the ink is added one layer at a time. The product is an item of clothing that mimics the appearance of hand-knitted items. Designs by Ronen Samuel have been shown at the Tel Aviv Fashion Show.	[46]
6	2017	Julia Daviy	fashion, jewelry, and home décor	Eco-Friendly Skirt. This item is the crown jewel of a 3D printed collection that debuted in 2019. Every single garment in the After Forever Collection was printed using a huge 3D printer. Digitally modifiable in over a thousand variations, the Organic Skirt was the first item of apparel to be 3D-printed and sold in the United States.	[47]
7	2022	Stratasys (SSYS 2Y22 Reflection collection)	accessories and apparel	Luxury 3D-printed clothing and accessories from the Reflection collection.	[48]
8	2014	Anouk Wipprecht	Proximity Dress	Multiple sensors built within the clothing may be able to detect nearby motion. In response to a person approaching too closely, the dress can extend to form an obstruction.	[49]
9	2015	Karl Lagerfield	Garments	Karl Lagerfield was one of the first high-end designers to embrace 3D printing. The highly acclaimed designer stunned the Paris Fashion Week crowds with a collection of garments made entirely with 3D software.	[50]
10	2013	Julia Körner	Garment	In the blockbuster film Black Panther, Julia, a prominent fashion designer, is known for her 3D printed garments. She created some spectacular graphics in the form of 3D clothes after developing the first 3D printed outfit in 2013. It appears that JK Design's creator finds most of his inspiration in the natural world.	[50]
11	2019	Zac Posen	Rose Petal Dress	Modeled after a rose, this dress consists of 37 printed petals attached to a frame. The dress was printed using SLA and EBM 3D printing processes.	[51]
12	2018	Maria Alejandra Mora Sanchez	Loom Dress	Inspired by Wayuu, an indigenous tribe in northern Colombia, Sanchez designed the dress to be evocative of the tribe's well-known patterns and textiles. The dress was printed in TPU on an FDM 3D printer.	
13	2016	Danit Peleg	Paralympics Dress	This dress was fitted to Purdy using 3D scanning technology, 3D modeled using Blender, and printed over the course of 100 hours in Recreus' FilaFlex material.	
14	2015	Laura Thapthimkuna	Vortex Dress	This design was modeled with ZBrush and Maya, then printed in Mammoth Resin on an SLA printer.	
15	2015	Anouk Wipprecht	The Spider Dress	Wipprecht's creation was printed on an SLS 3D printer and also incorporates sensors and microcontrollers (Edison chip) to achieve robotic effects.	

6. Discussion

The implementation of technology that allows for three-dimensional printing in the apparel and textile industries is advancing at a breakneck speed. The technology of 3D printing may one day completely change the planet. The production of goods and products all over the world could undergo a radical transformation that is both an improvement and a substantial change as a result of developments in 3D printing technology. The development of ideas is accelerated by 3D printing. The ability to print a concept on the same day that it was conceived shortens a development process from what would have been months to what might be a number of days, assisting businesses in remaining one step ahead of their competitors. The recent explosion of interest in digital art and design has given rise to a proliferation of opportunities that are not only rapidly expanding but also virtually unbounded. It is now possible to print almost anything in three dimensions after first sketching it up virtually or in some other way. Artists and research scholars are putting an emphasis on the mix of ease, originality, and innovation of clothes and fabrics, which enables them to create highly complex goods that are also soft and flexible. Nevertheless, the latest developments in 3D printing technology are restricted by size limitations. When it comes to building very huge objects, 3D printers still fall short of expectations. At this point in time, 3D printers are capable of working with around one hundred unique raw materials. This is negligible when weighed against the large variety of raw materials utilized in conventional production.

7. Conclusion

The manufacturing industry is undergoing a radical transformation as a result of the unprecedented growth of 3D printing technology. This flexible approach offers the benefits of customization, prototyping, a variety of production techniques, and complicated geometries in a short amount of time at a low cost. The fashion sector needs to find a new approach and start the necessary programmes to help producers, vendors, businessmen, creators, and customers receive training and education so as to adapt and shift in an expedient and effective way. This study has brought up a conversation about the changes that are expected in the 3DP era. Clearly, the contemporary fashion industry in its entirety continues to go through a transformation and embrace of ongoing technological advances, such as programmes that allow for two-dimensional computerised pattern drafting and virtual reality in fit analysis. To lay the framework for a comprehensive revolution, the industry must make incremental advances and seek niche applications while technological advancements continue. As a result, it is imperative that the fashion sectors remain receptive to the idea of restructuring and reassessing their current knowledge in light of the vocational and learning systems, the multidisciplinary strategy to accomplishing goals in a range of fields, and the information sharing between both sectors in order to facilitate an effective transition.

8. Future Scope

Additional study is required to develop procedures that will make things that have been manufactured with a 3D printer more resilient and long-lasting. Therefore, it is suggested that 3D printing become an official academic discipline, that subsequent works be proposed for improving the conceivable effects of 3D printing, and that the area of study be broadened to encompass all of the building projects accomplished by 3D printing, a variety of substances utilized by 3D printing, and supplemental modeling for multifaceted design procedures.

9. Authors' Contributions

Conceptualization, A.D., A.T, and N.A.; methodology, A.T., A.D.; Framework, A.D, A.T and N.A. Graphics Design, A.T., Literature, A.T., A.D., and N.A.; writing— original draft preparation, A.T, and A.D; writing—review and editing, A.T., A.D., N.A. authors have read and agreed to the published version of the manuscript.

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To Study the Cotton Yarn to Make for the Knitted Fabric on Handle Properties

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Abstract:

The knitted fabric structures greatly influence the dimensional, physical and comfort properties of fabric. In this work 100 % cotton knit fabric 1×1 rib, 2×1 rib was produced with 20 Ne, 25 Ne and 30 Ne ring yarn with varying stitch length on flat bed knitting machine. It is widely used to express the thickness of knit fabric. It is found, that fabric GSM decreases with the increased stitch length. GSM of 2x1 rib fabric is highest and 1x1 rib is lowest for both 20 Ne, 25 Ne and 30 Ne yarn count. The 1x1 rib structure having low fabric feel factor value leads to more comfort and soft feel appearance as compared to 2x1 rib having high fabric feel factor value and harsh feel. Bursting strength of 2x1 rib fabric is higher as compared to 1x1 rib structure knit fabric for 20 Ne, 25 Ne and 30 Ne yarn. Bursting strength also decreases with yarn fineness, i.e., lower for 30 Ne, 25 Ne yarn than 20 Ne yarn for all structures. It is found that 2x1 rib is highest value (Dry & Wet rubbing fastness) as compared to 1x1 rib structure knit fabric. The lower stitch length having higher dry & wet rubbing fastness because more compact structure and more GSM fabric. It is also found that 2x1 rib has highest value of Pilling propensity as compared to 1x1 rib structure knit fabric. The lower stitch length leads to more pilling propensity because of more compact structure and more GSM of fabric.

Keywords: *Bursting Strength, Fabric Feel, Knit Fabric, Pilling Propensity, Rubbing Fastness*

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1. Introduction :

The knitted fabrics in general are more stretchable than the woven fabrics. The open structure of knitted fabrics also helps in moisture vapour transmission making it suitable for the comfort garments. Rib has a vertical cord appearance because the face loop wales tend to move over and in front of the reverse loop wales. As the face loops show a reverse loop intermeshing on the other side, 1x1 and 2x1 rib has the appearance of the technical face of plain fabric on both sides until stretched to reveal the reverse loop wales in between [1, 2]. The knitted rib structures are widely used in body lengths for outerwear, their main use is in providing welts, cuffs, and collars for garments with plain-knitted bodies and sleeves [3, 4]. Knit wear industry is rising at a faster rate over the globe and technological advancements contribute a lot in the success of industry. Knit wear fabrics are popular on account of their excellent properties of comfort, softness; sweat absorption, durability and softness. Quality of the fabrics of prime concern in placement of new ties between buyers and manufacturers, Consumers, now days, are becoming more and more concerned and aware of fabric quality and accept higher quality standards than any time in recent years [5]. Knit fabrics provide outstanding comfort qualities and have long been preferred as fabrics in many kinds of clothing. Knit fabrics are produced on different machines with different knit stitches and conditions to created different patterns and fabric types. The commercial design of knitted garments is a process that shares many important characteristics with other types of aesthetic design and engineering [6, 7]. Rib is a costlier and heavier structured fabric to produce than plain fabric. The main utilization of knitted rib structures is in providing welts, cuffs, and collars for garments with plain-knitted bodies and sleeves moreover the knitted structures are also widely used in body lengths for outerwear. Knitted fabrics are gaining popularity day by day because of the comfort and easy-care properties. Many studies were carried out in the past to study various aspects of knitted fabrics [8]. The knitting parameters and the type of structure not only affect the comfort but also the performance properties of the knitted fabrics. Knitting machine gauge and the knitting stitch length are the two fundamental knitting parameters that directly affect all structure related properties of the knitted fabric.

2. Materials and Methods

2.1. Material

The cotton yarns used in this study have been prepared at DCM India Limited. The cotton yarns having 20, 25 & 30 Ne. Weft knitted fabric sample have been prepared on flat bed knitting machine with two different knit types 1x1 and 2x1 rib structures as shown in (Tables 1 to 3).

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Table 1 - Test result of cotton yarn

S. No.	Parameters	Cotton Yarn 1	Cotton Yarn 2	Cotton Yarn 3
1	Count	20 s/1 combed	25 s/1 combed	30 s/1 combed
2	Um%	8.8	8.98	9.7
3	CVm%	11.12	11.35	12.28
4	Thin (-50%)	0	0	0
5	Thick (+50%)	12	14	15
6	Neps (+200%)	16	24	45
7	TPI	28	39	60
8	H	8.35	7.56	6.77
9	Sh.	2.02	1.78	1.58
10	CSP	2954	2830	2750
11	RKM	19.9	19.51	18.5
12	CV%	8.25	8.3	8.5

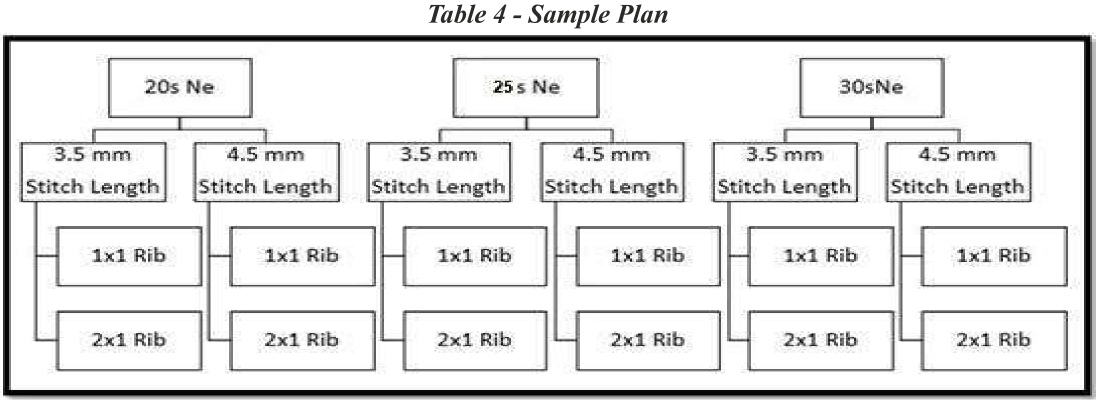
Table 2 - Specification for knitted fabric

Sr. No.	Count (Ne)	Type of Structure			
		1 x 1 Rib		2 x 1 Rib	
		Stitch length (mm)		Stitch length (mm)	
1.	20	3.5	4.5	3.5	4.5
2.	25	3.5	4.5	3.5	4.5
3.	30	3.5	4.5	3.5	4.5

Table 3 - Specification for the Cotton knitted fabrics

Sr. No.	Count (Ne)	Type of Structure	GSM (g/m^2)	Stitch Length	Wales per Inch	Course per Inch	Stitch Density	Thickness (mm)
1	20	1x1 Rib	375	3.5	29	23	667	2.5
2	20	1x1 Rib	329	4.5	24	18	432	2.3
3	25	1x1 Rib	345	3.5	32	24	768	2.2
4	25	1x1 Rib	305	4.5	25	19	475	2.0
5	30	1x1 Rib	319	3.5	33	24	792	1.9
6	30	1x1 Rib	295	4.5	26	21	546	1.8
7	20	2x1 Rib	343	3.5	26	24	624	2.4
8	20	2x1 Rib	302	4.5	21	20	420	2.7
9	25	2x1 Rib	318	3.5	27	26	702	2.5
10	25	2x1 Rib	286	4.5	22	21	462	2.5
11	30	2x1 Rib	294	3.5	28	26	728	2.3
12	30	2x1 Rib	265	4.5	23	22	506	2.4

Table 4 - Sample Plan



a. Methods

Before testing, the conditioning was done for 48 hours of all samples in standard atmospheric condition where temperature was 27 ± 2°C and relative humidity 65 ± 5% as per standards.

2.2.1. Pilling propensity

Pilling propensity of fabrics is determined by the machine Orbitor as per standards EN ISO 12945-1. Four tubular specimens are mounted on polyurethane pilling tubes and tumbled in the cork-lined box for an agreed number of revolutions. Specimens are usually prepared from samples which have been cleansed (wash or dry cleaned). This will help to preserve the useful life of the cork liners. Stringent quality control of the liners and the tubes is essential in order to ensure the critical demands of the standards are satisfied. ICI 444 modifies the cork lined box used for pilling tests by including one point in the center of each of the six (6) sides of the box. Snag Pod, which is used for BS 8479, has four (4) rows of 20 angled pins spaced evenly inside the octagonal chamber.

2.2.2. Rubbing test

As per standard ISO 105-X12 and AATCC 165 testing has been done. Crock Master is used to test the colour fastness to rubbing of carpets, knitted, laminates and printing inks. A colored test specimen is clamped and rubbed, under controlled conditions, against an undyed crocking cloth. Colour transferred to the crocking cloth is assessed in comparison with a standard Grey Scale for Staining. The Crock Master is normally supplied with the standard rubbing finger fitted.

2.2.3. Fabrics feel testing

Presently there are few instruments available for evaluating fabric handle objectively, like Kawabata evaluation system for fabrics and Fabric feel tester. In the present study fabric feel tester was used to obtain the objective evaluation about the fabric feel. Sample size of 24 cm diameter is used in the test. The fabric feel factor for the tested fabrics were obtained using the Equation 1. When the feel factor value is low the fabric would be softer and at higher value it's vice versa i.e., fabric would be harsher [9].

Calculations

Feel factor (f) = 26.58+ 20.65*PE – 0.436 * WE – 0.131* a + 5.064 * PR -0.361 * DR … (1)

Where, PE- Peak Height of Extraction curve (Kg)
WE- Area under the curve for extraction curve (Kgmm)
A -Unload fabric across orifile for extraction curve
PR -Peak height for radial curve (kg)
DR-Peak distance for radial curve (mm)

2.2.4 Busting strength

The unique laser technology was used to measure distension provides the most accurate possible results. TruBurst2 Model 810 is aimed at the conventional fabric and apparel markets where bursting pressure up to 1000 kPa are required. TruBurst2 Model 801 targets the more specialized area of the market that requires the highest levels of accuracy at bursting pressures not exceeding 100kPa. TruBurst2 conforms to the ISO 13938-2 and ASTM D3786 test standards.

