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THE TEXTILE ASSOCIATION (INDIA)
702, Santosh Apartment, 7th Floor, Plot No.72-A, Dr. M. B. Raut Road, Shivaji Park, Dadar (West), Mumbai - 400 028
Tel.: 022-2446 1145 • E-mail: taicnt@gmail.com • Website: www.textileassociationindia.org

Role of Technology in Improving Handloom Sectors

National Handloom Day is observed on August 7th every year to honour the Handloom Weaving Community for their contribution to the Socio-economic Development of our country. This day also creates awareness about the rich heritage of the Indian Handloom Industry amongst the public.

India is popular for making variety of handicrafts across different geographical locations. Handmade Textiles are one of the oldest products of this sector of pre and post Independent era. Even today as we celebrate the 75 years of Independence, the handloom sector plays a vital part in the Nation's economy. It is one of the segments giving direct work to more than 65 lakh people occupied with weaving and partnered exercises. The various government schemes and support for its execution has helped this sector to withstand the competition from the power loom sector and factory areas. Handloom is unmatched in its adaptability and flexibility, allowing experimentation and empowering advancements. The strength of handloom lies in presenting creative products, which can't be repeated by the power loom sector. The handloom products especially the woven cloths have created a niche market and brand value in the customers mind. The different motifs on the fabric using variety of colour patterns helps to create value-added products for apparel and upholstery applications.

Despite of having all the advantages of handloom sector, there is still scope to develop this sector using innovative concepts and technologies. The use of advanced fibers such as TENCEL, Modal, Bamboo, Soya can be explored for value addition in the existing products in place of the traditional cotton and silk fibers. The yarn dyeing concept can be also implemented to create the different colour combination in the weaving process as compared to piece dyeing for different appearance. Most of the handloom products are costly because of low production output due to the hand spun and hand-woven activity in the manufacturing process. The solar power energy can be utilized to operate the handloom and accelerate the production process without compromising the quality of product.

The Khadi and Village Industries Commission have already acknowledged this technology with the name of “Solar Charkha”. Set of standards and norms for evaluation of quality of handloom-based products can be framed to assign the labels to confirm the originality of handloom product. Creating research and development centers in the handloom organization can help develop value-added and need based products to meet the rapid changing demands of the customer. The handloom organizations can collaborate with Educational and Research Institute by signing MoU.

Incorporating innovative materials, technologies and practices in handloom will enhance the performance of handloom sector and boost rural economy.

Dr. Deepa V. Raisinghani
Hon. Editor

Acoustic Properties of Wovens - Part II: Studies on Corduroy and Fabric with Polyester Fabrics Made From Staple and Textured Weft Yarns

Dr. N. Gokerneshan[1]*, Ms. B. Padma[2], Ms. R. Haripriya[3], Ms. A. J. Abisha Raju[4], Dr. K. Sangeetha[5], Ms. Lakshmi Sudheer[6] & Dr. K. M. Pachiyappan[7]

[1]Department of Costume Design and Fashion, Dr. SNS Rajalakshmi College of Arts and Science, Coimbatore,
[2,3,4] Dr. SNS Rajalakshmi College of Arts and Science, Coimbatore
[5,6] Department of Textiles and Apparel Design, Bharathiar University, Coimbatore
[7] Department of Costume Design and Fashion, PSG College of Arts and Science, Coimbatore

Abstract

This part of the paper reviews the acoustical properties of corduroy fabrics in relation to air permeability and airflow resistance and polyester fabrics woven with staple fibres and draw textured yarns in weft with varying thicknesses. It is found that corduroy fabrics with thicker wale width exhibited higher air permeability and lower airflow resistance. Furthermore, the increased width of wale is beneficial to improve the acoustic absorption of corduroy fabric. The fabrics woven have been classified as porous, medium, and dense, on the basis of their densities and air permeabilities, and the sound absorption coefficients of the fabrics were found to be linearly related to the air permeability. Porous fabrics exhibited a shorter reverberation time and a higher sound absorption coefficient than dense fabrics owing to their good sound absorption property

Keywords: *Air permeability, Corduroy fabric, Draw textured yarn, Polyester fabrics, Reverberant field method, Sound absorption, Tube method*

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1. Introduction

Presently, majority of the research works relating to the the acoustic absorption characteristics of fibrous materials has been directed towards fiber felts and nonwoven fabrics [1-3]. The acoustic absorption coefficient was closely related to air permeability. In the case of non woven fabric lower the air permeability, the better would be the sound absorption efficiency. Textile materials have a broad range of applications in noise reduction such as room acoustics, industrial noise, transportation noise, studio acoustics, and so on. Owing to lower thickness, the acoustic absorption properties of woven fabrics are inferior to those of fiber felts and nonwovens. But, due to the superior aesthetic look of woven fabric that is artistically rich, it has normally been used for indoor and automobile decorations [4]. The acoustic absorption phenomena of woven fabrics have been studied for a long time. The acoustic wave attenuation mechanism could be mainly attributed to the internal viscothermal dissipative effects, the flow distortion effects, resonant effects, and bending vibration of the fabric [5].

A variety of sound-absorbing equipment are currently available, including acoustic panels and studio foam, which are able to decrease the sound levels in closed surroundings and eliminate unwanted noise [6]. Sound absorption occurs when the incident sound waves that strike a material are not reflected back. When a sound wave strikes an acoustic material, the sound wave causes the material constituents such as fibers to vibrate because of friction. Sound absorption is accomplished in a process whereby the acoustic energy is transformed into heat. Low-density textiles are highly attractive for acoustic and sound-absorption-applications although they are less than ideal in terms of sound diffusion because the textiles used in nonwoven, woven, and knitted fabrics are porous in nature. Sound absorption improves with increasing textile porosity. The acoustic properties of textiles differ depending on the structure of the textile, where small air spaces can improve their acoustic properties [7].

*** Corresponding Author:**
Dr. N. Gokerneshan
Department of Costume Design and Fashion,
Dr. SNS Rajalakshmi College of Arts and Science, Coimbatore,
Email: advaitcbe@rediffmail.com

2. Studies on corduroy fabrics

Certain empirical-based works have been done so as to investigate the acoustic absorption characteristics of woven structures. As an example, it has been found that pile surface, fabric-backing conditions, and different parameters determine the total permeability, which would contribute more significantly to sound absorption [8,9]. The relation between the sound absorption coefficient and structural factors of woven fabrics have been investigated [10]. The findings show that cover factor has the most significant effect on absorption coefficient, which is particularly emphasized in the curves corresponding to the frequencies ranging from 2000 to 4000 Hz. Recently, it has been reported that sound absorption characteristics of different woven fabric including plain, 2/1 twill, 3/1 twill, 2/2 twill, rib and satin fabrics get reduced in the corresponding order [11]. The findings also showed that fabric porosity as well as surface specific weight have marginal effect on acoustic absorption. Woven fabrics with lower weft yarn twist would absorb acoustic energy more efficiently, and air permeability can be taken as a criterion of sound absorption behavior [12]. Furthermore, a theoretical model for the acoustical behavior of thin woven fabrics backed with air gap space is presented by Pieren [13]. The technique is explained by airflow resistance and specific surface weight, and hence predict the acoustic absorption coefficient. It has been reported that airflow resistance is a reproducible parameter of porous materials, and acoustic absorption coefficient can be predicted by flow resistance [14,15]. In the case of fibrous materials, air permeability is an easily determined factor and can be used to assess acoustic absorption characteristics.

Corduroy fabric has gained prominence because of its applications extended to home furnishing, like curtains and carpets, and so on. The corduroy fabric structure comprises of two sets of filling yarns and warp yarns. In order to withstand the high forces of weaving, the warp yarns should have adequate strength and high evenness. The first set is configured with the warp yarns, and constitute the ground fabric, which give the structural integrity. The second set of filling yarns forms the floats, and the cutting of the pile is normally done after weaving on a specific machine fitted with circular knives and followed brushing [16,17]. The corduroy fabric holds the prospect of enhancing the acoustic absorption properties taking into account the special structure and cut pile filling. The raised rib on the surface of corduroy fabric is similar with nonwoven, and the ground fabric is woven structure. Hence, corduroy fabric can be visualized as multilayer acoustic absorber comprising of woven as well as nonwoven fabrics. The compound structure proves useful to the attenuation of acoustic waves. But, review of literature shows that the study on acoustical behaviour of corduroy fabric has not been reported.