3. Results and Discussion

3.1. Effect of yarn count, stitch length and knit structure on fabric feel factor

Figure 1 demonstrates the effect of yarn count, structure and stitch length on fabric feel factor. Basically, fabrics feel factor is related to one of the Kawabata comfort properties. When the feel factor value is low the fabric would be softer feel and at higher value it's vice versa i.e., fabric would give harsher feel properties. It has been observed from the figure 1 that with the finer yarn count, feel factor of the fabric increases irrespective of the knit structure due to reason of increase in twist/inch of yarn. It can be also observed from figure 1 that feel factor is higher for 3.5 mm stitch length as compare to 4.5 mm stitch length for both fabrics i.e., 1x1 and 2x1 rib structures. Further 2x1 rib fabrics exhibited higher feel factor as compared to 1x1 rib fabrics with same level of stitch length. The decrease in feel factor with increase in stitch length is due to increase in space required for each stitch for the same yarn count in both 1x1 and 2x1 rib structure. The values of fabric feel factor decreases may be due to increment in frictional properties. Rib fabrics with higher stitch length have lower feel factor in the fabric with same yarn counts.

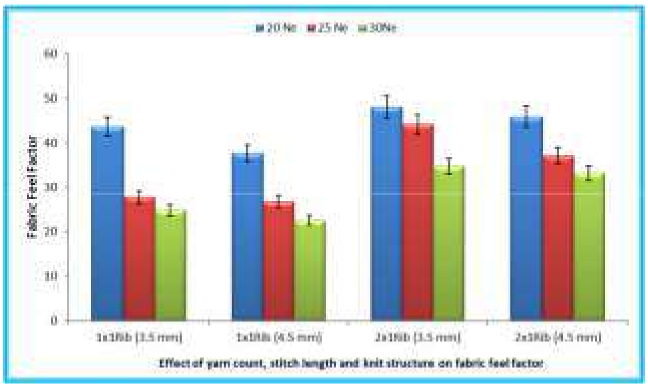


Figure 1 - Effect of yarn count, stitch length and knit structure on fabric feel factor

Table 5 - Effect of 1x1 rib structure, yarn count and stitch length on fabric properties

S. No.	Count (Ne)	GSM (g/m^2)	Stitch length (mm)	Pilling grading	Bursting Strength (Kpa)	Rubbing cycles		Fabric Feel Factor
						Dry (20)	Wet (10)	
1	20	375	3.5	4.5	490	4	4	43.72
2	20	329	4.5	3.5	465	3	3	37.65
3	25	345	3.5	4.5	460	4	4	27.82
4	25	305	4.5	3.5	410	3	3	26.79
5	30	319	3.5	4.5	435	4	4	24.87
6	30	295	4.5	3.5	356	3	3	22.61

Table 6 - Effect of 2x1 rib structure, yarn count and stitch length on fabric properties

S. No.	Count (Ne)	GSM (g/m^2)	Stitch length (mm)	Pilling grading	Bursting Strength (Kpa)	Rubbing cycles		Fabric Feel Factor
						Dry (20)	Wet (10)	
1	20	343	3.5	5	547	5	4	48.12
2	20	302	4.5	4	471	4	3	45.97
3	25	318	3.5	5	480	5	4	44.19
4	25	286	4.5	4	425	4	3	37.14
5	30	294	3.5	5	460	5	4	34.74
6	30	265	4.5	4	410	4	3	33.21

3.2. Effect of yarn count, stitch length and knit structure on bursting strength

Figure 2 shows the effect of yarn count, knit structure and stitch length on fabric bursting strength. Bursting strength is an alternative method of measuring strength in which the material is stressed in all directions at the same time and is therefore more suitable for such materials. It has been observed from the figure 2 that with the finer yarn count, the bursting strength of the fabric decreases irrespective of the knit structure due to increase in porosity of the fabric. It has been also observed from (Table 5) and figure 2 that bursting strength decreases as the loop length increases from 3.5 to 4.5 mm for each yarn count in 1x1 rib knit structure. This is due to the fact that, when stitch length is less, no. of loops per square inch is more. Therefore, the resistance towards the force is more in case of less stitch length of fabric. Similarly, in (Table 6) bursting strength is decreasing with increase in stitch length as seen from the figure 2. The decrease in bursting strength with increase in stitch length is due to decrease in stitch density for the same yarn count in both 1x1 and 2x1 rib structures. Rib fabrics with higher stitch length have lower bursting strength in the fabric with same yarn counts. The results are in accordance with the findings of Mst. Sarmin Khatun [10-12], who stated that 2x1 rib fabrics exhibited higher bursting strength as compared to 1x1 rib fabrics.

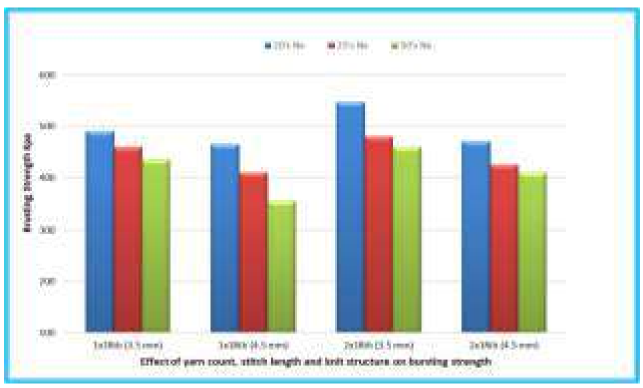


Figure 2 - Effect of yarn count, stitch length and knit structure on bursting strength

3.3 Effect of yarn count, stitch length and knit structure on rubbing fastness

The extent of fastness to dry and wet rubbing is assessed visually comparison with arbitrary standards 1, 2, 3, 4, 5, where 5 denotes good fabric color fastness i.e., no change in color and 1 denotes poor fabric color fastness i.e., severe change. Figures 3 and 4 demonstrate the effect of yarn count and stitch length on dry and wet rubbing fastness respectively. It has been observed from the figures 3 and 4 that yarn count does not have any effect on dry and wet rubbing fastness the rubbing fastness of the fabric is same irrespective of the yarn count. It can be also observed from Table 5, figures 3 and 4 that dry and wet rubbing fastness is higher for 3.5 mm stitch length as compare to 4.5 mm stitch length for both fabrics i.e., 1x1 and 2x1 rib structures due to increase in fabric thickness. Further 2x1 rib fabrics exhibited higher dry and wet rubbing fastness as compared to 1x1 rib fabrics with same level of stitch length. Similarly, table 6 shows rubbing fastness decreases with increase in loop length as seen from the figures 3 and 4. The decrease in rubbing fastness with increase in stitch length is due to increase in space required for each stitch for the same yarn count in both 1x1 and 2x1 rib structure. Rib fabrics with higher stitch length have lower value of dry and wet rubbing fastness in the fabric with same yarn counts.

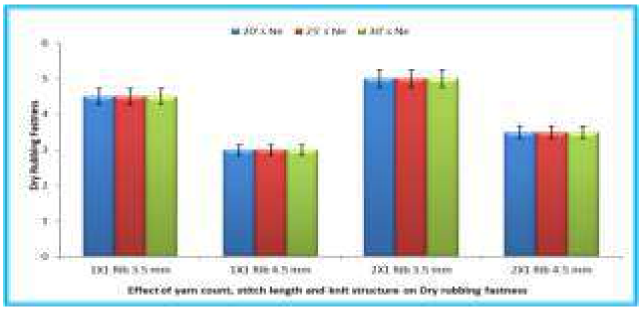


Figure 3 - Effect of yarn count, stitch length and knit structure on dry rubbing fastness

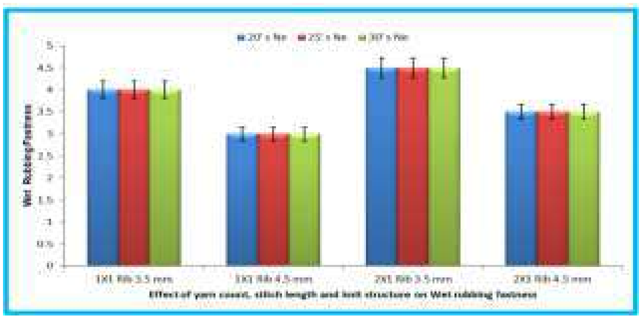


Figure 4 - Effect of yarn count, stitch length and knit structure on wet rubbing fastness

3.2. Effect of yarn count, stitch length and knit structure on Pilling Propensity

Figure 5 shows the effect of yarn count, knit structure and stitch length on pilling propensity of fabric. Pilling is a process that occurs on the surface of fabrics and leads to the formation of irregular clumps of fibers ranging from small to large, named "pills", more or less anchored to the surface of the fabric. The extent of pilling is assessed visually comparison with arbitrary standards 1, 2, 3, 4, 5, where 5 denotes no change in fabric surface i.e., zero pilling and 1 denotes the maximum pilling. It has been observed from the figure 5 that the yarn count does not have any major influence on the pilling propensity of the fabric irrespective of the knit structure [12- 14].

It can be also observed from Figure 5 that pilling propensity is higher for 3.5 mm stitch length as compare to 4.5 mm stitch length for both fabrics i.e., 1x1 and 2x1 rib structures due to a smaller number of loops per inch. Further 2x1 rib fabrics exhibited higher pilling propensity as compared to 1x1 rib fabrics with same level of stitch length. This is due to more compact structure. It has been also observed from table 5 and figure 5 that pilling propensity decreases as the loop length increases from 3.5 to 4.5 mm in 1x1 rib knit structure. This is due to the fact that when stitch length is less the stitch density is more. Similarly, Table 6 shows that pilling propensity decreases with increase in stitch length as seen from the figure 5. The decrease in pilling propensity with increase in stitch length is due to decrease in stitch density for the same yarn count in both 1x1 and 2x1 rib structures. Results were supported by the findings of Daiva Mikucioniene [15], who said that rib knitted fabric gives substantially fewer pills than the interlock, rib 1×1, and plain knitted fabric because of less operated surface area.

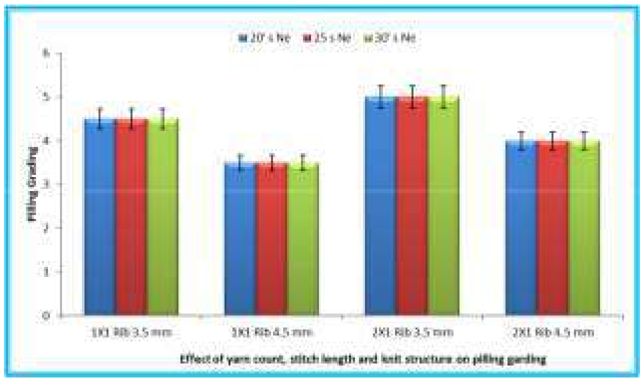


Figure 5 - Effect of yarn count, stitch length and knit structure on pilling garding

4. Conclusions

In present study an attempt is made to study the influence of various parameters on the comfort properties knit fabric, fabric feel factor, bursting strength, pilling strength and rubbing fastness on different yarn count like 20 Ne, 25 Ne and 30 Ne for 2x1 and 1x1 structure rib 100% cotton knit fabrics. Therefore, from the various combinations of knit fabrics, GSM, Stitch length and yarn count range 20 Ne, 25 Ne and 30 Ne, the following conclusions are drawn:

- Stitch density is highest for 2x1 rib for all yarn count and lowest for 1x1 rib. The again stitch density is higher for fabrics made from finer count yarn compared to coarser count for all structures in fabrics. Also, GSM depends on yarn count, knit structure & dimensional properties of knit fabrics. It is widely used to express the thickness of knit fabric. Fabric GSM decreases with the increased stitch length.

- Stitch length has greater effect on both 1x1 rib and 2x1 fabric but more on 1x1 rib in the sense that the lesser the stitch length, the more compact the knit structures is, the higher the stitch density and fabric weight but the higher the stitch length, the more loose the fabric becomes and the lesser the stitch density and fabric weight.

- Fabric feel factor changes with stitch length i.e. for shorter stitch length value is higher than longer stitch length fabrics. The 1x1 rib structure has low fabric feel factor value for this low value is more comfort and soft feel compared to 2x1 rib is high fabric feel factor value shown fabric harsher feel knit cloth.

- Bursting strength of 2x1 rib fabric is higher compared to 1x1 rib structure knit fabric and for all yarn count ranges. Like loop length, bursting strength also decreases with yarn fineness, irrespective of the stitch length for both structures.

- Pilling propensity is higher for 3.5 mm stitch length as compare to 4.5 mm stitch length for both fabrics i.e., 1x1 and 2x1 rib structures due to less number of loops per inch and The decrease in pilling propensity with increase in stitch length is due to decrease in stitch density for the same yarn count in both 1x1 and 2x1 rib structures.

- It has been found according to as research work that 2x1 rib is highest value (Dry & Wet rubbing fastness) compared to 1x1 rib structure knit fabric. Lower value of stitch length gives more dry & wet rubbing fastness because more compact structure and more GSM fabric.

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Review on Compound Fabrics

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Abstract:

This article presents a comprehensive review of compound fabrics, focusing on their structures, benefits, creation methods, and care considerations. Compound fabrics, synthesized from various structures, offer enhanced properties over single-component fabrics. The study outlines two primary structures employed in clothing fabrication: woven and knitted. Furthermore, it delves into the advantages of fabric compounding, elucidating synergistic properties, economical production, and weight reduction achieved through this process. The methods for creating compound fabric are discussed, encompassing lengthwise, widthwise, and layer wise compounding techniques. Moreover, the article highlights crucial care considerations during the stitching process, emphasizing seam balancing, precautions for stretchable fabrics, stability challenges, and techniques to prevent fraying and finish seams. By addressing these aspects, manufacturers and designers can optimize the performance and longevity of compound fabrics in various applications.

Keywords: *Hybrid Structure, Knits, Layering, Synergistic Properties, Structure Compounding*

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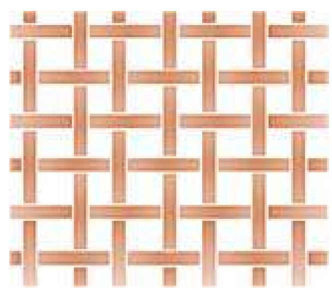
1. Introduction :

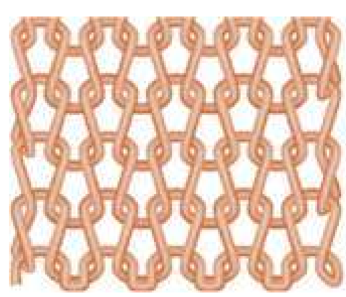
Textile fabrics stand as a fundamental element interwoven into the daily lives of every individual on Earth, serving humanity for countless centuries. These materials exhibit commendable strength, flexibility, permeability, and drape properties, collectively contributing to the creation of fabrics that provide substantial protection, aesthetic appeal, and comfort when incorporated into various applications such as apparel and garments [1]. In the interest of crafting the right product, fabric properties play a pivotal role, and these properties can be finely tuned through several influencing factors. The selection of fibres, including options like cotton, polyester, viscose, nylon, and others. The selection of yarn, ranging from spun yarn, fancy yarn, textured yarn, to filament yarn. The selection of fabric's structural composition adds another layer of customization, with options such as woven, weft knitted, warp knitted and nonwoven. Furthermore, the selection of finish of the fabric through the application of various chemicals, completes the comprehensive process of tailoring textiles [2]. Therefore, it becomes evident that the properties of fibres, the structural composition of the fabric, and the application of finishes all contribute significantly to the end properties of the garment [3, 4]. The intricate interplay of fibre characteristics, fabric structure, and the incorporation of different yarns collectively define the ultimate attributes of the fabric, influencing its suitability and performance in the world of fashion and every day wear.