The sound absorption characteristics of corduroy fabrics have been studied. The acoustic absorption coefficient of corduroy fabrics having identical surface density and varied wale width has been measured and compared. Two factors, namely, air permeability and airflow resistance which affected the acoustic absorption have been explained. Also, the difference of acoustic absorption curves of tested corduroy fabrics has been explained. The width of wale has been considered as a factor to assess the acoustic characteristics, which could predict acoustic absorption coefficients intuitively. Hence, two techniques, namely, empirical-based vibration absorption model and geometry-based Pieren model have been used to characterize the acoustic absorption coefficients. The predicted values have been compared with the test results. The Pieren model is found to well characterize the acoustic absorption of corduroy fabric at normal incidence.

Acoustic absorption coefficient

The measured results of corduroy fabrics having various air gaps have been determined. An equation has been used to calculate the average acoustic absorption coefficient over the frequency range from 100 to 6300 Hz. It has been found that the acoustic absorption is weak for all the tested fabrics without air gap. Test fabric having air gap distance of 1 cm has the maximum acoustic absorption coefficient. The test fabrics showed the best acoustic absorption characteristics at the distance of 2 cm. It is because of the fact that optimum distance is determined by the intrinsic properties of fibrous materials, and the optimal air gap distance differ based on various fabrics. It has been found that all corduroy fabrics exhibit poor sound absorption properties without air gap. It has been proved that acoustic absorption coefficients increase with the presence of back air gap. Also, *as shown in Figure 5*, the fourth as well as fifth test fabric show relatively good acoustic absorption properties at high-frequency range at 1-2cm air gap distance. The acoustic peak shits to lower frequency as the air gap is increased to 3cm. But in the case of first, second and third test fabrics, the maximized acoustic absorption coefficient has been noticed at low frequency [20]. It is indicated that the frequency range of coefficient higher than 0.5, and is considered to explain the effective absorption frequencies. For the acoustic absorption behaviour of sheet fibrous materials the air gap is considered crucial. The average and peak acoustic absorption coefficients are influenced due to the presence of air gap. The air gap thickness behind the fabric decides the acoustic impedance of air. The frequency based acoustic wave transmission path is also restricted by the cavity length. Hence, the various absorption coefficients are created by the different distance of air gap. A formula has been used to calculate the octave frequency range of coefficient higher than 0.5 for five corduroy fabrics considering the octave frequency range at the start and terminated frequency peak of coefficient greater than 0.5. The findings reveal that the third, fourth and fifth test fabrics have octave frequency range greater than 2 with 1 cm air gap. In particular, when the air gap is 2 or 3 cm, there has been rise in the octave frequency range. It has to be taken into account the first and second test fabrics have at least two separated octave frequency range caused by the serve fluctuation of absorption curves at low- and middle-frequency range. Hence, it can be stated that a wider width of the wale can improve the acoustic absorption properties. To further study the difference of five corduroy fabrics, two simulation methods characterized the acoustical behavior in the following sections.

Predicted results based on vibration absorption model

In order to explain the acoustic characteristic of corduroy fabrics, vibration absorption model has been utilized. The measured and predicted acoustic absorption coefficients for corduroy fabrics having air gap is depicted in Figure 1. Owing to the various air gap distances the difference arises in the four types of curves. The air gap distance decides the absorption curves and coefficients depending on the acoustic absorption theory of fibrous materials. Vibration model can approximately explain the trend of acoustic absorption properties considering the air gap of 2 and 3 cm. Considering five test fabrics having 1 cm air gap, the prediction curve cannot sufficiently explain the acoustic behaviors [20]. But, the acoustic absorption characteristics of fourth and fifth test fabrics can be simulated with certain deviation. Thus, vibration absorption model is not valid for prediction of the acoustic absorption coefficient of corduroy fabrics [18]. For comparison of the prediction accuracy of established models, the error rate has been calculated by using an following equation. The findings of various fabrics have been depicted.

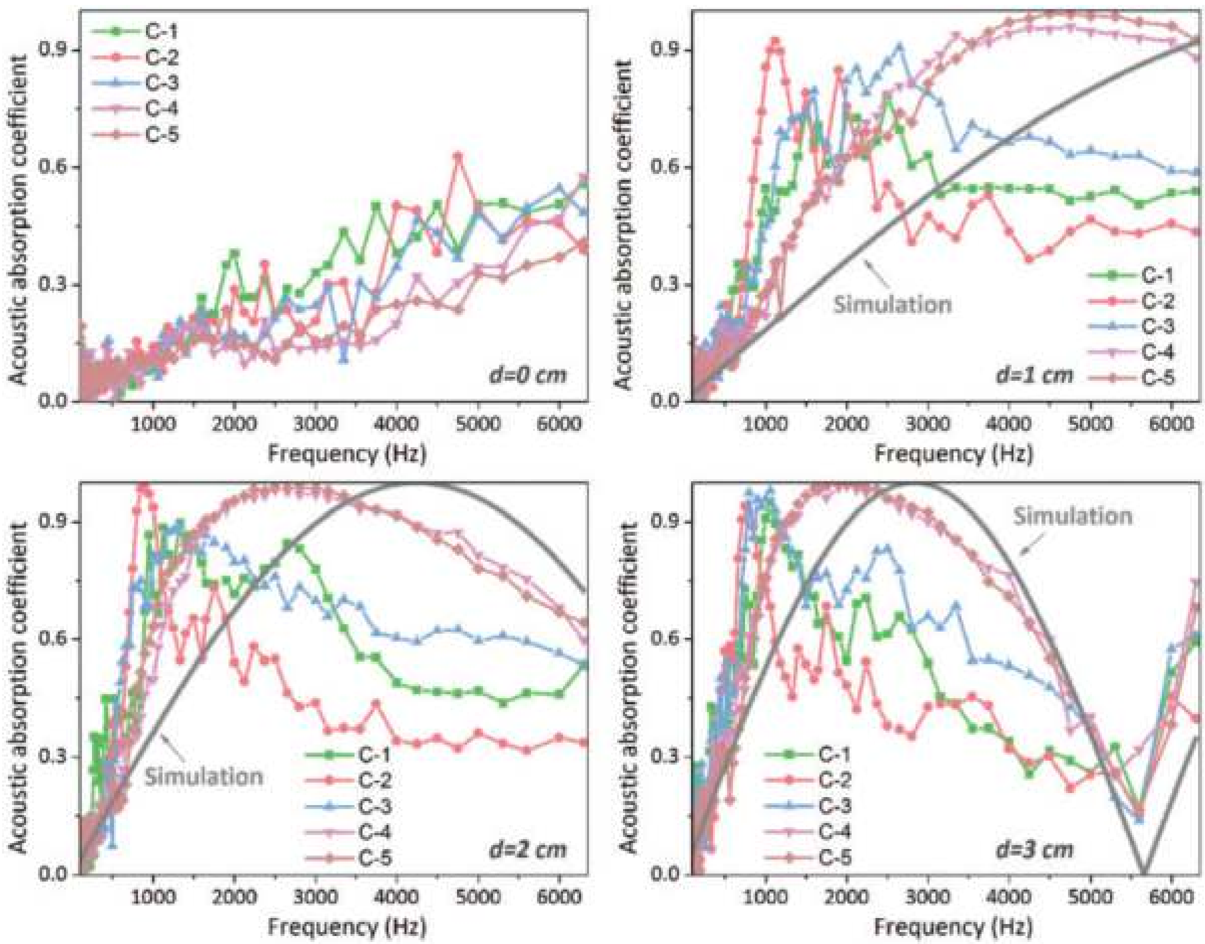

Figure 2 - Measured and simulated acoustic absorption coefficient of corduroy fabrics with vibration absorption model [20].

A modified vibration absorption model has been established taking into account the air permeability of fabric so as to confirm the influences of air permeability on sound absorption. The simulated and measured values of acoustic absorption have been compared. The predicted error rate of five corduroy fabrics have been determined. The findings show that the deviations in the case of first and second test fabrics are lesser than those of third, fourth and fifth test fabrics. But, it has been found that the predicted curves did not explain the tendency of measured values sufficiently well. Likewise, with the vibration absorption model that does not take into account the air permeability, a revised model could better characterize the acoustical behavior of corduroy fabrics with thicker wale width. The reason could be attributed to the applicability of vibration absorption model, where acoustic absorption coefficient is affected by the air permeability of fabric [19].

Predicted results based on Pieren model

The geometry-based Pieren model involves surface area mass density, air gap distance, and airflow resistance. In particular, it is explained by a set of formulae involving some equations. The measured and predicted findings of five corduroy fabrics have been determined. Generally, the measured and predicted curves agree better than the vibration absorption model, and the error rate. But, it is similar to the vibration absorption model in that the prediction deviation of thick wale corduroy fabric is higher than fine wale corduroy fabric. The findings could be attributed to the improved resonance effects of fabrics having low air permeability. Therefore, the fabrics gradually exhibited the acoustical characteristics similar to synthetic films [20].

Elaborately, the airflow resistance values of the five corduroy fabrics considered are significantly greater than that of Pieren's work. As an instance, the airflow resistance of first and second test fabric was 1986 and 2038 Pa s/m, respectively, which is far greater than the values reported by Pieren. The fourth and fifth test fabrics have relatively low airflow resistance and high air permeability. Hence, the model of Pieren could better characterize the acoustical behavior. The intrinsic properties of the test corduroy fabrics can be explained indirectly by airflow resistance, thereby creating the difference in acoustic absorption. The characteristics of acoustic absorption of corduroy fabrics can be well characterized based on the factors of surface mass density, airflow resistance, and air permeability.

In the investigation considered herein, the vibration model depends on the optimal acoustic absorption coefficient at the odd number multiplication of 1/4 wavelength and the minimal acoustic absorption coefficient at the integer number multiplication of 1/4 wavelength. A modified empirical formula has been evolved taking into account the role of air permeability of thin fabric, based on derived equations. Hence, the error rate of first and second test fabrics vary conspicously from those of third and fourth test fabrics. It can arise from the difference of air permeability and airflow resistance. In the case of first and second test fabrics, the air permeability is relatively low. Hence the acoustic behavior is similar with membrane materials. The sound absorption bandwidth of first and second test fabrics are found to be very narrow *(Figure 5)*. The fourth and fifth test fabrics evidently show characteristics of porous materials, and the porous mechanism determines vibration model. Hence, the error rate of first and second test fabrics is greater than that of fourth, fifth, and sixth test fabrics. In Pieren model, various physical elements are represented by equivalent electrical elements, and the ratio of sound pressure and sound velocity yields an acoustic impedance. The calculation involved in Pieren model is done by derived equations. The simulation of Pieren model is based on the surface mass density of corduroy fabrics. In the investigation considered, all the five test fabrics have the similar surface mass density. Hence, Pieren model can predict the acoustic absorption coefficient with greater accuracy in comparison with vibration model. The findings have been determined.

3. Sound absorbing polyester fabrics

A number of investigations have been carried out with regard to the relation between the air space in textiles and their acoustic properties. Yanping and Hong presented an experimental investigation on the sound-absorption behavior of spacer fabrics, which are fabrics that consist of a uniform pattern of micropores and provide reasonable sound absorption at mid-to high frequencies [21]. Heylighen, Rycht_arikov and Vermeir tested the effects of hanging curtains along the wall with some distance between the curtain and the wall, and found that the sound absorption at low frequencies was better with a larger separation between the wall and the curtain [22].

Also, curtains that have been hung in a folded manner showed better sound absorption than those that have been hung in a flat manner. Hence, with the increase in the surrounding air space of the textile curtains the sound absorption increased. Some papers relate to acoustic properties of woven fabrics with fabric air permeability. Zang reported the relationship between the maximum sound absorption and air permeability coefficients [23]. In other words, sound absorption coefficient attains a peak value at a certain air permeability followed by commencement of reduction. Parham and Mohammad deal with the study of the acoustic characteristics of woven fabrics in relation to fabric structural parameters and air permeability, which was concluded that fabric air permeability can be used as a criterion of sound absorption behaviour of woven fabrics [24].

In addition, many researchers have analyzed the relation between sound absorption and various fiber-related parameters, including surface treatment, film coverage, formation processes, and physical parameters, for fibrous and porous textiles [25,26]. Na, Lancaster, Casali, and Cho reported that the most influential factors affecting acoustic performance of textiles are elastic modulus, thickness, porosity, and flow resistance. Soltani and Zarrebini revealed that both the fabric porosity and fabric density have profound effect on fabric sound absorption performance [27].

In spite of deep investigations of factors pertaining to the sound absorption of fabrics, only little research has been done related to the weaving design of sound absorbing fabrics depending on such factors. In the investigation considered, a number of innovative fabrics with air spaces have been designed and woven so as to achieve good sound absorbance. Polyester staple yarn and draw textured yarn have been utilized in weaving of the fabrics. The fluffs and crimps in the fabrics offered an effective conversion of acoustic energy to thermal energy by friction. For wefts and warps, two different thicknesses of the thick SY and thin DTY were used to create sound-absorbing fabrics when blended with the other yarns. The acoustic properties of the woven fabrics were investigated in the frequency range of 100–5000 Hz, considering that human hearing is most sensitive in the 1000–3000 Hz frequency range.

Structural properties of the woven fabrics

The pattern designs of fabrics have been chosen. The wefts and warps have been designed for producing sound-absorbing fabrics through combination of various ratios of thick SY and thin DTY yarns, wherein many interconnected microspores are present. It is possible to achieve good sound absorption from porous structures by adjusting the thickness and ratio of the thick SY yarn and thin DTY yarn, it can be possible to control and adjust the number and size of pores in the sound-absorbing fabric. Of the many acoustic damping materials, porous sound absorption material has gained prominence, at which sound waves travelled in the material and was converted into heat and gradually diminished. It leads to enhanced performance of sound absorption. Also, a number of short fibers present on the surface of the spun yarn and the internal spaces of the textured yarn can improve the sound damping effect. It can be anticipated that micro pores of different sizes formed by the combination of thick and thin yarns can show a sound absorbing effect.

The selected fabrics have been woven based on the fabric structure. The weaves have been constructed using various floating steps (5/5, 7/7, and 9/9). The ratio of thick SY to thin DTY fibers for the warps were the same for all fabrics. On the other hand this ratio for the wefts has been used differently (1/1, 2/1, 3/1, and 4/1). The dense fabrics having more air permeability *and* porous fabric having less air permeability have been woven with the same pattern but with different number of ratios of thick SY to thin DTY yarns for weft, i.e., in the ratios of 3/1 and 1/1, respectively.

The structural characteristics of the test fabrics have been characterized as per their thickness, density, weight, and air permeability. The weights and thicknesses were in the range of 634–713 g/m2 and 2.16–2.41 mm, respectively, which are appropriate for use in interior decoration, such as in curtains, carpets, and wall fabrics. Density has been arrived at by dividing the fabric weight by fabric volume, assuming a parallelepiped shape, and has been found to be in the range of 0.29–0.32 g/cm3. Considering the density of polyester fibers as 1.35 g/cm3, these fabrics have a heavy inner air space.