2. Structures Used for Clothing

The structural composition of fabric stands as a crucial determinant in influencing the overall performance, particularly in the state of maintaining the thermo-regulation of the human body through apparel. The selection of fabric structure becomes a strategic decision, intricately tied to the intended end use of the garment. Predominantly, woven, and knitted structures are the stalwarts in the textile industry, offering diverse characteristics. Woven and knitted fabrics, while both serving as fundamental pillars in textile manufacturing, exhibit distinct variations in their structural organization, thereby impacting their functional attributes. The utilization of woven structures involves the interlacement of warp and weft yarns, resulting in a fabric known for its durability, strength, and dimensional stability. On the other hand, knitted fabrics are characterized by interlooping yarns, providing them with superior flexibility, elasticity, and drape. These inherent differences in structural arrangements contribute to the unique performance of each fabric type.



(a) Woven Fabric



(b) Knitted Fabric

Figure 1 - Woven and Knitted Structure

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The significance of fabric structure in thermo-regulation is underscored by the fact that the body's comfort is influenced by how efficiently the fabric allows for heat exchange. The choice between woven and knitted structures, or even nonwoven and braided structures, becomes pivotal in achieving the desired balance between insulation and breathability. This structural variability, as outlined by Özdil et al. [5], underscores the nuanced interplay between fabric structure and performance, serving as a guiding principle for textile engineers and designers aiming to optimize the functionality of garments for diverse end uses.

2.1 Woven Structure

In the intricate world of woven fabrics, the synergy of two or more sets of yarns intricately interlaced at right angles gives rise to a textile marvel. This unique interlacement creates a structured matrix, endowing woven fabrics with distinctive properties that set them apart in textile engineering. The meticulous choice of weave determines not only the aesthetic appeal of the fabric but also its inherent ability to resist creases and maintain a crisp appearance. Additionally, the woven structure manifests commendable stability under stress, offering a fabric that withstands various forces without compromising its integrity. This stability extends to the realm of air permeability, with denser woven fabrics displaying a lesser tendency to allow air passage, making them particularly suitable for specific applications.

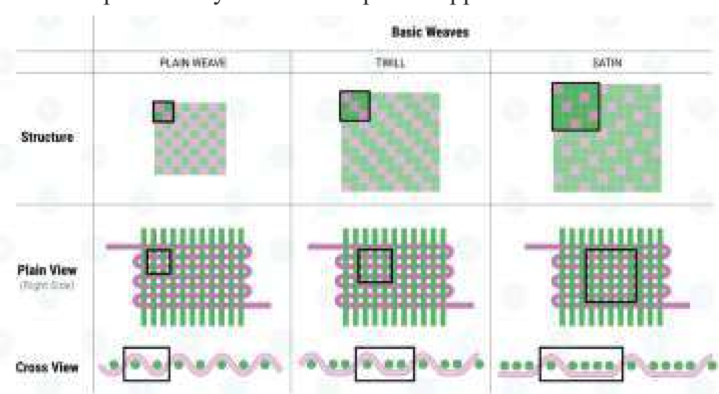

Figure 2 - Basic Woven Fabric Weaves [6]

Furthermore, woven fabrics boast remarkable stability in normal use and care, showcasing minimal shrinkage, typically less than 2%. This minimal shrinkage contributes to the longevity and reliability of woven garments, ensuring that they maintain their original dimensions over time. The preference for woven structures extends to scenarios where heightened breaking strength, tearing resistance, dimensional stability, and specialized material requirements are paramount. In essence, the woven structure emerges as a stalwart choice in the textile landscape, embodying a harmonious blend of durability, stability, and versatility for applications ranging from everyday wear to specialized industrial uses.

2.2 Knitted Structure

In the intricate world of knitted structures, a fascinating interplay of interconnected loops takes center stage, crafted with either a single set or multiple sets of yarns. This method of construction gives rise to fabrics with unique characteristics that distinguish knitted textiles in the vast landscape of textile engineering. At the core of knitted fabrics lies their exceptional stretch and elasticity, a property that endows them with the ability to gracefully adapt to the dynamic movements of the human body, thereby ensuring unparalleled comfort and flexibility. A notable feature of knitted structures is the presence of open spaces between yarns, contributing to their inherent breathability and air permeability. This openness not only facilitates moisture regulation but also enhances the overall comfort level of garments fashioned from knitted fabrics. Another distinguishing quality of knitted textiles is their remarkable capacity to recover from wrinkles, presenting an advantage in terms of maintaining a smooth and neat appearance even after periods of wear. Moreover, these fabrics tend to exhibit higher shrinkage unless subjected to heat-setting processes.

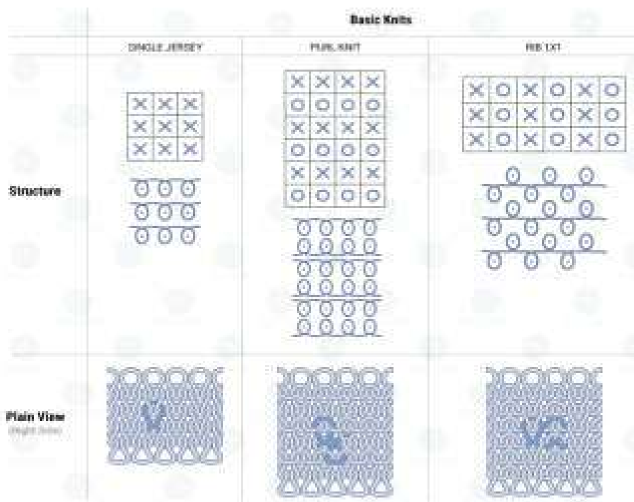

Figure 3 - Basic Knits [6]

Despite these considerations, the preference for knitted structures remains strong in various applications due to their exceptional drape, moisture permeability, and overall comfort. As Choudhary and Goel [7] highlight, the unique attributes of knitted fabrics position them as the fabric of choice for those seeking a perfect blend of style, functionality, and ease of wear in diverse settings.

3. Meaning and Need of Compound Fabric

A compound material refers to a composite entity comprising two or more distinct things or substances harmoniously blended to form a cohesive whole. Similarly, in the realm of textiles, a compound fabric structure signifies the combination of two or more types of structures to create a unified product. Traditionally, a single structure is employed in the creation of a textile product, chosen based on the specific parameters and requirements dictated by the intended application. However, there are instances where a single structure may not fully meet all the desired criteria for a particular product, leading to the need for a more versatile solution – the compound fabric. The concept of compound fabric structures becomes invaluable when a product necessitates diverse structural attributes in different areas. For instance, a garment might require enhanced durability in certain regions while demanding superior crease recovery capabilities in others. The compound fabric structure offers a flexible and tailored approach to address these specific and often contrasting requirements within a single product. Combining different fabric structures, manufacturers can create textiles that exhibit a bespoke blend of properties, effectively solving the challenge of customizing products to meet multifaceted demands. This versatility is particularly advantageous in the textile industry, where diverse applications and performance criteria coexist. The compound fabric structure thus emerges as a strategic solution, allowing for the optimization of textile products to cater to the varied and nuanced needs of consumers and industries alike.

3.1 Benefits of Fabric compounding

3.1.1 Synergizing Properties

Fabric compounding, the combinations of two different types of fabrics, offers a unique advantage by synergizing their properties. When distinct fabrics are combined, their individual strengths can complement each other, resulting in a final fabric that exhibits a harmonious blend of desirable characteristics. For instance, if one fabric provides excellent durability but lacks in terms of softness, compounding it with another fabric that offers superior comfort can create a composite material that excels in both durability and softness. This synergy enhances the overall performance and functionality of the fabric, making it a versatile choice for various applications.

3.1.2 Economical Fabric Production

Fabric compounding is employed strategically to produce textiles that are not only versatile but also economical. By combining the aesthetic and comfort properties of one fabric with the structural or performance characteristics of another, manufacturers can create a fabric that meets specific requirements without compromising on cost-effectiveness.

3.1.3 Weight Reduction

Another significant benefit of fabric compounding is the ability to reduce the weight of the fabric without compromising its essential characteristics. Through a thoughtful combination of different fabrics, it becomes possible to create a composite material that retains all the desirable properties while being lighter in weight. This is particularly advantageous in industries where lightweight textiles are preferred, such as in sportswear or outdoor gear. The reduction in weight enhances the comfort and wearability of the fabric without sacrificing the integrity of its key attributes [8].

3.2 Ways to Create Compound Fabric

The process of fabric compounding unfolds through a countless of possibilities, exploring numerous permutations and combinations to achieve diverse textile outcomes. Even within the context of just two basic fabric structures, such as woven and weft-knitted structures, the potential for compounding expands significantly. In this scenario, compounding can occur in multiple dimensions, including length wise, width wise, and layer wise configurations, each yielding distinct fabric characteristics. Fig. 4 and Fig. 5 visually represents the outcomes derived from the combination of woven and weft-knitted materials.

i. Lengthwise Compounding

In lengthwise compounding, the woven and weft-knitted structures are combined along the length of the fabric. This integration allows for the creation of fabrics with a continuous blend of characteristics spanning the entire length. The resulting textile may exhibit properties derived from both structures, offering a balanced combination of strength, flexibility, and other attributes along the length of the fabric.

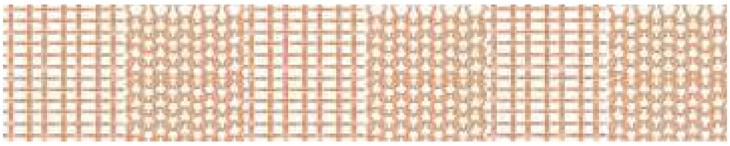

Figure 4 - Lengthwise Compounding

ii. Width wise Compounding

Conversely, width wise compounding involves the incorporation of woven and weft-knitted structures across the width of the fabric. This lateral integration allows for the juxtaposition of the two structures side by side. The width wise compounding technique is advantageous in tailoring fabric properties to suit specific areas of the garment, contributing to a fabric with localized characteristics optimized for functions.

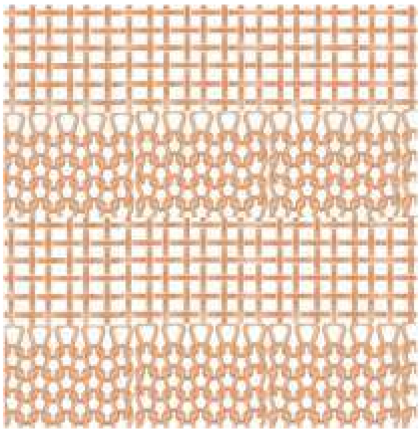

Figure 5 - Widthwise Compounding

iii. Layer wise Compounding

Layer wise compounding takes fabric complexity to another level by combining woven and weft-knitted structures in layers. Each layer contributes unique attributes, and the stacking of these layers creates a composite fabric with a multifaceted performance profile. This approach is particularly valuable in achieving a nuanced combination of properties such as insulation, moisture-wicking, and durability, layer by layer. Fig. 6 serves as a visual representation of the innovative possibilities arising from the combination of woven and weft-knitted materials.

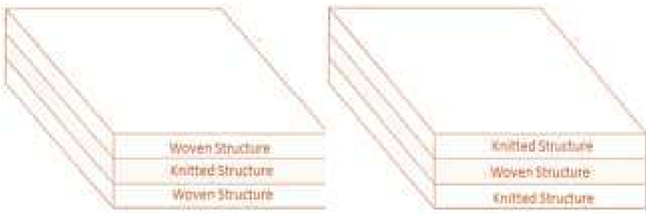

Figure 6 - Layer wise Compounding

Through strategic compounding, fabric engineers can craft textiles that not only exhibit a harmonious fusion of structural elements but also cater to specific and customized requirements across different dimensions of the fabric. This approach underscores the versatility and adaptability offered by fabric compounding in tailoring textiles for diverse applications.

3.3 Factors to Fix at Compounding

The process of compounding woven, and knitted structures is not merely a union of materials but requires a meticulous optimization of various factors to ensure a seamless integration and enhance the overall performance of the fabric. Several critical considerations come into play during this optimization process, emphasizing the need for precision and expertise.

a). Seams and Stitches

Achieving a harmonious fusion between woven and knitted structures involves careful attention to seams and stitches at the joining points. The choice of stitching techniques and seam types becomes crucial to maintain the structural integrity of the compounded fabric. This optimization ensures that the transition between woven and knitted segments is smooth, minimizing any potential weaknesses at these interfaces.

b). Fabric Strip Length

In lengthwise and width wise compounding, the optimization of fabric strip length is paramount. The length of each strip must be calculated to facilitate a seamless integration of the woven and knitted structures. This optimization prevents uneven tension, distortion, or misalignment in the compounded fabric, contributing to a uniform and well-balanced product.

c). Thickness in layer wise Compounding

For layer wise compounding, where woven and knitted structures are combined in layers, optimizing the thickness of each layer is essential. This involves a precise control of the layer dimensions to achieve the desired overall thickness of the compounded fabric. Striking the right balance ensures that the fabric meets specific requirements for applications such as insulation, moisture management, or comfort.

d). Thread Ticket Number and Needle Selection

The ticket number of the thread and the choice of needle are critical aspects of the optimization process. These elements impact the strength, flexibility, and overall quality of the stitched seams. Selecting an appropriate ticket number and needle type ensures that the compounded fabric maintains its structural integrity, with stitches that endure wear and tear while contributing to the fabric's overall performance.

By optimizing these parameters, fabric engineers and manufacturers can enhance the efficacy of compounded fabrics. The careful consideration of seams, strip lengths, thickness, thread characteristics, and needle selection collectively contributes to the creation of a fabric that not only combines woven and knitted structures effectively but also meets the specific performance requirements of the intended application. This optimization process underscores the precision and expertise required in achieving the desired outcomes in compounded fabric manufacturing.

4. Care to be Taken While Stitching Compound Fabric

4.1 Seam Balancing

A seam, defined as a joint created by stitching together two or more pieces of material, plays a pivotal role in determining the strength and efficiency of a fabric. Achieving balance in a seam is imperative to ensure optimal performance. In the context of compounding woven and knitted structures, maintaining seam equilibrium becomes even more critical due to the inherent differences in the characteristics of these materials.

4.2 Precautions for Stretchable Fabric

When stitching together woven and knitted structures with the same seam length, special precautions are warranted, particularly concerning the stretchability of knitted fabric. Knitted fabrics have the propensity to stretch, which can lead to defects such as seam puckering and waviness. To counteract this, a walking pressure foot, capable of stabilizing the seam, should be selected. If attaching a walking foot to the machine is unfeasible, preliminary testing at the raw fabric stage is advisable. The arrangement of knitted fabric on top of the woven, or vice versa, should be explored to mitigate potential stretching issues.

4.3 Addressing Stability Challenges

An additional challenge arises when the knitted fabric lacks sufficient stability to support the weight and drape of the woven fabric without undesirable pulling at the seam. This issue can be rectified by adding stabilization to the seam. Incorporating an elastic strip, matching the width of the bodice, along the seam provides additional structure, ensuring stability and preventing unattractive distortions.

4.4 Preventing Fraying and Finishing Seams

The combination of woven and knitted fabrics may introduce another concern – woven fabric fraying. Unlike knitted fabric, woven fabric is susceptible to fraying. To address this, it is imperative to finish the seam after stitching the fabrics together. Alternatively, finishing the edge of the woven fabric with pinking shears before stitching it to the knit serves as a preventive measure against fraying.

The compounding of woven and knitted structures requires a meticulous approach to seam construction. Balancing the seam for strength, addressing stretch-related challenges, ensuring stability, and preventing fraying are essential considerations. These precautions not only enhance the structural integrity of the compounded fabric but also contribute to the overall success of the manufacturing process [9].

5. Conclusion

Compound fabrics offer multifaceted benefits and versatile applications in textile engineering, outperforming single-component fabrics due to diverse fibre and structure synthesis. Understanding their structures, creation methods, and care is crucial. Adherence to proper stitching techniques and stability management ensures durability. Future research and innovation in fabric compounding will advance textile possibilities with enhanced properties.

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Gamcha of Bankura – A Traditional Craft in Handlooms

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Abstract:

The craft of making gamcha in handloom has been practised by the 'Tanti' community in Bankura, West Bengal, and has seen a decline in demand due to increased raw material costs, poor wages, use of synthetic yarn, and lower market prices. The lack of education among artisans, the use of banned dyes and chemicals, and limited product variety have also contributed to the decline. However, the industry has strengths such as excellent weave quality, inherited craftsmanship, and lower capital requirements. A SWOT analysis reveals advantages and disadvantages, offering opportunities for designers to improve the industry while preserving the essence of gamcha in diversified products.

Keywords: *Bankura, Craft, Gamcha, Handloom, Weaving, West Bengal*

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1. Introduction :

The handloom sector can create employment generation opportunities amongst rural people and contribute nearly 15% of the total cloth production. According to the Ministry of Textiles, Government of India, Annual Report 2018–2019, 95% of the world's handwoven fabric comes from India. According to the 4th All India Handloom Census, 28.2 lakh handlooms operate across India. The average number of weavers per household in rural and urban areas is 1.04 and 1.10, respectively [1]. West Bengal, Tamil Nadu, Andhra Pradesh, Assam and Tripura account for over 78.6% of the country's handloom saree production.

Most of the problems the handloom industry faces are perpetual and this sector has been seriously threatened by a sharp rise in yarn, dye, and chemical costs [2]. The share of income through handloom weaving in West Bengal has decreased, indicating considerable occupational diversification among the artisans engaged in handloom weaving. Numerous studies on the diverse facets of the handloom industry have been compiled by academics, Central and State Government agencies, and Research organisations [3-6].

The craft of making gamcha has been practised for a very long period in the Bankura district of West Bengal. The 'Tanti' communities of Kenjakura, a village located in the Bankura-I block and Rajogram, near the main town of Bankura, are mainly engaged in this craft for a long time. In earlier days, the majority of villagers were involved in this textile craft. But now, the whole scenario has changed, and most artisans are ready to choose another source of income to sustain their livelihood. The artisans of Rajogram village quickly change their profession of gamcha making to other professions. However, because of distance and communication, the artisans of Kenjakura village continue this craft and prefer to weave the traditional gamcha to maintain their way of life.

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The gender-wise role of making gamcha in the Kenjakura village is based on the workload of that specific job to produce a gamcha. Generally, the male members of the village are doing heavier works, such as 'Punni kara' (Creeling), 'Charka gutano' (Ball warping), 'Dhal gutano' (Beaming) and 'Tant bandha/ Tant bona' (Weaving) and sometimes, they have also engaged in allied activities viz., 'Suto bulano' (Yarn winding), 'Khi porano' (Drafting), 'Sana gatha' (Denting) and 'Noli pakano' (Pirn winding). Previously, the dyeing was also performed by the male members of the family. The female members of the family are doing lighter works such as 'Suto bulano' (Yarn winding), 'Khi porano' (Drafting), 'Sana gatha' (Denting) and 'Noli pakano' (Pirn winding). Sometimes, they are involved in 'Tant bandha/ Tant bona' (Weaving) operations to help their male counterparts.

The working hours for making gamcha vary based on gender and roles in the family. Male family members work from 5 a.m. to 10 a.m., then engage in other work. They rest for half an hour before completing the warping, drafting, and denting processes. Female family members work during their leisure time. In the morning, they are engaged in their household activities, such as cleaning the house, making food for family members, etc. Then in the afternoon, after getting a short rest, like male members, they are engaged in weaving and other work such as pirn winding up to the evening. However, when the workload increased, they used to weave and do the pirn winding in the evenings until 8 p.m.

2. Handwoven Gamcha

Since the beginning, the gamcha of Bankura has been used in various cultural, social, and economic functions. The primary function of this gamcha is as a bath towel. In addition, these are used for a variety of other purposes, including birth rituals, marriage rituals, death rituals, puja, etc. Occasionally, farmers and daily workers use this gamcha as headgear for carrying food items. In the past, this gamcha was also worn as a lungi and given as a gift. This is also used to make Punjabi, sari and blouses, along with other garments.

3. Raw Materials

3.1 Yarn

Cotton of various counts ranging from 2/40 Ne, 17 Ne, 2/17 Ne, 40 Ne, 60 Ne, and 2/60 Ne is used for making the gamcha. 2/40 Ne is generally used as the warp yarn. The yarns are sold to the market in the 'Bundle' form. The cost of yarns varies depending on the colour and fineness. Table 1 shows the cost of dyed yarn according to count.

Table 1 - The Cost of Different Counts of Dyed Yarn

Colours	Cost/Bundle (Rs.)		
	17 Ne, 2/17 Ne	2/40 Ne	40 Ne, 60 Ne, 2/60 Ne
Red	160	168	180
Purple	145	158	167
Green	220	240	280
Blue	285	315	400
Golden yellow	140	140	140
Mustard yellow	140	140	140
Pink	140	140	140
Parrot green	247	260	275
White (Bluing agent)	90	90	90

3.2 Dye

In earlier days, cotton yarns were purchased from Barabazar, Kolkata. Then those yarns were processed for dyeing by the Tanti family members in their village. But. presently, the yarns are purchased from the Barabazar by some agents of Bankura's main town. Then those yarns are processed in Rajogram village and other parts of Bankura, for dyeing purposes. After that, those yarns are sent back to the same agents. Those dyed cotton yarns are purchased by the Tanti from those agents. There are several colours, viz., red, purple, blue, green, golden yellow, mustard yellow, pink, parrot green, and white, are being used for making the gamcha. The red, purple, and pink colours are produced from naphthol, whereas the blue, green, golden yellow, mustard yellow and parrot green colours are obtained from vat dye. The white colour is bleached yarns treated with a bluing agent. The artisans called this naphthol colour 'Kachha Rong' and the vat colour 'Pakka Rong'. Among these colours, red, purple, blue, and green are the most commonly used.

3.3 Tools and Equipment

Figure 1 depicts various tools and equipment used for producing hand-woven gamcha.

Tool 01 - Hook used for passing the warp yarns from one side of the heald eye to another side of the heald eye

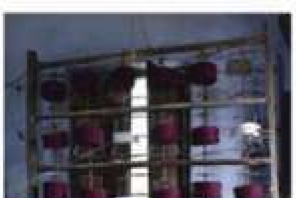
Tool 02 - Picking grip used to transfer the shuttle from one side of the selvage to another side of the selvage

Tool 03 - Pirn used for winding and passing the pick yarns

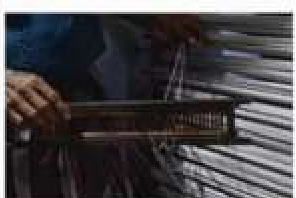
Equipment 01 - Charkha used for winding the yarns

Equipment 02 - Hand driven winding machine used for winding the yarns

Equipment 03 - Bobbins used for creeling



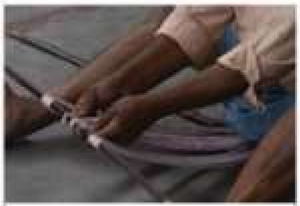
Equipment 04 - Creel used for creeling



Equipment 05 - Reed used for denting at the time of Peg warping

Equipment 06 - Peg warping device used for primary warping

Equipment 07 - Latay used for ball warping



Equipment 08 - Lease rod used for forming a rectangular tunnel at the time of warping

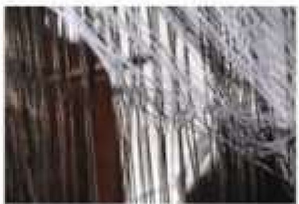
Equipment 09 - Reed used for primary denting

Equipment 10 - A weight mechanism used for warping on the weavers beam

Equipment 11 - Weavers beam (Dhal) used for rolling the warp yarns

Equipment 12 - Weavers beam used for warping

Equipment 13 - Heald shafts used for making shed at the time of weaving

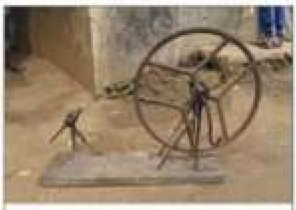


Equipment 14 - Heald eyes used for drafting

Equipment 15 - Reed used for final denting

Equipment 16 - Shuttle used for picks insertion from one selvage to another selvage

Equipment 17 - Paddle used for changing the heald shaft by leg



Equipment 18 - Charkha used for pirn winding

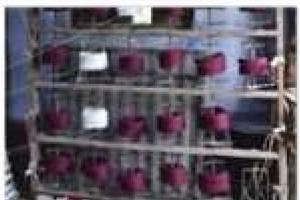
Figure 1: Various tools and equipment used

4. Flow Chart of the Processes

Figure 2 shows the different stages of making hand-woven gamcha through a flow chart.

Process 01 - Conversion of the dyed cotton hank leases to the small leases. And the process is called 'Yarn winding'.

Process 02 – By tie-upping those small leases and send those leases to the further processing of creeling.



Process 03 - Then those small leases are placed on so many small charkis called Bobbins, are placed on a rectangular wooden frame called a Creel. And the process is called 'Creeling'.

Process 04 - Then after creeling another process is carried out by passing the warp yarns coming from those bobbins through a reed made up of bamboo cane.

Process 05 – After that, a primary warping procedure is performed by winding the warp yarns coming from those bobbins onto a rectangular wooden frame called the Peg warping device. And the process is called 'Denting for peg warping'.

Process 06 – From that peg warping device, the yarns are collected with the help of a conical roller called a 'Hand Driven Winding Device'.

Process 07 – From that hand-driven winding device, the yarns are collected and rolled to make a ball-like structure called a Ball warp with the help of that hand driven winding device.

Process 08 – Then that ball warp is ready for further processing of primary denting.

Process 09 – From that ball warp, a rectangular tunnel is being formed with the help of a wooden rod called the Lease rod.

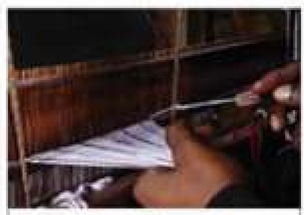
Process 10 – Then those tunnel-formed yarns are passed through a bamboo cane-made reed. This process is known as 'Primary denting'.

Process 11 – After denting those warp yarns are rolled on a wooden roller called Weaver's beam. This process is known as 'Beaming'.

Process 12 – After beaming, the weaver's beam is being placed on the frame loom.

Process 13 – Then the warp yarns are separated with the help of that lease rod and passed for the further processing of warping.

Process 14 – Then from that weaver's beam, the warp yarns are passed through the heald eyes of the heald shaft with the help of a metallic hook and form a rectangular tunnel. This process is known as 'Drafting'.



Process 15 – After that, a simultaneous process is being performed, i.e., the yarns which are coming from those heald eyes are passing through the dents of a reed. This process is known as 'Final denting'.

Process 16 – Then the final weaving process of making Gamcha has begun.

Process 17 – Parallelly, the wefting yarns are enrolled on the pirns with the help of a charki and a hand-operated charka. This process is known as 'Pirn winding'.

Process 18 – Finally the gamcha is ready for sale.

Figure 2: The different stages of the production process of hand-woven gamcha

5. Production Process

5.1 Warping

The first process of warping starts with the conversion of dyed cotton hanks purchased from the local markets to small leases with the help of boro charki and a hand-driven winding device (Latay). This process is known as 'yarn winding' (Suto Bulano). The female allied members of the family mostly performed this process. Then those small leases are placed on many small charkis on a rectangular wooden frame called a creel (Archi). Those small charkis are called bobbin (Archi charki), and the process is known as 'creeling' (Punni kara). The male allied members of the family perform this job.

Parallelly, a primary warping process is performed by winding the warp yarns from those bobbins onto a rectangular wooden frame called the peg warping device (Punni ara). This process passes those warp yarns through a reed (Punni hata) made of bamboo cane. This process is known as 'denting for peg warping' (Sana gatha). This process helps to decide the width and the length of the final fabric, and it also helps to count the number and colour-wise grouping of the yarns. The male allied members of the family perform this process. The weaver also decides the dimensions of the warp at this stage. Some weavers use a big rotating drum, apart from the peg warping device, for this process. But this drum is placed at a far distance from the weaver's village. So, most people didn't prefer this drum.

Then from that peg warping device, the yarns are collected and rolled to make a ball-like structure called a ball warp (Punni) with the help of a conical roller called a 'hand-driven winding device' (Latay). Presently, it has been modified to a cylindrical roller called 'Lately'. This process is known as 'Ball warping' (Charka gutano). The male allied members of the family perform this process.