The fabrics have been categorized into three types depending on the density and air permeability as follows: dense, medium, and porous. The dense fabrics had densities 0.299 g/cm3 and air permeabilities 27 mm/s, the porous fabrics had densities 0.295 g/cm3 and air permeabilities 29 mm/s, and the medium fabric had a density of 0.291 g/cm3 and an air permeability of 27 mm/s. In the case of the dense fabric having more air permeability, porous fabric having medium air permeability and more air permeability, rise in the floating steps and the proportion of thick yarn resulted in an increase in the air permeability due to an increase in the air space. But, on the one hand the dense fabric having more air permeability and porous fabric having less air permeability had the same floating steps (7/7) in the same structure, whereas a greater proportion of thick yarn in P1 exhibits a higher increase in the air permeability than that exhibited by dense fabric having more air permeability. Hence, within the same fabric structure, a rise in the proportion of thick yarn results in an increase in the air permeability, probably due to a consequent reduction in the inner air space of the fabric. Thus, fabric structural parameters, namely, the floating steps and the proportion of thick yarn in fabrics, affect the inner pore formation in a fabric, rendering them key factors for sound absorption.

Several studies have reported an increase in the sound-absorption capacity of fabrics with increasing density up to a certain extent, after which the sound-absorption capacity decreases [28,29]. Rettinger determined that the highest sound absorption occurred at a density of approximately 0.14 g/cm3. But, in the investigation considered, even though the densities are almost similar, i.e., 0.300 ± 0.014 g/cm3, the air permeability varied considerably based on the structural factors of the fabrics, i.e., a rise in the floating steps for warps and a rise in the ratio of thick to thin yarns for wefts. Hence, the relation between sound absorption and fabric structural factors requires more study.

Table 1 – Structural properties of sound absorbing fabrics [34]

Fabric properties	Test						
	D1	D2	D3	M	P1	P2	P3
	(dense)			(medium)	(porous)		
Weight (g/m^2)	682	693	634	383	713	694	702
Thickness (mm)	2.16	2.32	2.22	2.35	2.27	2.35	2.41
Density (g/cm^3)	0.003	0.299	0.314	0.291	0.286	0.295	0.291
Air permeability ($cm^3/cm^2/s$)	25	26	26	27	29	32	35

Use of impedance tube technique for study of sound absorption

The sound absorption coefficients have been determined in the case of porous, medium and dense fabrics as a function of frequency. In all the fabrics tested it has been found that as the sound frequency increased the absorption coefficient increased. In the case of porous and medium fabrics the slopes of the curves are considerably steeper and are far greater at mid-and-high frequencies in comparison with those for the dense fabrics. For the porous fabric having highest air permeability the sound absorption coefficient maintained the highest level across the complete frequency range, followed by the medium fabric. The porous fabric having greatest air permeability had a relatively low density of 0.291 g/cm3 and an especially high air permeability of 35 mm/s. The medium fabric was also characterized by the same low density of 0.291 g/cm3. But, it had a low air permeability of 27 mm/s. Though density offers an assessment of the void/air spaces in a fabric, which is considered crucial in determining the sound-absorption capacity of a fabric, other parameters like air permeability are also critical.

As an example, although the porous fabric with least air permeability had the lowest density (0.286 g/cm3) and a mid-range air permeability value, its sound absorption coefficient over all frequencies was within the level of that of the porous fabrics. The porous fabric with least air permeability was lightweight and relatively thin and the proportion of thick yarn in the blend was high (3/1), and its relatively porous structure lead to the formation of air spaces. Hence, the sound absorption of fabrics is likely influenced by the length of sound transmitting path but fabric thickness or density. That is, the longer the transmitting path was, the larger are the frictional losses [30]. The sound absorption coefficient, averaged across the full frequency range of 100–5000 Hz, as a function of air permeability. The averaged coefficients have been greater in the case of porous fabrics than with those in the case of dense and medium fabrics, with the porous fabric of maximum air permeability having the highest overall average. It has been found that there is an almost linear increase in the average coefficients as the air permeability is increased. Hence, air permeability could be utilized as an indicator for reflecting the volume of air space in a fabric and to predict the ability of a given fabric to absorb sound. But, the relation between air permeability and sound absorption coefficient is limited. Based on the finding of Parham and Mohammad, there is increase in sound absorption effect with increase in the air permeability between 20–29 cm3/cm2/s. There is reduction in sound absorption in the region where the air permeability is above 29 cm3/cm2/s. The air permeability of these fabrics ranges from 25 to 35 cm3/cm2/s, and the fabric thickness is rather thick compared to fabrics studied by other researchers (almost four times). Hence, it appears logical to have a proportional relationship between air permeability and sound absorption coefficient in the range of fabric thickness and air permeability. Very compact fabric surface prevents transmission of sound wave through the fabric, thus, a great proportion of incident sound waves is reflected. The sound absorption coefficients have been determined as a function of frequency in the case of one, five, and seven-layered fabrics respectively.

In the case of all the fabrics there has been increase in rise in frequency. However, the trend of the increase varied with the number of layers. The single-layer fabrics exhibit a gradual increase in the sound absorption coefficient with frequency. On the other hand, the increase has been more steep at frequencies of 1000 and 2000 Hz in the case of the 5- and 7-layered fabrics, respectively, followed by a levelling-off. There has been rise in the sound absorption coefficient with increase in number of layers at frequencies below 1000 Hz. However, at frequencies above 2000 Hz, the coefficients of the 5- and 7-layered fabrics have been found to be almost similar.

Hence, it has been found to be effective to use fabric layering for improvement of sound absorption. The use of layers dampens the sound waves by creating a complex path through the fabric, particularly in low frequency regions. In this regard, Seddeq, Aly, and Elahakankery reported that the sound absorption coefficient improved on increasing the thickness of nonwoven fabrics because of the dampening of sound energy through frictional losses [31]. Likewise, the utilization of overlapping fabrics for use in enhancement of sound absorption has been confirmed.

Use of reverberant field technique to determine sound absorption

The reverberation time has been determined as a function of frequency for three fabrics: one by one for dense, medium, and porous. As the sound frequency increased there is reduction in reverberation time. A sound resonance phenomenon can create the much longer reverberation times found at low frequencies as it is challenging to absorb low frequency sounds due to their long wavelengths. The reverberation time of the chamber was shorter when it contained a fabric because of the sound absorption by the fabric; the reverberation times of the porous fabric having medium air permeability and medium fabrics have been found to be shorter in comparison with that of the dense fabric of medium air permeability.

The sound absorption coefficient has been determined as a function of frequency in the case of the dense fabric with medium air permeability, medium fabric, and porous fabric with medium air permeability, which have been measured with the reverberant field technique. There has been steep rise in the coefficients, which attained a maximum value near 800 Hz since these fabrics are quite thick (in excess of 2.3 mm). This is consistent with the findings of earlier investigation where low-frequency sound absorption was positively correlated to the fabric thickness [32]. The dense fabric shows the lowest absorption at all frequencies, probably since it had the lowest porosity. The sound absorption coefficient at frequencies of 125, 250, 500, 1000, and 2000 Hz have been listed and also the NRC values for the porous fabric with medium air permeability, medium fabric, and dense fabric with medium air permeability. The dense fabric with medium air permeability shows a lower sound absorption coefficient than the medium and porous fabrics with medium air permeability. The values of noise reduction coefficient for the dense fabric with medium air permeability, medium fabric, and porous fabric with medium air permeability have been 0.5, 0.6, and 0.7, respectively, which is significantly higher than the value for a carpet or terry of a similar weight or thickness [33,34].

4. Conclusion

Corduroy fabrics with thicker wale width exhibited higher air permeability and lower airflow resistance. Furthermore, the increased width of wale is beneficial to improve the acoustic absorption of corduroy fabric. Two models based on air permeability and airflow resistance are taken to characterize the acoustical behavior. It has been indicated that Pieren model could well predict the acoustic absorption coefficient of corduroy fabric, and the difference of acoustic absorption is due to the varied air permeability and airflow resistance resulting from the different wale width. Corduroy fabric has bright promise for noise reduction applications. The design and preparation of sound absorbing woven fabrics was accomplished by considering several parameters related to sound absorbance for fabrics used in interior decoration, such as in curtains, carpets, and wall hangings. The thick staple yarn and the thin draw-textured yarn were used for the weft and warp of the fabrics and it was possible to control the sound-absorption properties of the fabrics by blending the yarns. The prepared fabrics were classified in porous, medium, and dense, on the basis of their densities and air permeabilities, and the sound absorption coefficients of the fabrics were found to be linearly related to the air permeability. The sound absorption coefficient determined by the impedance tube method was higher for porous fabrics compared with that for dense fabrics in the high frequency region. By the reverberant field method, the sound absorption coefficients for all fabrics were highest in the low frequency region. Porous fabrics exhibited a shorter reverberation time and a higher sound absorption coefficient than dense fabrics owing to their good sound absorption property. The recent researches in acoustic behaviour of woven fabrics clearly indicate that wovens would in the near future occupy a more prominent place in the area of acoustic applications. However, more research is required relating to influence of structural parameters, chemical treatments, etc. to enhance their importance in relation to non wovens which are presently dominating the area of acoustic applications.

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Biotechnological Applications of Microbial Enzymes to Replace Chemicals in the Textile Industry- A Review

Aparajita Sen[1], Rachna Kapila[2], Sonia Chaudhary[2] & Arti Nigam[2]*

[1]Department of Genetics, University of Delhi, South Campus, New Delhi, India
[2]Institute of Home Economics, University of Delhi, New Delhi, India

Abstract:
The use of enzymes is increasing in the textile industries as replacements of chemicals, for performing various functions like desizing, bleaching, scouring and denim washing. This is a result of people becoming more aware of the significance of environmental conservation. Enzymology in textile processing is rapidly gaining recognition globally as enzymes are non-toxic and eco-friendly and aid in reducing pollution in the textile production units. Moreover, they are specific and highly efficient, and can work under mild physiological conditions. Furthermore, their rate of catalysis is faster, thus conserving water and energy, and improving the final product quality. Many enzymes such as cellulases, laccases, amylases, catalase and peroxidases are used in various stages of textile processing, such as in enzyme wash, desizing, biopolishing, bioscouring and effluent treatment. In this paper, we compile and elaborate on how various microbial enzymes are replacing chemicals used in the textile industries, thereby offering more sustainable solutions to environmental contamination.

Keywords: *Biobleaching, Biopolishing, Bioscouring, Biowashing, Desizing*

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1. Introduction

Enzymes are biocatalysts which lower the activation energy of a reaction to increase its rate. However, they do not directly participate in the reaction, or alter the equilibrium of a reaction. Ever since their discovery, they have been widely used in various industrial processes, such as in the food, paper and pulp, textile and biofuel industries [1]. They are highly efficient and very substrate-specific, and are primarily obtained from plants, animal tissue and microbes. Microbial enzymes are usually preferred due to their availability in sufficient quantities for industrial applications [2]. Further work on screening and isolating microbial strains that can produce the desired enzyme in large quantities, along with optimizing the conditions for growth and enzyme production, collectively resulted in higher yields of enzymes in a cost-effective manner. Nowadays, recombinant DNA technology and genetic engineering are being used to obtain necessary traits of microbial enzymes, such as the ability to remain functional under extreme conditions of temperature and pH. The main microbial sources of enzymes are fungi like *Aspergillus* and *Trichoderma*, and bacteria like *Streptomyces* and *Bacillus* [3, 4].

Earlier, textile production processes of desizing, scouring and bleaching were done using chemicals like urea, caustic soda, acids, bases, salts and bleach, which are toxic to humans, and can cause environmental pollution when discarded after use. Therefore, enzymes provide a much cleaner and environment-friendly alternative. Two main applications of enzymes in the textile industries are the use of amylases in desizing, and cellulases for softening and bio-stoning of cotton products. Textile processing also uses enzymes like lipases, pectinases, catalases, proteases, xylanases etc. for processes like bio-scouring, bio-polishing, fading of denim and non-denim, wool finishing, peroxide removal etc [5, 6, 7].

Enzymes are the most suitable alternatives to chemicals for use in textile industries due to various advantages over the chemicals that were earlier used. Apart from accelerating the rate of the reaction and being highly substrate specific, enzymes operate under milder conditions, are easier to control, are biodegradable and are safer alternatives to toxic chemicals [4].

2. Applications of Enzymes in Textile Industry

Hydrolases and oxidoreductases are the main classes of enzymes used in the textile industry. Amylases are used for desizing of cotton [8] and other enzymes like cellulases, hemicellulases, pectinases, catalases and lipases are used for pre-treatment and finishing [9]. Enzymes like sericinases are used for degumming of silk [10], proteases for felt-free-finishing of wool [11] and cellulases and xylanases for the softening of jute [12]. Potential of enzymatic treatment of synthetic fibers such as polyacrylonitrile or polyester is also being studied [13, 14]. Some of the applications of enzymes in the textile industry have been listed in the following sections.

2.1. Desizing

The removal of the starch-based protective layer (size) applied on textiles for improved and uniform wet processing is called desizing. Conventionally, oxidizing agents or inorganic acids in low concentrations were used, but due to less control and non-specificity of the reaction, the cellulosic material usually got damaged and lost strength [15].

Amylase, a hydrolytic enzyme produced by *Bacillus amyloliquefaciens, Bacillus licheniformis* and *Bacillus stearothermophilus*, can catalyze the degradation of starch to dextrin and maltose subunits, which can be easily washed

Corresponding Author:
Dr. Arti Nigam
Institute of Home Economics, University of Delhi,
New Delhi- 110 016,
Email: arti.nigam@ihe.du.ac.in

away or dissolved in hot water, and is thus appropriate for desizing [16].

It is better than chemical desizing, as amylase is specific only for starch, and thus does not damage the cellulosic fabric, allowing better strength retention. A temperature of 30-60ºC and pH of 5.5-6.5 is optimum for amylase desizing, and also water is saved as multiple washings are not required to remove the residual chemicals after desizing [17]. Incorporation of neutral cellulase with amylase improves wetability, dye uptake and reduces stiffness. Other advantages include safer handling of enzymes, no adverse effects on machinery, and a softer fabric [15].

2.2. Bioscouring

Non-cellulosic impurities like proteins, pectins, waxes, fats, minerals, natural colorants etc. are found in the primary cell walls of cellulosic fibers of the textile fabrics in different proportions. These limit the efficiency of dyeing and finishing, and result in a dirty appearance and poor wetability [18]. The removal of these non-cellulosic contaminants from the surface of cotton is called scouring, and it is conventionally done using strong alkali like sodium hydroxide [15].

Bioscouring is the use of microbial enzymes like cellulases, pectinases, proteases, and cutinases for selectively removing pectin and waxes from the cotton fabric. Cellulases produced by *Clostridium thermocellum* and *Trichoderma reesei* digest the cellulosic structures in the primary wall under the cuticle [19].

Pectinases produced by *Aspergillus niger* and *Tetracladium s*p. digest and remove pectin, waxes and non-cellulosic impurities from cotton by catalyzing the random hydrolysis of 1,4-α-D-galactosiduronic linkages in pectin substances, thus degrading the cuticle of the cotton fibers. The process is substrate specific and does not alter the cellulosic component [20]. Proteases produced by *Bacteroides fragilis*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Proteus* and *Propionibacterium acnes* catalyse the hydrolysis of proteinaceous contaminants from the cellulose fibers [21]. Cutinases are hydrolytic enzymes produced by *Fusarium solani, Streptomyces scabies* and *Pseudomonas putida* which degrade cutin and wax [22].

Bioscouring has many advantages over traditional scouring, as it is cost effective and eco-friendly and also reduces the total consumption of chemicals and possibilities of accidents. The Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Dissolved Solid (TDS) of bioscouring are much lesser (20-50%) than alkaline scouring (100%) [18]. Moreover, the finishing is very soft after bioscouring as compared to the harsh texture after alkaline scouring. Furthermore, bioscouring does not negatively impact the fabric, the environment, or the health of the workers [23].

2.3. Biobleaching

Bleaching of cotton fibers is done to decolorize the natural pigmentation provided by flavanoids, and to render the fibers a white color so that they can be later dyed according to demand. Conventional bleaching uses sodium hypochlorite, chlorine and hydrogen peroxide (H_2O_2). Too much of these can react with the fibers and result in decreasing the rate of polymerization and leading to severe damage [24].