After that, from that ball warp, a rectangular tunnel is formed with the help of a wooden rod called the lease rod (Dangi). Then those tunnel-formed yarns are passed through a reed made of bamboo cane. This process is known as 'Primary denting' (Sana gatha). The male allied members of the family perform this process. Then those denting warping yarns are rolled on a wooden roller called a 'Weaver's beam' (Dhal). This process is known as 'Beaming' (Dhal gutano). The male allied members of the family perform this process. Sometimes, this process is done as a commission job by some master craftsperson. Then the weavers' beam is placed on a frame loom for the upcoming processes. Then the warping process is finished, and the weaver's beam is ready for weaving. Figure 3 and Figure 4 show the creeling process and beaming process for warping respectively

Figure 3: Creeling process

Figure 4: Beaming process for warping

5.2 Drafting and Denting

Then from that weaver's beam, the warp yarns are first passed through the heald eyes (Bow) of the heald shaft (frame) with the help of a metallic hook and form a rectangular tunnel. This process is known as 'Drafting' (Khi porano) shown in Figure 5. In this process, one warp yarn passes per one healed eye. This process is performed by both male and female members of the family. After that, a simultaneous process is performed, i.e., the yarns coming from those heald eyes pass through the dents of a reed (Sana). This process is known as 'Final denting' (Sana gatha) depicted in Figure 6. In this process, two yarns pass per one dent in the selvedge section, and one thread in the body section is passed per one. Male and female allied family members also do this process. These two processes require two people at the same time. These two processes are sometimes performed as commission work by master craftspeople. Now the total frame loom is ready for the upcoming processes.

Figure 5: Drafting process

Figure 6: Denting procedure

5.3 Weaving

Then those rectangular tunnels formed by yarns from that reed are attached to a wooden stick called a beam stick (Fupi kathi) which is attached to the cloth roll (Kolloraj) of the frame loom. Then the frame loom is ready for the 'Weaving process' (Tant bandha) shown in Figure 7. The male or female allied members of the family perform this process. In this process, the enrolled pirns (Noli) are passed in between the rectangular tunnel of the warping yarns with the help of a shuttle (Maku). This movement of the shuttle is performed using a wooden handle called the Picking grip (Muthokath / Hatol). Then the newly inserted yarn is transferred to the fell of cloth with the help of a sley (Kol). Then the heald shaft is changed with the help of a paddle (Jhap) attached to each heald shaft. Then again, the weft yarn is passed in between the rectangular tunnels. Then again, the same procedure is being performed. In this way, weaving of the Gamcha is done on a frame loom.

Figure 7: Weaving process

5.4 Pirn Winding

In this process, a set of yarns is required to pass between the warping tunnels for weaving purposes. This set of yarn is known as 'weft yarn'. For this purpose, the weft yarns are placed on the pirns (Noli Khari) with the help of a charki (Boro charki) and a hand-operated charka (Hat charka). This process is known as 'Pirn winding' (Noli pakano) as shown in Figure 8. The male or female allied members of a tanti family perform this process. This process is performed simultaneously with the weaving.

Figure 8: Pirn winding

6. Weaves and their Significance

Bankura gamcha is a yarn-dyed handwoven fabric. All the motifs and patterns are applied to the fabric with the help of weaving. Traditionally, the weavers use Huck-a-back weave, which has the special characteristic of gaining moisture very quickly. Some other weaves used to make this handwoven gamcha are plain weave, honey-comb weave, mixing plain and huck-a-back weave etc. Traditionally, the weavers use these weaves in a certain way such that the weave itself plays the role of a motif, and by repeating those weaves, it plays the role of a pattern. Sometimes, by manipulating the reed no. or, by changing the size of the weave repeat, the weavers try to ornament the gamcha's aesthetical appearance with a specific name of that modified gamcha.

7. Motifs, patterns and their significance

Several motifs and patterns are used in the Bankura gamcha, inspired mainly by the daily used items and the Kenjakura villagers' daily words. Some of the motifs with their patterns are discussed below and shown in Figure 9.

7.1 Dhansis

This motif is inspired by the 'paddy crop'. Paddy is the most grown crop in that village and in Bengali, it is called 'Dhansis'. Traditionally, this motif and its name came verbally from the ancestors of the Tantipara weavers. This motif is generally used in the weft direction of the 'Plain check gamcha' and on the 'Tom-tom plain check gamcha' on a single side. This pattern is created by twisting two different coloured yarns by hand and inserting those twisted yarns in a single direction of the gamcha at the time of picking. This pattern is generally created to differentiate the handloom gamcha from the power loom gamcha.

7.2 Gol Dor

This motif is inspired by the 'round metallic chain'. Traditionally, this motif and its name also came verbally from the ancestors of the Tantipara weavers. This pattern is generally used in the weft direction of the 'Towala gamcha' and on the 'Chera-phara gamcha' on both sides in combination with the Chain pattern and the Cycle chain pattern. This pattern is created by a plain weave.

7.3 Chain

This motif is inspired by the 'metallic chain'. Traditionally, this motif and its name also came verbally from the forefathers of the Tantipara weavers. This pattern is also used on the weft direction of the 'Towala gamcha' and the 'Chera-phara gamcha' on both sides in combination with the Gol dor pattern and the Cycle chain pattern. This pattern is created by a plain weave.

7.4 Cycle Chain

This motif is inspired by the 'chain of a cycle'. This pattern is also used on the weft direction of the Towala gamcha and the Chera-phara gamcha on both sides in combination with the Gol dor pattern and the Chain pattern. This pattern is also produced by a plain weave.

7.5 Baki

This motif is inspired by the 'nature of line orientation as well as from the waves of water'. This pattern is used on both sides in the weft direction of the 'Mukum gamcha' and on the 'Harkum gamcha'. This pattern is created by twill weave.

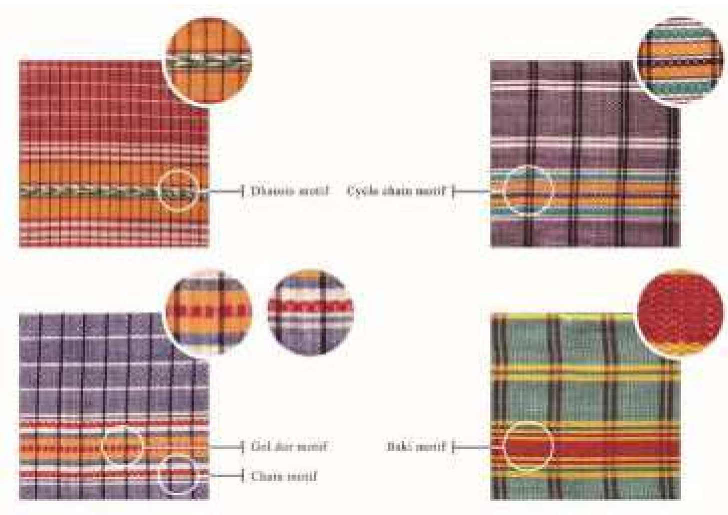


Figure 9: Different famous motifs on different gamcha

8. Reeds and their Significance

There are several types of reeds which are used to make the gamcha of Kenjakura, such as 600 dents per 36 inches (Reed count – 33s stock port), 625 dents per 36 inches (Reed count – 35s stock port), 650 dents per 36 inches (Reed count – 36s stock port), 675 dents per 36 inches (Reed count – 38s stock port), 700 dents per 36 inches (Reed count – 39s stock port).
The most commonly used reed count is 36s stock ports, i.e., 650 dents per 36 inches. Reed counts vary based on the specific requirements of the buyer.

9. Colours and their Combinations

The colours used for making the gamcha are red, purple, blue, green, golden yellow, mustard yellow, pink, parrot green, and white. Generally, the combinations are made from red, purple, blue, green, golden yellow, and white colours. Nowadays, some extra colours are added to enhance the aesthetic value of the gamcha.

10. Yarns and their Combinations

Cotton is the most commonly used yarn for making the gamcha. Several yarn combinations are being developed for the production of gamcha and other diverse products. Table 2 shows some of these products and yarn combinations.

Table 2 - Yarn Combinations for Different Products

Warp (Ne)	Weft (Ne)	Type of product
2/40	17	*Gamcha*
2/60	60	Saree and Stoles
2/17	17	Curtain, Hand towel, Table runner, Cushion cover
17	17	Santhal saree (Here, the warp yarns are used by sizing with the rice extracted from the water, or Sabu dana)
2/40	40	Stole

11. The Layout of the Gamcha

The layout of Kenjakura's handmade gamcha varies from one gamcha's type to another gamcha's type, and the size of the gamcha varies from customer to customer. Apart from these, the other design elements are the same for a single type of gamcha. The most commonly used sizes of the gamcha fabric are 70/32 inches and 86/32 inches. Apart from these two popular sizes, several other options are also available, i.e., 70/30 inches, 70/31 inches, 80/30 inches, 80/31 inches, 80/32 inches, 86/30 inches, 86/31 inches etc. Traditionally, the craftsmen call this 70-inch gamcha 'Char hat gamcha' and the 86-inch gamcha 'panch hat gamcha'. For 'Baby towel gamcha, the options are 52/30 inches, 52/31 inches, 52/32 inches, 61/30 inches, 61/31 inches, and 61/32 inches.
For puja purposes, the most commonly used sizes of the gamcha are 44/30 inches, 44/31 inches, and 44/32 inches.

12. Types of Kenjakura's Handmade Gamcha

There are several types of gamcha which are available in the Kenjakura village. The weavers of Kenjakura village can make about 10 types of gamcha, such as 'Plain check gamcha', 'Tom-tom plain check gamcha', 'Towala gamcha', 'Chera-phara gamcha', 'Mukum gamcha', 'Harkum gamcha', 'Choto phul gamcha', 'Boro phul gamcha', 'Bibi dial gamcha' and 'Honeycomb gamcha'. From these gamchas, the most popular and well-known gamcha are 'Plain check gamcha' and 'Towala gamcha'.

Figure 10: Different types of famous handloom gamchas of Kenjakura village

12.1 Plain Check Gamcha

Figure 11: Plain check gamcha

Plain check gamcha (Figure 11) is the second most sold-out gamcha after Towala gamcha in the Kenjakura village. It is also a very well-known gamcha in the whole of West Bengal. It is famous for its design elements like colour, texture, pattern, and weave. It is generally available in 4 colour combinations, i.e., 'red with white', 'purple with white', 'green with white', 'blue with white' and sometimes it is available in a 'golden yellow with white' colour combinations.

Plain check gamcha is generally made up of 2/40 Ne yarn in the warp direction in combination with the 17 Ne yarn in the weft direction. The drafting and denting plan for the selvedge section is maintained by using 1 end per 1 heald eye of the heald shaft and 2 ends per 1 dent of the reed. For the body part, the drafting plan is the same as the selvedge section, but for the denting purpose, 1 end is passed per 1 dent of the reed. Generally, 2 heald shafts are used for making this Plain check gamcha, and the reed count varies from 38s stock ports to 40s stock ports depending on the width of the gamcha.

The whole part of the Plain check gamcha will consist of mainly two parts, i.e., the selvedge and the body part. Again, the selvedge part of the plain check gamcha will consist of several factors with their specific names and denting orders, i.e., 'Agari consists of 10 dents', followed by 'Koni consists of 6 dents', 'Parh consists of 20/22/25 dents (based on the width of the gamcha)', 'Gondi consists of 24 dents', 'Churi consists of 6 dents' and 'Matha pati consists of 15 dents'. The body part will consist of two parts, i.e., 'Toila pati consists of 15 dents', followed by the 'Check consists of 2 dents and this pattern of Toila pati and Check will continue for the whole body. Then again, this pattern will end up with the selvedge portion starting with Matha pati after completing 62 numbers of Toila pati (which also depends on the width of the gamcha). So, the total number of Toila pati and Matha pati on a single Plain check gamcha will be 62+2=64.

Theoretically, Matha pati and Toila pati will form a square on the gamcha, which means if Matha pati and Toila pati, 15 dents are present, it means the total number of yarns present in Matha pati and Toila pati is also 15 yarns; so, at the time of weft insertion, the total number of yarns should be 15 yarns. But practically it doesn't happen. The weavers usually insert the picks according to their eye resemblance.

On a single side of the Plain check gamcha, one pattern is created by twisting two different coloured yarns crossly by hand and inserting those twisted yarns in a single direction of the gamcha at the time of picking. This pattern is generally created to differentiate the handloom gamcha from the power loom gamcha. The motif of this pattern is called 'Dhansis'. This motif is inspired by the 'Paddy crop'. As paddy is the most grown crop in the Kenjakura village and Bengali it is termed as 'Dhansis'. Traditionally this motif and its name came verbally from the forefathers of the Tantipara weavers. The layout of the plain check gamcha is shown in Figure 12.

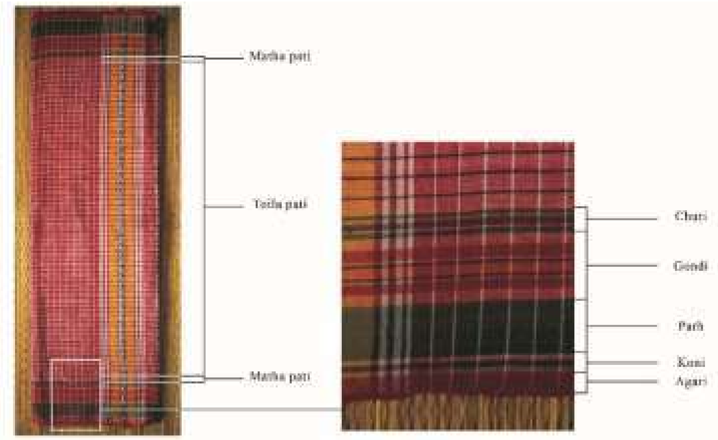


Figure 12: Layout of plain check gamcha

Technical sheet

- Weaving plan drawing
- Loom used – Frame loom
- Name of the weave – Plain weave
- No. of heald shafts – 02
- Reed count – 38s stock port to 40s stock ports (depending on the width of the gamcha)
- Count of warp – 2/40 Ne
- Count of weft – 17 Ne
- Drafting plan - 1 end per 1 heald eye (in both the selvedge portion and the body part)
- Denting plan - 2 ends per 1 dent (in the selvedge portion), 1 end per 1 dent (in the body part)
- EPI – 40
- PPI – 44

12.2 Towala Gamcha

Towala gamcha as shown in Figure 13, is the most popular gamcha in the whole Kenjakura village. It is the most famous and well-known gamcha not only in the Kenjakura village or, in the Bankura district, but it is famous throughout the West Bengal, and it is called 'Bankura gamcha.' It is well-known for its design elements such as colour, texture, pattern, weaves, and its most important parameter, i.e., it has a very high moisture regain property. It is generally available in 4 colour combinations, i.e., red with white, purple with white, green with white and blue with white and sometimes it is available in a golden yellow with the white colour combination. Its good moisture regains property; texture and pattern are enhanced by its famous weave, i.e., Huck-a-back weave in combination with a plain weave.

Towala gamcha is generally made by using 2/40 Ne yarn in the warp direction in combination with the 17 Ne yarn in the weft direction. The drafting and denting plan for the selvedge section is maintained by using 1 end per 1 heald eye of the heald shaft and 2 ends per 1 dent of the reed. For the body part, the drafting plan will be the same as the selvedge section but for the denting purpose, 1 end is passed per 1 dent of the reed. Generally, 4 heald shafts are used for making this Towala gamcha, and the reed count will vary from 38s stock ports to 40s stock ports depending on the width of the gamcha.

The total part of the Towala gamcha will consist of mainly two parts, i.e., the selvedge part and the body part. Again, this selvedge part of the Towala gamcha consists of several parts with their specific names and denting orders, i.e., 'Agari consists of 10 dents', followed by 'Koni consists of 6 dents', 'Parh consists of 20/22/25 dents (based on the width of the gamcha)', 'Gondi consists of 24 dents', 'Churi consists of 6 dents', and 'Matha pati consists of 30 dents'. This selvedge portion is made up of Plain weave. The body part consists of two parts i.e., 'Toila pati consists of 30 dents', followed by the check consists of 4 dents, and this pattern of Toila pati and Check will continue for the whole body. Here the Toila pati is made up of Huck-a-back weave and the check portion is made up of plain weave. Then again, this pattern will end up with the selvedge portion starting with Matha pati after completing 26 numbers of Toila pati (which also depends on the width of the gamcha). So, the total number of Toila pati and Matha pati on a single Towala gamcha will be 26+2=28.

Earlier it was measured that if the number of 2 floats (2 Phul) present on the Toila pati section (generated due to Huck-a-back weave) is 18, then the warp yarns present on that single Toila pati section will be 30 (which also depends on the width of the gamcha). The same number of warp yarns is also present in the Matha pati section, but the differentiating part is that it is made up of plain weave only.

Theoretically, Matha pati and Toila pati will form a square on the gamcha, which means if in Matha pati and Toila pati, 15 dents are present, it means the total number of yarns present in Matha pati and Toila pati is 15 yarns; so, at the time of weft insertion, the total number of yarns should be 15 yarns. But practically it doesn't happen. The weavers usually insert the picks according to their eye resemblance. On two sides of the Towala gamcha, one pattern is created with the combination of some designed motifs termed 'Gol dor', 'Chain' and 'Cycle chain'. In total, this combined pattern is called 'Dor'. The layout of a towala gamcha is shown in Figure 14.

Figure 13: Towala gamcha

Figure 14: Layout of towala gamcha

Technical sheet

- Weaving plan drawing
- Loom used – Frame loom
- Name of the weave – Huck-a-back weave, Plain weave
- No. of heald shafts – 04
- Reed count – 38s stock port to 40s stock ports (depending on the width of the gamcha)
- Count of warp – 2/40 Ne
- Count of weft – 17 Ne
- Drafting plan - 1 end per 1 heald eye (in both the selvedge portion and the body part)
- Denting plan - 2 ends per 1 dent (in the selvedge portion), 1 end per 1 dent (in the body part)
- EPI – 40
- PPI – 42

13. The Production Cost of the Gamcha

The production cost of Kenjakura's handcrafted gamcha varies from one type to another. The cost of manufacturing a single gamcha is estimated by comparing the cost of its 18-inch length shown in Table 3.

Table 3: The production cost of different types of gamcha

Name of the *gamcha*	Length of the *gamcha* (in inches)	The cost of that specific length (Rs.)
Plain check gamcha	18	11
Tom-tom plain check gamcha	18	11
Towala gamcha	18	12
Chera-phara gamcha	18	15
Mukum gamcha	18	18
Harkum gamcha	18	19
Choto phul gamcha	18	12
Boro phul gamcha	18	11
Bibi dial gamcha	18	18
Honeycomb gamcha	18	18

14. The Present Condition of the Craft

This is a conclusive piece based on the observation and interaction with artisans in the Kenjakura village.

- The number of genuine practitioners of traditional handloom weaving is decreasing day by day. Thus, slowly, the handloom sector is coming to an end.
- Government subsidies are not reaching the ground level of artisans properly. Most of them are not aware of any government subsidy.
- The artisans are mostly uneducated, so they fail to produce crafts more effectively or learn about government policies and benefits.
- The cost of raw materials has increased, but the remuneration of weavers and the selling price of woven goods have not increased.
- The younger generation is not allowed to participate because of the current market conditions. They are losing interest in learning or following traditional weaving over time.
- The lifestyle, in general, is very slow-paced, and the work environment is extremely informal.
- Product diversification is limited.
- Due to the increase of mill-made gamcha in the market, the demand for handloom gamcha is becoming very low.
- The artisans are finding another source of income for their basic needs, which can't be fulfilled by weaving the gamchas.

15. Conclusion

Previously, Bankura gamcha enjoyed a very good market throughout West Bengal. However, as a result of commercialisation, the competition between mill-made gamcha is increasing day by day. The common people were influenced to choose mill-made gamcha due to their inability to identify the exact handloom product and their desire to purchase a cheaper one. This issue can be resolved if there is a proper marketing strategy and channel to sell the products. Artisans sell this gamcha alongside other textile items because handloom gamcha do not generate as much revenue on the market. Based on the interactions with the artisans and after a detailed survey, the following measures can be taken to improve this traditional craft:

- Measures must be taken to educate the younger generation on traditional gamcha weaving techniques.
- It is necessary to generate demand among local residents and make them aware of this traditional craft and its cultural significance and value.
- Provide incentives for artisans to visit government centres for proper training and instruction on how to increase their rate of productivity and profit.
- Craftsmen could be instructed to lead workshops for schools, summer camps, etc. This could assist them in

promoting their craft, generating income, and encouraging others to learn and continue the craft traditions.

- Product diversification should go beyond the gamcha to reach a broader range of consumers.
- The middleman who purchases woven products from artisans and sells them on the physical market, can open online stores to reach a broader consumer base.
- Conducting a public education campaign to obtain the GI Tag and Handloom Mark for this handwoven gamcha.
- According to the current situation, the major threat to the traditional gamcha weaving craft is the growing demand for gamcha woven on power looms. Ordinary people typically cannot tell the difference between the two, and they are willing to pay less for gamcha produced by that mill. If these factors can be managed, then the market demand for Bankura's traditional handwoven gamcha will increase significantly.

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Recent International Trade Agreements: Opportunities and Challenges for Global Businesses

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Bharat Trivedi is an experienced international trade and export management professional with an MBA in International Trade from the International School of Business Management and a Master of Commerce degree from North Maharashtra University.

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Introduction

International trade agreements serve as the backbone of global commerce, shaping the interconnectedness of economies worldwide. These agreements establish the rules and regulations governing trade relations between countries, providing both opportunities and challenges for businesses operating in a globalized marketplace.

In this article, we explore the various dimensions of international trade agreements, delving into the opportunities they present as well as the challenges they pose for businesses operating across borders.

Recent Trade Agreements

- India-Mercosur PTA. (06 JUNE 2024) - The India-Mercosur Preferential Trade Agreement (PTA) is a trade arrangement aimed at fostering economic cooperation and boosting trade between India and the Mercosur bloc. Mercosur, or the Southern Common Market, includes Argentina, Brazil, Paraguay, and Uruguay. The PTA, which originally came into force in June 2009, covers a limited list of products for preferential treatment. The agreement provides tariff concessions to a specified number of goods traded between India and the Mercosur member countries. (Argentina, Brazil, Paraguay, Uruguay and Venezuela. Venezuela became a full member in 2012 but was suspended in 2016 due to non-compliance with Mercosur's democratic norms and other requirements.)
- India-EFTA TEPA. (10 MARCH 2024) - The India-EFTA Trade and Economic Partnership Agreement (TEPA) is a significant trade negotiation effort between India and the European Free Trade Association (EFTA), which comprises Switzerland, Norway, Iceland, and Liechtenstein. The TEPA aims to cover a broad range of trade-related areas, including goods, services, investment, intellectual property rights, and competition policy. It seeks to provide a comprehensive framework for enhancing economic cooperation and trade flows between India and EFTA countries.
- Ind-Aus - ECTA. (30 June 2022) - The ECTA covers a wide array of sectors including goods, services, investment, and intellectual property. It aims to reduce or eliminate tariffs on a substantial number of products, facilitating easier market access for businesses from both countries. Under the ECTA, Australia agreed to eliminate tariffs on over 85% of its tariff lines for Indian goods, including textiles, leather, gems, and jewellery. India, in return, committed to reducing or eliminating tariffs on Australian products such as coal, sheep meat, wool, and wines.

India is also actively engaged in several Regional Trade Agreements (RTAs) with various countries and regional groups to enhance its trade and economic cooperation. Here are some of the key RTAs and ongoing negotiations as listed below:

Existing RTAs: (Regional Trade Agreements)	Scope	Member Countries
India-ASEAN Free Trade Area (AIFTA)	Goods, services, and investment	India and the 10 ASEAN countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam)
India-Sri Lanka Free Trade Agreement (ISLFTA)	Goods	India and Sri Lanka
India-Korea Comprehensive Economic Partnership Agreement (CEPA)	Goods, services, and investment	India and South Korea
India-Japan Comprehensive Economic Partnership Agreement (CEPA)	Goods, services, investment, intellectual property, and other areas	India and Japan
India-MERCOSUR Preferential Trade Agreement (PTA)	India-MERCOSUR Preferential Trade Agreement (PTA)	India and MERCOSUR countries (Argentina, Brazil, Paraguay, Uruguay).
India-Chile Preferential Trade Agreement (PTA)	Limited tariff concessions on selected goods.	India and Chile.
India-UAE Comprehensive Economic Partnership Agreement (CEPA) Signed: February 18, 2022	Goods, services, and investment.	India and the United Arab Emirates.
India-Australia Economic Cooperation and Trade Agreement (ECTA) Effective: June 30, 2022.	Goods, services, investment, and other areas.	India and Australia.

India continues to actively seek new trade agreements and enhance existing ones to bolster its economic ties and expand market access for its goods and services.

Opportunities Arising from International Trade Agreements

Market Access and Expansion:
International trade agreements often aim to reduce barriers to trade, such as tariffs and quotas, thereby facilitating market access for businesses. This expanded access allows companies to tap into new markets, reach a broader customer base, and diversify their revenue streams. For instance, agreements like the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) have opened up lucrative markets across the Asia-Pacific region for participating businesses.

Cost Reduction and Efficiency Enhancement
By harmonizing trade regulations and standards, international trade agreements streamline cross-border transactions, reducing bureaucratic hurdles and compliance costs for businesses. This enables companies to operate more efficiently, allocate resources effectively, and achieve economies of scale. Additionally, agreements like the European Union's Single Market eliminate internal tariffs and facilitate seamless trade among member states, driving cost savings and enhancing competitiveness.

Access to Resources and Inputs
Trade agreements often facilitate the flow of goods, services, and investment across borders, enabling businesses to access critical resources and inputs at competitive prices. Whether its raw materials, skilled labour, or advanced technologies, businesses can leverage international trade agreements to source inputs from global markets, enhancing productivity and innovation. For example, the North American Free Trade Agreement (NAFTA, now USMCA) has facilitated integrated supply chains across North America, benefiting industries such as automotive manufacturing.

Challenges Confronting Global Businesses

Regulatory Complexity and Compliance Burden:
Navigating the diverse regulatory landscapes of different countries can be a daunting task for businesses, particularly small and medium-sized enterprises (SMEs). International trade agreements often entail complex rules of origin, sanitary and phyto-sanitary standards, and intellectual property rights protection, requiring businesses to invest resources in compliance efforts and legal expertise. Moreover, changes in trade policies or geopolitical dynamics can introduce uncertainty and disrupt established business strategies.

Disruption from Trade Disputes and Tariff Escalations
Trade tensions and disputes between countries can escalate rapidly, leading to the imposition of tariffs, retaliatory measures, and trade barriers. Such disruptions can adversely affect global supply chains, increase input costs, and disrupt market access for businesses. For instance, the trade conflict between the United States and China has resulted in tariffs on billions of dollars' worth of goods, causing uncertainty for businesses and dampening investor confidence.

Vulnerability to Political and Economic Instability

Global businesses operating across multiple jurisdictions are exposed to geopolitical risks, economic downturns, and regulatory changes in host countries. Political instability, currency fluctuations, and expropriation risks can undermine business operations and investments, necessitating robust risk management strategies. Moreover, shifts in government policies or leadership changes can alter the business environment unpredictably, requiring businesses to adapt quickly to changing circumstances.

Conclusion

International trade agreements offer significant opportunities for global businesses to expand their market reach, enhance efficiency, and access valuable resources. However, navigating the complexities and challenges posed by these agreements requires careful planning, strategic foresight, and a deep understanding of local regulations and market dynamics. By staying informed, agile, and resilient, businesses can capitalize on the opportunities presented by international trade agreements while mitigating the associated risks, ensuring sustainable growth and competitiveness in the global marketplace.

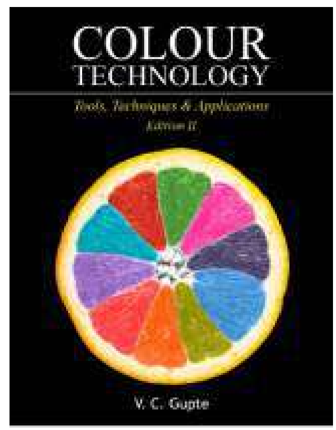
Second Edition book launched

Colour Technology – Tools, Techniques and Applications

Mr. V. C. Gupte

The Second Edition of the book "Colour Technology – Tools, Techniques and Applications' by Mr. V. C. Gupte, Chairman has been launched by TAI Mumbai Unit on May 26, 2024.

The first edition was launched in June 2008. The book was launched by Padma Vibhushan, Dr. Anil Kakodkar, India's greatest nuclear scientist, in a grand function. Mr. Rahul Bhajekar and Mrs. Priya Bhumkar were the other guest speakers who talked about Mr. Gupte's journey into colour science during last 54 years and his contribution to Indian Colour Industry.



The book covers detailed information about the tools (spectrophotometers and different types of colour measuring instruments), the basic colour theory and the applications related Textiles, Garments, Paints, Dyes & Pigments manufacturing and Automobiles, the last two chapters have been added in this edition. Mr. Gupte has covered the latest developments in these fields and hence it should be very useful to the technology students, industrial colourists (who use these systems & techniques in their everyday working) and those interested in understanding basic colour theory. Mr. Gupte is visiting faculty in institutes like ICT, Mumbai, DKTE Institute, Ichalkaranji teaching the subject of Colour Technology and its applications and this book should be useful to all these students.

Mr. Gupte said "There are many books on colour technology, which may be better than this book. However, these books contain a lot more mathematics which the students would like to skip & avoid. There are very few books which cover applications which are not experienced by the industrial colourists. So I wanted to write a book which could generate interest and inspiration for undergraduate student to pursue further education in colour. A book which would help industrial colourist in his day-to-day applications, which should help him in not only handling & solving his shop-floor problems, but also help him in using his colour matching system very effectively. A book, which should help an unskilled colourist in any colour industry. So, I have included minimum mathematical equations and covered applications which are experienced in day-to-day working. In the Second edition, I have maintained 50% matter of the first edition and added the latest developments in the colour theory, colour instrumentation and new applications related to colour, besides two new chapters." The other special thing about the book is every chapter is independent. If any reader wants to read about textiles, he/she can straight open the textile chapter, which should provide him complete information. There is latest information on banned dyes, REACH and SVHC, which should be useful for the dyer, particularly engaged in exports. Mr. Gupte says at the end, "If the readers make full use of the theory and applications in their day-to-day work, I would feel the objective of writing this edition is fulfilled."