Biobleaching is replacing these chemicals with enzymes, which causes less fiber damage and substantially saves the amount of water needed to remove the residual H_2O_2. It uses a combination of enzymes like pectinase, amyloglucosidases, glucose oxidases and laccases that provide a white color due to oxidation of flavanoids [25, 26].

The advantage of laccase is that it specifically acts on the indigo dyes of denims, and the natural raw white of weft yarn is retained, giving the woven fabric a darker shade, which cannot be achieved when bleaching with hypochlorite. This enzyme does not affect any other dye. The process is based on enzymes, so there is minimal risk of environmental pollution and toxic effluent discharge [27].

2.4. Biopolishing

Polishing is the finishing step to improve the quality of fabric. The pilling property and fuzziness of the cellulose fibers are removed by eliminating the microfibrils of cotton. When acidic cellulases from *Aspergillus, Penicillium* and *Trichoderma* sp. are used for polishing, the process is called biopolishing [28]. Biopolishing hydrolyses pills and breaks off the fiber, giving a smoother yarn surface, resulting in a clean, softer, cooler and lustrous feel [4].

2.5. Biowashing of Denims

Denim is a variety of heavy grade cotton, where dye is absorbed by the surface of the fiber, and thus fading is not indicative of loss of strength. Conventionally, potassium permanganate and sodium hypochlorite, known as pumice stones, were used to treat denims [24]. These methods had certain limitations, like back-staining, wear and tear to the fabric. These along with the huge quantities of pumice stones needed, gave rise to use of cellulases in denim washing. Cellulases loosen the indigo dye by Bio-Stonewashing. An advantage is the small amount of enzyme required. Laccase can also be used for denim washing [29, 30].

2.6. Effluent Treatment

The peak in the spread of textile industries has also increased the levels of water pollution as a result of unchecked release of dye-contaminated effluents into the water bodies. This not only causes loss in aesthetic value, but also causes major damage to the health of aquatic organisms, as most of these dyes are carcinogenic, mutagenic, and generally toxic. The textile effluents contain very high concentrations of these dyes (10-200mg/L), along with other pollutants like surfactants, dispersants, bases, acids, salts, detergents, oxidants and humectants, which make these effluents non-biodegradable. Thus, effective treatment of the textiles before being released into the environment is highly needed [31].

The available physio-chemical methods of dye decolorization are not suitable for large scale application in developing countries, as they have limitations like expensive chemicals, labor, and production of sludge as an end product, which needs further safe disposal. Thus, enzymatic methods are now preferred due to certain advantages, such as being eco-friendly, cost effective, and non-toxicity of end products. This technique of using biomass such as bacteria, actinomycetes, fungi, yeasts, algae and even plants for treating chemical pollutants is called bioremediation [32].

Ligninases such as laccases and peroxidases (Lignin Peroxidase and Manganese Peroxidase) obtained from white rot fungi such as *Phanerochate chrysosporium* and bacteria like *Serratia marcescens* are able to decolorize many synthetic dyes present in the textile effluents, such as reactive orange-16 upto 92.52% in 10 days, Reactive-107, Reactive-19, Ranocid Fast Blue and Procion Brilliant Blue-H-GR. *S. marcescens* can also decolorize real textile waste water, with dyes almost up to 82% [33, 34, 35].

2.7. Other Applications

The use of an engineered oxidatively stable Alkaline Protease produced by *Bacillus subtilis* and *Bacillus licheniformi*s has been reported, that can tolerate a range of operating temperature and pH conditions. It offers a flexible and alternative process for improved contrast of denim finishes, back staining clean-up and reduced residual cellulose of fabric [36].

Catalase, produced by *Aspergillus niger*, is used to clean the remnant H_2O_2 by conversion to oxygen and water, and also protects the fibers from oxidative damage by reactive oxygen species. These enzymes result in cleaner effluents and decreased water, energy and time consumption [4].

Proteases are also used in the textile industries for improving wool properties like handle and shrink resistance. In the processing of woolen textiles, transglutaminase produced by *Streptomyces mobaraensis* helps reduce the propensity of wool fabric to shrink, and maintains or increases fiber strength [37, 38]. This enzyme also allows amine or protein grafting to bring desired traits in wool fibers [39, 40, 41]. Esperase is a protease produced by *Bacillus luteus* that is responsible for wool shrink-resistance, whiteness and improved dye-ability [42].

Table 1: Biotechnological Applications of Microbial Enzymes in the Textile Industry

Enzyme	Microbial Source		Substrate	Biotechnological Application	Reference
	Bacteria	Fungi			
Amylase	*Bacillus coagulans*	*Aspergillus niger*	Starch	Desizing	[6, 16]
Catalase	*Staphylococci*	*Aspergillus fumigatus*	Peroxides	Clean remnant biobleaching solution	[47]
Cellulase	*Clostridium thermocellum*	*Trichoderma reesei*	Cellulose	Biostoning of jeans, Biopolishing, Carbonization of Wool	[44]
Collagenase	*Acinetobacter*	*Aspergillus*	Collagen	Modify Surface of Wool	[38]
Cutinase	*Thermobifida fusca*	*Fusarium solani*	Cutin	Bioscouring	[22]
Esterase	*Bacillus subtilis*	*Rhizomucor miehei*	Ester bond	Biobleaching and modification of surface properties	[49]
Glucose Oxidase	*Bacillus subtilis*	*Penicillium notatum*	Pigments	Biobleaching of Cotton	[48]
Laccase	*Pseudomonas putida*	*Trichoderma reesei*	Chromophores	Biobleaching, Textile Effluent Decolorization	[46]
Lipase	*Bacillus subtilis*	*Candela lipolytica*	Fats and Oils	Desizing	[45]
Pectinase	*Pseudomonas*	*Aspergillus*	Pectin	Bioscouring Cotton and Jute	[20]
Peroxidase	*Bacillus subtilis*	*Candida krusei*	Chromophores	Biobleaching	[46]
Protease	*Bacillus licheniformis*	*Aspergillus oryzae*	Protein	Bioscouring, Degumming of Silk, Modification of Wool	[21]
Transglutaminase	*Streptomyces mobaraensis*	*Candida albicans*	Protein	Reduce shrinkage of woollen fabric, increases the strength	[21]

3. Enzymes used in the Textile Industry

Microbial enzymes have gained a lot of importance as alternatives to chemicals in the textile industry, as they improve the economy of textile production as well as reduce pollution in the process. Enzymes used in the textile industries have been summarized in the following sections. Table 1 summarizes all the enzymes used in the textile industries along with their microbial producers.

3.1. Amylases

Amylases produced by *B. licheniformis, B. amyloliquefaciens* and *B. stearothermophilus* are used for desizing in the textile industries. Fungal amylases from *Aspergillus* can also be used for the same. Cotton and other blended fabrics use wrap threads coated with an adhesive known as 'size'. Size lubricates and protects the yarn from abrasion and prevents the threads from breakage during weaving. Starch and its derivatives have excellent film forming capacity, are relatively cheaper and are easily available, and are thus most commonly used in this process. Desizing is done after weaving to remove the non-cellulosic material present on the cotton fiber for dyeing and finishing. Alpha amylases are used as desizing agents due to their high specificity and because they do almost no damage to the fabric [16, 17].

3.2. Pectinases

A number of microorganisms isolated from the soil produce pectinases [5]. The pectinases produced by *Fusarium* are widely used in the textile industry. The backbone and the side chain of pectin are attached to impurities such as proteins and waxes, and the use of pectinases effectively degrades these pectins along with the impurities. This has reduced the use of hard chemicals, energy demand and usage of extra water. It breaks the pectin into low molecular weight soluble molecules while also improving the absorbance of the fibers [20, 25].

3.3. Proteases

Proteases catalyze splitting of protein molecules into amino acids. Proteases have been used for the improvement of wool properties like the handle and shrink resistance [42]. However, there is a little reduction in the tensile strength properties on the use of this enzyme, which is mitigated by the enzyme transglutaminase, that helps reduce the propensity of woollen fabric to shrink and maintains or increases the fibre strength [21].