Readiness of SMEs in the Indian Textile Industry to Embrace ESG Practices

P. Suganthi[1], S. Jaisankar[1] & P. Nalini[2]

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[2]PSG Institute of Management, Coimbatore

Ms. P. Suganthi

Ms. P. Suganthi is a Textile & Management professional over 11 years of comprehensive experience in Textile production, Textile Research and Management Education. She holds a B. Tech degree in Textile Technology, P. G Diploma in Apparel Production and Management, MBA and pursuing her Phd in Operations and Management. She is currently working as an Assistant Professor in School of Management, Sri Krishna College of Engineering and Technology.

Her specializations include

- Production Management
- Quality and Quality Control
- NABL Audit and Documentation
- Co-authored books on Quality Norms, trends in cotton, research articles on medical textiles.
- Project coordinator for various projects like Quality update on sewing thread, Calibration cotton etc.

She is a member of QCFI, organised 10th National conclave, presented papers and developed case studies in National and International Conferences. She has 8 + years' experience at SITRA with wide expertise on fibre, yarn, fabric testing and knitting and weaving Department. She has also trained national and international candidates on textiles. She had undergone training programs on Proficiency testing (NABL), research study selections and statistical calculations. She also coauthored research paper on “Poisson's Ratio of Non-Woven Spun Bonded Fabric for Medical Apparel” in medical textiles, published in international journal (A1) TEKSTİL VE KONFEKSİYON. Apart from all above she also has implemented TQM work methods, Production planning and control at Cheslind Textiles India Pvt. Ltd. during her tenure.

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Introduction

ESG (Environmental, Social, and Governance) considerations have rapidly ascended to the forefront of global investment priorities. ESG ranks top five for business performance beyond financial metrics. This trend is partly driven by the United Nations' Climate Action initiatives aimed at achieving Net-Zero emissions, coupled with ambitious environmental targets set by nations worldwide.

In 2020, the European Union took a significant step by drafting regulations that require companies to disclose their performance against ESG benchmarks, signaling a move towards transparency and accountability in corporate practices. The textile industry, known for its substantial environmental footprint, is at a critical juncture where integrating ESG principles into its operations mitigate its ecological impact and also enhance its competitiveness in the global market. This article investigates the critical role of ESG in transforming the textile industry, emphasizing the necessity of adopting sustainable practices that align with global sustainability goals, consumer expectations for ethical and responsible production and challenges.

World Indexes

The World Economics ESG methodology developed a composite index based on the average of three indexes: (i) Environmental Factors, (ii) Social Factors, and (iii) Governance Factors. The index is based on a scale of 0-100, where a higher score indicates better resilience towards ESG. According to their data, India scores 60.6 (Grade E) on Environmental Impact, 51.3 on Social Impact (Grade D), and 47.2 on Governance Impact (Grade C).

ESG in Textile Industry

The textile industry process includes fiber production, cleaning, yarn manufacturing, knitting or weaving, dyeing, and garmenting & packaging. Natural fibers are cultivated from farmland and processed, while synthetic fibers. Regenerated fibres involve harmful chemical processing. The conversion process from fiber to fabric consumes significant natural resources, leaves carbon footprints, and creates pollution of air, water, and land.

According to the World Bank, the fashion industry accounts for 10% of global carbon emissions annually and is the fourth highest category for resource and water consumption. The industry uses around 215 trillion liters of water each year, contributing to water pollution with chemicals, cleansing agents, and microfibers. Social concerns within the textile industry include working hours, diversity in leadership, fair wages, job security, discrimination, safe working conditions, and supply chain management. These factors underscore the necessity of considering environmental and social impacts when formulating and executing mitigation strategies.

ESG in the International Scenario - US & Europe

The US aims for a net-zero target by 2050, and the New York State legislature is deliberating on the Fashion Sustainability and Social Accountability Act. This bill mandates clothing companies earning over $100 million in annual revenue to outline and disclose their supply chains and environmental impact. These companies must establish emissions reduction targets based on scientific standards. This disclosure impacts the textile industry of importing nations like India and Bangladesh if ESG compliance is ignored. The textile industry contributes significantly to global environmental challenges, accounting for 8-10% of humanity's carbon emissions.

Europe has emerged as a leader in implementing policies and strategies for sustainable fashion. In 2021, France enacted legislation imposing new requirements on the fashion industry concerning waste prevention, materials reuse, and accountability for environmental claims. The 2023 ESG fashion agenda is anticipated to reshape industry norms and catalyse substantial change, positioning the fashion sector as a crucial participant in the global sustainability movement.

Gearing up with the Global ESG Requirement

Amidst the rising global significance of ESG considerations, the Indian textile sector must meet ESG criteria, particularly in anticipation of forthcoming sustainability mandates from the EU. Given Europe's substantial contribution to India's apparel exports, Indian exporters face pressure to swiftly adjust their practices to adhere to ESG standards, ensuring their competitiveness and continued access to this critical market.

Steps Taken by the Central Government for ESG

At the COP26-Glasgow summit, Prime Minister Narendra Modi pledged to set a net-zero target by 2070. The Securities and Exchange Board of India (SEBI) has introduced Business Responsibility and Sustainability Report (BRSR) guidelines, mandating ESG disclosure from the current financial year. Additionally, SEBI established an ESG advisory committee in May 2022 to enhance BRSR requirements and streamline ESG ratings and investing. The Reserve Bank of India (RBI) issued guidelines in February 2023, encompassing acceptance of green deposits, a disclosure framework on climate-related financial risks, and guidance on climate scenario analysis and stress testing.

Challenges Faced in Implementation of ESG

Medium and Small-Scale Sectors (MSME) and small-scale textile industries are already in financial crisis due to rising cotton prices and electricity charges. Several industries have downscaled operations or closed due to the impact of COVID-19 and rising cotton prices. The awareness of ESG concepts is limited, and small-scale sectors are mostly Scope 3 suppliers, which complicates comprehensive reporting efforts.

Key areas requiring improvement include transparency in raw material sustainability declarations, equitable treatment and statutory benefits for migrant laborers, and ensuring safe working conditions for all workers. Additionally, achieving gender pay parity, enhancing water and waste management, transitioning to renewable energy sources, and adhering to pollution control norms for fly, fluff, and sound pollution are crucial. The industry must also focus on comprehensive effluent treatment, ensuring organic cotton sustainability, improving accident reporting, and complying with safety regulations.

Moreover, significant investments in renewable energy, water consumption management, and implementation of checkpoints to ensure sustainability across business processes are essential for long-term viability. Addressing these ESG-related issues will not only help the textile sector meet global sustainability mandates but also enhance its competitiveness and market positioning in the international arena.

Conclusion

Integrating ESG principles in the textile industry (SME's) is vital for mitigating environmental impacts and ensuring social responsibility. Aligning with global sustainability goals and consumer expectations, particularly in the face of emerging regulations, is crucial for maintaining competitiveness. Addressing challenges through comprehensive reporting, investment in sustainable practices, and adherence to stringent standards will enhance the industry's resilience and market position.

UNITS ACTIVITY

TAI – Mumbai Unit

Hybrid Lecture on
"5S - The First Step to Building a World Class Organisation"

The Textile Association (India), Mumbai Unit organized a Hybrid Lecture on the topic "5S - The First Step to Building a World Class Organisation" in the Conference Room of TAI, Mumbai Unit Office held on 12th April 2024 at TAI, Mumbai Unit Office.

Mr. Rajiv Ranjan, President, The Textile Association (India), Mumbai Unit and Convenor of this lecture, welcomed the speaker and participants to the lecture. Mr. Ranjan in his address briefed about the TAI and its activities and said that Association aims to keep its members abreast of contemporary developments related to the industry in the field of technology and other topics relevant to the industry.

Mr. G. V. Aras, Trustee of The Textile Association (India), Mumbai Unit welcomed the Speaker Mr. Hemendra K. Varma with a bouquet of flowers.



The lecture was addressed by Mr. Hemendra K. Varma, Director, The 5S Institute. He said that 5S has today become an "unstated" mandatory requirement for being qualified to supply goods and services in the international market. Mr. Varma shared his interpretation of 5S and what was required to implement it successfully. He also illustrated through some example & case studies how it can benefit industry in the areas of Safety, Quality, Productivity, Cost Reduction & Response Time reduction. The 5S Institute has implemented 5S in a wide range of organisations from Engineering, Steel, Chemical, Foundry, Ceramic, Banking, Healthcare and even 2 of the country's major High Courts.

Mr. Haresh B. Parekh, Hon. Secretary, The Textile Association (India), Mumbai Unit proposed the Vote of Thanks.

This lecture was appreciated by all with the active participation of all both physically and virtually. The response to the session was very enthusiastic. There was good interaction between the speaker and participants who asked many questions and the same were lucidly answered by the speaker.

Interactive Session with U. S. Consulate General Mumbai

The Textile Association (India), Mumbai Unit has organized an interactive Session with U. S. Consulate General Mumbai on Friday, 18th April 2024 at 02.30 p.m. in the Conference Room of TAI, Mumbai Unit Office.

The followings vice consuls and consulate staff from U. S. Consulate General Mumbai and Office Bearers from TAI, Mumbai Unit were present in the Mumbai.

TAI, Mumbai Unit:

1) Mr. G. V. Aras
2) Mr. V. C. Gupte
3) Dr. V. D. Gotmare
4) Mr. Haresh B. Parekh

U. S. Consulate General Mumbai:

1) Mr. Karen Gilbride (Vice consuls)
2) Ms. Ana Lipscomb (Vice consuls)
3) Ms. Mauricio Parra (Vice consuls)
4) Ms. Esther Lee (Vice consuls)
Mr. Keval Choksi (Consulate Staff)
Mr. Tuzar Mobedji (Consulate Staff)

The object of this interactive session and external training program was a value-added opportunity for officers to observe, interact with, and learn about Textile Industry and thereby facilitate a better understanding of the Mumbai and India contexts in which they serve.

Mr. G. V. Aras, Mr. V. C. Gupte and Mr. Haresh B. Parekh welcomed all the officers from U. S. Consulate General Mumbai for the session.

Mr. Aras, Mr. Gupte and Mr. Parekh gave the introduction of the Association, working of the Association and its activities like conferences, seminars, student's activities, membership, etc.

Mr. Aras gave the overview of the Indian textile industry and also mentioned about the use of textiles in other than apparel like geo-textiles, space, train, aircrafts, etc. termed as Technical Textiles.

Officers inquired about right information about the visit of people from India particularly in context to textile industry which was properly answered by Mr. Aras, Mr. Gupte and other members. Mr. Aras said that people travel to Europe, US for their business, for selling their products or procuring some products. Mr. Aras said that number of exhibitions are organised in different parts of the world and exhibitors as well as visitors wish to attend these of exhibitions for their product promotion, marketing and to know about innovations in the textiles industry, machinery, and other products.

Many apparel makers, machinery manufacturers and textile companies are exporting to U. S. and need to visit there for business purpose. Mr. Aras mentioned that travel for textile business to US is less compared to Europe. U.S. is the biggest market for India particularly for Home textiles, furnishing fabrics, terry towels, bed sheets, etc.

Mr. Aras and Mr. Gupte also gave answer to the question that how to find out genuine visitors to U.S. from India. Mr. Aras and Mr. Gupte said that Exhibitors mostly travel in groups or from their corporate companies through tour & travel companies. Visitors also travel through their companies but in some cases they travel on their own also. In these cases, one needs to check their credentials, purpose of visit, financial backgrounds, qualifications, etc. Many people from educational and research institutes as well as consultants also visit such exhibitions.

Dr. V. D. Gotmare also mentioned that many students from the various textiles and research institutes from India need to apply for visa who wants to travel to U.S. for higher education. Many textile and research institutes also participate in exhibitions all over the worlds and also travel for presentation or attending conferences.

The travel of small Shop Owners makes no sense to travel for exhibitions out of India. There might be rare case where the shop owners want to expand their business or to start their own manufacturing in future, in which cases they may travel to US for knowing more about the market potential for the products, etc.

Mr. Gupte said that many US brands in apparel have their regional offices in India like H & M, Walmart, GAP, etc. This also needs people to travel from India to US.

The meeting was very successful. There was good interaction between the office bearers from Mumbai Unit and Officers from U. S. Consulate General Mumbai who asked many questions and the same were promptly answered by the Mumbai Unit Office Bearers.

Online Meeting with IVL Swedish Environmental Research Institute

The Textile Association (India), Mumbai Unit has organized a online meeting with Dr. Mathias Gustavsson, Senior researcher and project leader, IVLSwedish Environmental Research Institute on Monday, 22nd April 2024 at 10.30 a.m. The followings members were present in the meeting.

- Dr. Mathias Gustavsson, Senior researcher and project leader, IVL Swedish Environmental Research Institute
- Mr. V. C. Gupte, Chairman, TAI, Mumbai Unit
- Mr. Rahul Bhajekar, Trustee & Managing Committee Member, TAI, Mumbai Unit
- Dr. G. S. Nadiger, Vice Chairman, TAI, Mumbai Unit
- Dr. V. D. Gotmare, GC Member, TAI, Mumbai Unit
- Mr. Haresh B. Parekh, Hon. Secretary, TAI, Mumbai Unit

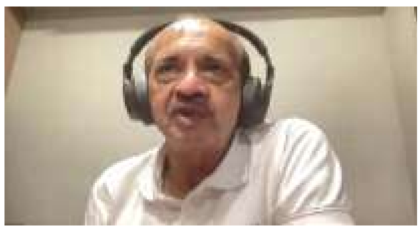
The object of this meeting was to discuss on bi-lateral collaboration (Indo-Sweden) on innovations and research cooperation on reducing microplastics from textile industries. They were of the views that The Textile Association (India), Mumbai Unit could provide important insights in the sector's important work and steps to have a world class textile production that is sold on exports all around the globe. They seen the several initiative of ZLD and sustainable wastewater management and want to discuss more in details.

All the members introduced themselves in the meeting. Dr. Mathias Gustavsson also introduced himself and gave the reason of this meeting.

The meeting was very successful. There was good interaction.

Opportunities & Threats AI poses for MSME textile units

The Textile Association (India), Mumbai Unit organized a Online Lecture on the topic "Opportunities & Threats AI poses for MSME textile units" on 17th May 2024.



Mr. Rajiv Ranjan, President, The Textile Association (India), Mumbai Unit welcomed the speaker and participants to the lecture. Mr. Ranjan in his address briefed about the TAI and its activities. He further said that TAI, Mumbai Unit planned to aggressively work on its Industry Outreach programme during the year 2024 - 25 and he requested the support of all the members to achieve this. As a part of this TAI, Mumbai Unit conducted three activities during this year. He also informed about the Social Media initiative by using LinkedIn & WhatsApp.

The lecture was addressed by Mr. Sharad Tandon, CEO, Standon Consulting. In his presentation he mentioned that AI presents unprecedented opportunities for MSME textile units to optimize operations, enhance customer engagement, and stay ahead in a fiercely competitive market landscape. However, realizing these benefits requires a concerted effort towards workforce upskilling, cybersecurity preparedness, and strategic adoption of AI technologies across all facets of textile manufacturing. By embracing AI, MSMEs can not only navigate the challenges posed by automation but also emerge as industry leaders poised for sustainable growth and innovation. The integration of Artificial Intelligence (AI) into Micro, Small, and Medium Enterprises (MSME) within the textile industry represents a paradigm shift with far-reaching implications. As highlighted throughout this discourse, AI offers a myriad of opportunities for MSME units, from streamlining operations and enhancing productivity to bolstering customer relationships and staying competitive in the global market. However, these opportunities are accompanied by significant challenges, including job displacement, cybersecurity risks, and the imperative need for workforce upskilling.