3.4. Cellulases

Melanocarpus albomyces produces novel cellulases for the treatment of textiles at neutral pH. These are widely used in textile industry for the manufacture and finishing of cellulose containing textiles. Textile wet processing, biostoning of denim fabric, biopolishing of textile fibre, removal of excess dye from fabrics are some of the major applications of cellulases [43]. Biopolishing is the process of enzymatic treatment for improvement of cotton fibres. This prevents pilling out of other fibres, or forming a ball of fuzz, and giving a knotty and unattractive appearance to the fabric. Cellulases hydrolyse these pills and they break off the fibre, give a smoother yarn. Cellulases can also perform bio-stoning of denims. A number of cellulases are obtained from *Trichoderma* sp. The commercial preparation Celluclast is obtained from *Trichoderma reesei*, Denimax Ultra obtained from *Humicola* sp. Neutral cellulases also play an important role in this process by preventing back staining [44].

3.5. Lipases

Lipases hydrolyze triglycerides into diglycerides, monoglycerides, fatty acids and glycerol. Lipases catalyze both synthesis and hydrolysis of esters of long fatty acids and glycerol. Lipases remove size lubricants and enhance the dye-ability of the fabric. It also decreases the occurrence of cracks and streaks in denims [44]. Lipases along with alpha amylases are used for the desizing of denim and other cotton fabric at commercial levels. Synthetic fibres have been processed and modified by the action of enzymes in production of yarn, fabric, textiles etc [45].

3.6. Cutinases

Cutinase is used for wax removal or bioscouring of cotton fibre at low temperatures. Cutinases from *Fusarium solani* degrade and remove cotton waxes at a low temperature. Their degree of wax removal is comparable to solvent extraction in fifteen minutes. Cutinases remove waxes from cotton even in the presence of high concentrations of detergents. They also increase pectinase kinetics in terms of pectin removal from textiles fibres [22].

3.7. Peroxidases

These are the enzymes which catalyze the chemical reduction of the peroxides, mainly H_2O_2. Peroxides are part of the antioxidative protection system. These are used in dye bathing (decolorization of dye stuffs). A chemical bleaching with H_2O_2 or benzoyl peroxide is mandatory which may be replaced by peroxidase enzymes [46].

3.8. Other Enzymes

As seen earlier, many other enzymes also play a role in the textile industry. Transglutaminase produced by *Streptomyces mobaraensis* helps reduce the propensity of woollen fabric to shrink and maintains or increases the fibre strength [21]. Catalase produced by *Aspergillus fumigatus* is used to clean remnant biobleaching solutions containing peroxides [47].

Glucose oxidases produced by *Bacillus subtilis* are used in biobleaching, as they act on chromophores and transform them to colorless products [48]. Laccases from white rot fungi are used in biobleaching and to treat textile effluents as they have dye decolorization properties [45]. Ligninases (Lignin Peroxidase and Manganese Peroxidase) obtained from white rot fungi such as *Phanerochate chrysosporium* and bacteria like *Serratia marcescens* are able to decolorize many synthetic dyes present in the textile effluents [31].

Collagenase produced by *Acinetobacter* sp. has been reported to modify the surface of wool, indicating potential application in textile industries [38]. Esterase is another enzyme obtained from *Bacillus subtilis* that is used to modify surface properties of fabrics and also used for biobleaching [49].

4. Conclusions

Enzymes have proven to be a reliable and flexible alternative to the conventional chemicals used in textile processing. Properties like high substrate-specificity, faster rate of catalysis, and environment safety has resulted in enzymes replacing chemicals like sodium hydroxide, peroxide, and pumice stones etc. that were earlier used for processes like desizing, bleaching, scouring and polishing. Nowadays, enzymes like amylases, cellulases, pectinases, proteases, cutinases, peroxidases and lipases are used instead. Enzymes are not only advantageous for ecology, but also for economy, as a lot of money is saved by reducing water and energy consumption. Even though the apparent potential of enzymes in textile industries is constantly increasing, much such potential is yet to be explored.

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Development of Sustainable Biobased Binder for Pigment Printing on Natural, Man-made and Blends Substrates

A. N. Garje[1], R. D. Kale[2], R. V. Adivarekar[2] & R. N. Jagtap[1*]

[1]Department of Polymer and Surface Engineering Technology, ICT, Mumbai
[2]Department of Fibres and Textile Processing Technology
Institute of Chemical Technology, Mumbai

Abstract:
In view of the growing demand for sustainable material for textile and fashion industries, the author herewith has replaced a petrochemical-based binder system with a bio-binder system for the localised textile substrate's colouration. A novel biobased waterborne polyurethane dispersion system has been synthesised from castor oil (bio polyol), IPDI (diisocyanates), DMPA (emulsifying agent) and 1,3, butanediol (bio chain-extender). A castor oil-based polyurethane has been developed using different concentration of crosslinker for cotton, polyester and Cotton/Polyester blend (50:50) textile substrates. The physical and thermal parameters of the biobased polyurethane binder have been further analysed to ascertain the stability of the crosslinked films. Printed fabric performance has been analysed by colouration, bending, rubbing, scrubbing and fastness properties. As the crosslinker percentage increases in printed samples, we observe that improvement in the colouration, rubbing, scrubbing, and colour fastness properties and inversely affects fabric bending properties.

Keywords : *Bending, Biobased Material, Biobinder, Colour Fastness, Pigment Printing*

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1. Introduction:

The biobased materials defined biomass used for the partial or complete replacement and alternatives to crude oil-based materials [1], [2]. Biobased materials complement sustainable material, but all the material used as biobased chemistry need not be considered efficient and sustainable[3]. Therefore, the following different considerations for selecting biobased material land uses are competitive to edible products, deforestation, and all life cycles of that product like water, energy, and carbon[4]. It is crucial to select biobased material even after the material processability and atom economy constitute a significant factor[5].

In a selection of biomass of this study, we considered all the major parameters. The castor oil majorly produced in cultivated drought areas, deforestation and life cycle assessment shows a minimum impact on climate [6], [7]. Castor oil has an inherently present free hydroxyl group due to ricinoleic fatty acid accounts for the unique properties, making it a better candidate for chemical reactions, modifications and transformation [8]. Castor oil used without any modification makes them better candidates than any other green polyol candidates [9] [10]. The atom economy of castor oil-based polyol is higher than any other natural oil-based polyol [11]. A waterborne polyurethane dispersion chemistry is among the no contain or low contain volatile organic compounds making them more sustainable and environmentally compatible [12]. A castor oil-based polyurethane has good tuneable physical properties [13] [15].

Colourations of textile material are highly polluting and more visible in effluent load even at very low concentrations [16], [17]. The printing along with pigment considered as most versatile and sustainable among the current best available technology. A pigment printing shows minimal water pollution than other dyes printing in various application forms like screen prints, transfer prints and digital print. A petrochemical-based binder like acrylic, butadiene acrylonitrile, acrylic butadiene, carboxylated butadiene-acrylonitrile, styrene acrylate, polyurethane or its mixture used in solvent and waterborne chemistry[18] [20].

In modern screen, pigment printing methods used colouring matters, thickeners, binder, crosslinker and other auxiliaries [21][23]. A pigment binder should have fulfilled requirements like inexpensive, good colour yield, wash fast, easily polymerised, rubbing fastness, no stain build-ups, non-toxic, non-yellowing, soft, and stable application[24], [25]. The fastness property of cured prints majorly depends on the binder nature and crosslinking of a binder. A crosslinker improves the fastness properties of prints rubbing, scrubbing, and washing and crosslinkers affecting fabric handle properties [26], [27]. Textile printing binders have used the crosslinking agent like aziridine based, melamine-formaldehyde based and blocked isocyanate based crosslinkers [10], [28]. Among the man-made fibres and natural fibres, polyester, cotton, and blends have the highest share in textile apparel consumptions.