Mr. Haresh B. Parekh, Hon. Secretary, The Textile Association (India), Mumbai Unit proposed the Vote of Thanks. This lecture was appreciated by all the participants with the active participation of around 80 participants. There was good interaction between the speaker and participants who asked many questions and the same were lucidly answered by the speaker.

Hybrid Session on

Automation of GST Refund for Textile Industry - Traders, Manufacturers and Job Workers

The Textile Association (India), Mumbai Unit in association with MyGST Refund (A brand under Fintaxicorn Solutions) organized a Hybrid Session on the topic "Automation of GST Refund for Textile Industry - Traders, Manufacturers and Job Workers" on 28th June 2024 in the Conference Room of TAI, Mumbai Unit Office.

Mr. Rajiv Ranjan, President, The Textile Association (India), Mumbai Unit welcomed the speaker CA Kapil Mahani with a boueut of flowers. Mr. Ranjan in his address briefed about the TAI, Mumbai Unit activities. He said that TAI, Mumbai Unit planned to aggressively work on its Industry Outreach programme during the year 2024 - 25 and he requested the support of all the members to achieve this. As a part of this TAI, Mumbai Unit conducted five activities during this year. He also informed about the Social Media initiative by using LinkedIn & WhatsApp. I was happy to inform the members that TAI, Mumbai Unit has crossed 8000 followers on LinkedIn.



The session was addressed by CA Kapil Mahani, a qualified Chartered Accountant who shared insights on various aspects of GST refunds pertinent to the textile industry. CAKapil Mahani provided a comprehensive overview of the eligibility criteria for GST refunds specific to the textile sector. Detailed discussions on the various types of GST refunds were conducted, focusing on practical challenges and technological solutions at different stages of the refund process. The session emphasized the importance of leveraging technology to streamline the identification, filing, and verification stages of GST refunds. Real-world case studies were presented to illustrate common issues and their resolutions.

Mr. Haresh B. Parekh, Hon. Secretary, The Textile Association (India), Mumbai Unit proposed the Vote of Thanks.

The session successfully addressed critical aspects of automating GST refunds for the textile industry, offering valuable insights and solutions to enhance efficiency and compliance. The event was well-received, with active participation both in-person and online, reflecting the relevance and importance of the topic to the industry stakeholders. This session was attended by more than 100 participants online. More than 20 viewers joined the live stream on YouTube. There was good interaction between the speaker and participants who asked many questions and the same were lucidly answered by the speaker.

ATTENTION JTA AUTHORS

Journal of the TEXTILE Association

ARICLE PROCESSING CHARGES (APC)

The Textile Association (India) published its Journal of the Textile Association (JTA) since 1940, which is a prestigious bimonthly Peer-Reviewed journal, JTA is available in Print and Digital version available online on TAI Website.

For the benefit of the Authors and wide acceptance of the journal, from March 2024 & onwards, the Editorial Board Committee has decided that the Author has to pay Rs. 5000/- per paper as Article Processing Charges (APC) while submitting the article for the publication in JTA.

The APC needs to be paid online on the below given Bank details and the screenshot of UTR of the same has to be mailed to TAI Office.

Bank Details;

Beneficiary Name: The Textile Association (India)
Bank Name: Bank of Maharashtra
Account Number: 60059709862
Bank Code No.: 400014004
IFSC No.: MAHB0000016

Hon. Editor
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Online Visitor Registration for ITMA ASIA + CITME 2024

Visitors to ITMA ASIA + CITME 2024, Asia's leading business platform for textile machinery, can register their visit online to take advantage of early bird rates. The combined exhibition will be held from 14 to 18 October 2024 at the National Exhibition and Convention Centre, Shanghai, China.

Visitors who pre-register on the combined show websites (itmaasia.com and citme.com) by 13 October will enjoy early bird rates which are at a 40% discount. The early-bird rates are US$9 (RMB 60) for a five-day badge and US$5 (RMB 30) for a one-day badge. Standard onsite rates are RMB 100 for a five-day badge and RMB 50 for a one-day badge.

The combined show owners - CEMATEX and the Sub-Council of Textile Industry, CCPIT (CCPIT-Tex), China Textile Machinery Association (CTMA) and China Exhibition Centre Group Corporation (CIEC) are pleased with the positive response received for space application. Compared to the previous edition, the size of the exhibition is expected to be bigger.

To-date, about 1,700 leading textile machinery manufacturers have applied for space. Among them are CHTC, Cixing, Fadis, Groz-Beckert, Itema, Karl Mayer, Memminger-Iro, Murata, Picanol, Rifa, Saurer, Savio, Shima Seiki, SPGPrints, Staubli, Tsudakoma, Truetzschler, Toyota, Vandewiele and Yoantion.

Mr. Ernesto Maurer, President of CEMATEX said: "The textile industry is undergoing rapid transformation due to factors such as digitalization and sustainability. Automated systems are driving efficiency across fibre processing, yarn production, weaving, dyeing and finishing. Textile machinery manufacturers are excited to promote these technologies at the upcoming ITMA ASIA + CITME exhibition."

Mr. Gu Ping, President of China Textile Machinery Association concurred: "The textile industry is witnessing rapid changes driven by the progress of the Internet and AI technological advancements, and textile processing technologies are also developing rapidly. ITMA ASIA + CITME 2024 will showcase the latest development trends of the global textile machinery sector. We warmly invite buyers to visit the exhibition to source the highest quality and efficient technologies."

Featuring 18 product chapters of the textile-making manufacturing chain, ITMA ASIA + CITME 2024 will showcase a comprehensive range of machinery, from spinning, weaving, knitting, nonwoven, printing and inks, dyeing and finishing, to garment making, recycling, testing and packaging.

The previous edition - ITMA ASIA + CITME 2022 – was successfully staged, grossing over 160,000 square metres of the exhibition venue. It featured more than 1,500 exhibitors from 23 countries and attracted visitor-ship of 100,000 from 105 countries and regions.

ITMA ASIA + CITME is organized by Beijing Textile Machinery International Exhibition Co., Ltd and co-organized by ITMA Services. Japan Textile Machinery Association is a special partner of the combined show. For more information on ITMA ASIA + CITME 2024, please contact:

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ITTA Meeting with Hon'ble Textile Minister

The Indian Technical Textile Association (ITTA) is pleased to announce that we had a highly productive and cordial meeting with the Honorable Minister of Textiles, Shri. Giriraj Singh Ji on 13th June, 2024 in New Delhi. On behalf of ITTA Mr. Avinash Misar, Chairman congratulated and welcomed Shri Hon'ble Shri Giriraj Singh ji.

During the meeting, we extended our warm greetings on behalf of ITTA and provided an overview of our activities and achievements over the past decade in the field of technical textiles. We highlighted our ongoing efforts and innovations, which have significantly contributed to advancements in this sector.

Mr. Avinash Misar. Chairman, ITTA is welcoming Hon'ble Shri Giriraj Singh ji, Textile Minister

Shri. Giriraj Singh Ji shared his insightful vision for the future of technical textiles, emphasizing the importance of

integrating emerging technologies with cost-effective strategies to ensure widespread adoption, particularly in the areas of Agrotech, Geotech, Protective Wear, and Carbon & Glass Fibre.
He underscored the need for innovative approaches that can drive mass dissemination and make a substantial impact.

Furthermore, the Honorable Minister encouraged ITTA's active participation in various governmental interventions and initiatives aimed at fostering growth and development within the industry. His support and encouragement have further strengthened our resolve to continue our mission with renewed vigor.

The meeting was also graced by the presence of Shri. Kumar Priyadarshi IAS, Private Secretary to the Honorable Minister, and Mr. Raman IAS. Their presence and contributions added significant value to the discussions.

ITTA is committed to advancing the technical textiles sector and will diligently work towards the goals outlined during this esteemed meeting. We look forward to collaborating closely with the Ministry of Textiles and other stakeholders to drive innovation and growth in the industry.

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Trützschler service goes digital

Everybody has felt the pain of digital tech that creates more problems than solutions – but our new service will make sure that won't happen to you. Digital Start-Up is a special service that helps our customers get maximum value from Trützschler's digital solutions. From personalized

configurations through to analyzing data and optimizing production processes in real time, you can rely on Digital Start-Up to support your yarn production processes.

Entering the virtual space
Every day, technical service experts from Trützschler visit customers around the globe. We travel to Brazil, India, Türkiye, the USA… and now we're adding another location to the list: The virtual space. Our Trützschler Services team works with you to make sure you feel the full benefit of our digital solutions for yarn production.

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Now, all customers that commission a new installation can also access our new service: Digital Start-Up. This comprehensive onboarding program generates quick wins from Day One and will help you achieve top levels of performance for many years. It offers:

- Guided onboarding for our all-in-one platform My Trützschler including My Mill, Training, Shop and much more.
- On-site training for all machines and services.
- Digital audits that combine online and on-site guidance, training and troubleshooting.

During digital audits, technical experts from Trützschler guide and train each customer's team based on specific real-time data from our mill monitoring system My Mill. By working closely in this way, you can get your mill to 100 %

performance faster than ever, while also learning how to finetune your unique processes on your own. Online support is always available to help you solve issues quickly and achieve stable yarn quality.

With you everywhere
The My Trützschler platform offers the best way to keep track of all digital solutions. It provides seamless access to your digital Trützschler world, with important insights from digital services including My Mill, Training, Shop and My Wires. The My Identity tool ensures safe access on any device, anywhere – and it saves you time with single sign-on authentication. The digital Trützschler world is growing all the time. Find out about the latest apps and services on My Trützschler.

- Stay up-to-date, anywhere and all the time.
- Order parts and components online quickly and easily (My Shop).
- Upskill your employees with online training activities (My Training).
- Expert know-how to improve the performance of your Mill (My Mill)

The New Generation Rieter Ring Spinning Machine G 38 Redefines Boundaries

Maximum production in ring and compact spinning not only means offering the highest spindle speeds. Noticeable production benefits can be achieved by significantly reducing machine downtimes. And this is where the new version of the ring spinning machine G 38 leads the way.

The market for ring yarns is large and highly competitive. To succeed in this fiercely competitive market, spinning mills must be highly efficient. The latest ring spinning machine G 38 offers maximum production based on new technical solutions and upholds its reputation for efficiency by minimizing its energy consumption.

The highlights of the latest generation ring spinning machine G 38 are: the new doffing system with a doffing cycle time of just 90 seconds, the 12% faster cop transport with SERVOdisc and the new short-balloon setting for balanced yarn tension peaks to reduce the ends down rate. Combined with the highest spindle speed of 28 000 rpm, the G 38 ensures maximum competitiveness in the production of ring and compact yarns in all yarn count ranges.

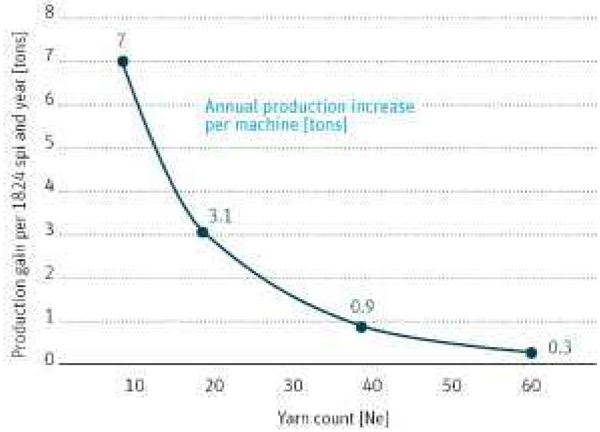
Doffing in 90 seconds leads to production gain

The latest and highly reliable automatic doffing system of the G 38 (Fig. 1) is equipped with a perfect alignment of grippers, tubes, and cop trays and thus enables a fast sequence of all doffing process steps. The redesigned doffing system completes its cycle in just 90 seconds (Fig. 2), which means 25% less time compared to the prior version of the G 38 and all known competitors. The advantage is particularly evident with coarse yarn counts. With a yarn count of Ne 10 the annual production gain is seven tons and for Ne 20 it is 3.1 tons for a machine with 1 824 spindles.

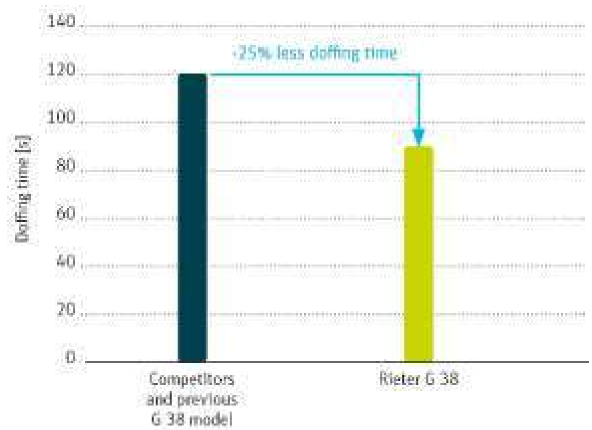
12% faster cop transport

The new cop transport system SERVOdisc for the link system with the winding machine Autoconer X6 is 12% faster than the previous solution. It forwards up to 45 cops per minute directly to the winding machine. This open rail system is fast enough to remove all cops on time before the next doffing cycle is due. This is important for long machines with short spinning cycles because of very coarse yarn counts. The optimized SERVOdisc is even more reliable and needs less maintenance. Intelligent cop trays, called Smarttray, with an integrated RFID chip are available with the link system to the Rieter winding machine Autoconer X6.

The highly reliable automatic doffing system doffs in just 90 seconds



25% faster doffing leads to a remarkable production gain



25% faster doffing leads to a remarkable production gain

Production increases of up to 2%

The limiting factors in ring yarn production are yarn tension peaks and the interaction with the ring and traveler. One of the most important tasks therefore is to balance the tension peaks during cop build-up. A short-balloon setting optimizes these ratios and brings clear advantages in terms of less ends down and longer traveler lifetime. Alternatively, the short-balloon setting allows to increase spindle speed by up to 2% while keeping the ends down rate constant.

New G 38 generation – today's offering for flexible yarn production

The new G 38 is available either as a machine with a fully electronic system or with a semi-electronic system. In both cases, the spindle speed, the yarn twist, and the yarn twisting direction, Z or S, can be changed electronically and without additional mechanical adjustment. The yarn count can be changed electronically via the panel on the fully electronic machine.

The Individual Spindle Monitoring (ISM)-system premium is now standard on every ring spinning machine and for all applications. This is a great advantage for efficient operator guidance and easy detection of spindles which are not running correctly. ISM premium is the precondition for the fully automated piecing robot ROBOspin to produce high-quality yarn while mitigating labor related challenges.

With a million units installed, customers clearly recognize the benefits of the add-on compacting devices COMPACTdrum and COMPACTapron in terms of yarn quality and performance. The flexible conversion into compact, slub or core yarn production, is a major advantage of the ring spinning machine G 38.

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