In this work, the pigment screen printing has studied with pigment, thickener, polyurethane dispersion with different

***Corresponding Author:**
Prof. R. N. Jagtap
Department of Polymer and Surface Engineering Technology
Institute of Chemical Technology, Mumbai
Email- rn.jagtap@ictmumbai.edu.in

concentration of crosslinker effect on colour and physical properties. Pigment prints applied on cotton, polyester, and cotton/polyester blends with the same recipe for better understanding. The printed textile substrates were evaluated for bending, rubbing, scrubbing, washing and perspiration fastness.

2. Material and Method

2.1. Material

Castor oil (CO, LR grade), and triethylamine (TEA, AR) purchased from SD Fine Chem Ltd (India). Biobased 1,3-butanediol (1,3-BD, LR grade) provided by Godavari Biorefineries Ltd (India). 2,2-Bis(hydroxymethyl) propionic acid (DMPA, AR) purchased from Sigma-Aldrich (USA). Isophorone diisocyanate (IPDI, AR), was purchased from TCI (Shanghai) Chemical Ind. Co., Ltd. Dibutyltindilaurate (DBTDL, AR), and acetone obtained from Amrut Industrial Products (India). Pigment Orange (SBG) received from Sohan Dye-chem (India). Ready for dyeing polyester fabric (100%) (GSM 60, EPI 80, PPI 84), Polyester/Cotton blend (50:50) (GSM 160, EPI 56, PPI 52), and cotton (100%) (GSM 110, EPI 90, PPI 64) purchased from the local market. CHT India Pvt provided Tubicoat ASD 60 (synthetic thickener) and MF200 (60.0 wt%) (Partially etherised N-methoxymethyl melamine crosslinker) CHT Ltd (India). Acetone dehydrated with 4 Å molecular sieves and DMPA dried at 80°C for moisture removal. Other chemicals used without any further purification.

2.2. Synthesis of polyurethane dispersion

A glass reactor equipped with a motorised stirrer, temperature controller, and condenser constant nitrogen supply for the inert atmosphere. The IPDI with OH/NCO ratio of 1:1.4 dropwise addition into a CO polyol in the presence of acetone to avoid uncontrolled exotherm at room temperature. After completing diisocyanate addition, a reaction carried out the heating rate at 2° C/min for 60°C. After that, DMPA and DBTDL (0.02%) were added a homogenous mixture in the reaction was carried at 78°C with a 1°C/min rate. The polymer synthesis was carried out at 80°C at the heating rate of 1°C/min for 90-120 min, after reaching theoretical isocyanate value with back titrated isocyanate value ISO105-E04. The pre neutralisation of reactants (100%) was carried out at 50°C for 20 min by adding TEA. Chain extension carried out with 1,3 butanediol after pre-neutralisation, followed by reverse dispersion in distilled water using a high-speed disperser [29]. Polyurethane dispersions solids content adjusted to 20.0 wt % after removing the acetone, and then the pH was adjusted to 8. The total green renewable material used for the preparation of bio-binder was 58.6%.

Table 2.1. Chemical composition of polyurethane dispersion

Sr. No	Chemicals	% Weight (pbw)	Mole (M)
1.	Castor Oil	54.5	0.486
2.	IPDI	35.55	1
3.	DMPA	5.04	0.2282
4.	1,3 Butanediol	4.10	0.2858

2.3. Preparation of printing pastes and films

Printing paste enables the formation of the localised colouration with predefined areas. A screen table printing method used for printing on textiles. A homogenous printing paste with constant viscosity was prepared. The pigment printing pastes prepared according to the following recipe is described in table no 2.2.

Cast films were prepared by casting the polyurethane dispersion with a crosslinker (0%, 10%, 20%, and 30% on a total weight basis) on a Teflon smooth surface plate and dried at ambient temperature. After complete drying, the films were further cured in an oven at 150°C for 5 min.

2.4. Printing techniques

A homogenous printing paste was printed on different fabrics using the flat-screen technique. The printed fabrics dried at 90°C for 3 min, and thermal fixation carried out at 150°C for 5 min in stenter. The printed fabric further tested and analysed without any washing or post-treatment. The printing screen parameter for all samples was 100% coverage with 120 threads per inch mesh size. The printed fabrics coded as per table 2.3.

Table 2.2. Printing paste composition with a different concentration of crosslinking agent

Ingredient	Recipe 1	Recipe 2	Recipe 3	Recipe 4
MF Crosslinking agent	0	1	2	3
PUD	30	30	30	30
Pigment	1	1	1	1
Thickener	1	1	1	1
Distilled water	68	67	66	65
Total	100	100	100	100

Table 2.3. Sample coding

Recipe	Fabric	Sample Coding
Blank	Polyester	PET 0
Recipe 1	Polyester	PET 1
Recipe 2	Polyester	PET 2
Recipe 3	Polyester	PET 3
Recipe 4	Polyester	PET 4
Blank	Cotton	COT 0
Recipe 1	Cotton	COT 1
Recipe 2	Cotton	COT 2
Recipe 3	Cotton	COT 3
Recipe 4	Cotton	COT 4
Blank	Polyester / Cotton blend	PCB 0
Recipe 1	Polyester / Cotton blend	PCB 1
Recipe 2	Polyester / Cotton blend	PCB 2
Recipe 3	Polyester / Cotton blend	PCB 3
Recipe 4	Polyester / Cotton blend	PCB 4

2.5. Measurement and analysis

2.5.1. Evaluation of polyurethane dispersion and films

Acetic anhydride-pyridine method ISO 4629-1978 (E) used to evaluate the hydroxyl number of polyols. ISO 105 – EO4

1994 (Method A) back titration test method followed for the isocyanate values. A Polyurethane dispersion pH measured on model SV3T, Arvind Industries Ltd. (India). A NanoPlusS particle size analyser and Zeta sizer-2590 measure particle size and zeta potential using a dynamic laser light scattering principle.

FTIR spectra of the cured films recorded on a Bruker ATR spectrophotometer (USA) range from 400- 4000 cm^{-1} and a resolution of 4 cm^{-1}.

Thermogravimetric analysis (TGA) of the films tested on Shimadzu DTG-60H, Japan instrument in the temperature range of 40–500°C using 10°C/min of rate under an inert nitrogen atmosphere. Differential scanning calorimetry (DSC) experiments performed on TA DSC Q100 V6.2 instrument, Japan in -40 to 200°C range with a rising temperature of 10°C /min under nitrogen gas.

2.5.2. Evaluation of physical and colour fastness properties of the printed fabric

The surface topography analysed by laser scanning principle using Olympus DSX1000 models.

The stiffness of printed and control samples was determined according to ASTM D1388-96 using Shirley stiffness tester (Option A). The conditioned printed samples colour depth analysed by measuring the reflectance values on a computer colour matching system using spectra scan 5100+ spectrophotometer (India, Mumbai). Rubbing fastness determined on standard ISO 105-X12:2016 crock meter of James R. Heal & Co Ltd, England. The wet scrubbing of printed textile tested as per standard IS/ISO 105-C07: 1999 on Wet Abrasion scrub Tester (Raj Scientific Ltd, India). The colour fastness to washing of printed samples determined as per IS/ISO 105-C10: 2006 (Test no. 2) on labtech laundr-o-meter (Rossari Ltd, India). The perspiration fastness of the samples was measured in acidic and alkaline conditions according to ISO 105-EO4 1994 on a perspirometer (SASMIRA, India).

3. Result and Discussion:

3.1. Particle size and zeta potential analysis of polyurethane dispersion

A synthesis of waterborne polyurethane dispersion polymer internal emulsifying agent helps stabilise the polymer in an aqueous medium after neutralisation. Herewith, the minimum amount of internal emulsifying agent to achieve stable dispersion. The average particle size and zeta potential of polyurethane dispersion of 5% DMPA added in the formulation obtained 598 nm and -54.5 mV, respectively. Average particle size distribution and negative zeta potential show good stability of polyurethane dispersion. The dispersion stability further analysed under accelerated study on centrifugation for 30 min at 3000 rpm after this dispersion was uniform with no coagulation occurring at the bottom of the tube. Overall the above results conclude that the dispersion was stable, and extended storage calculates over 18 months validated stability[30].

3.2. FTIR analysis of films

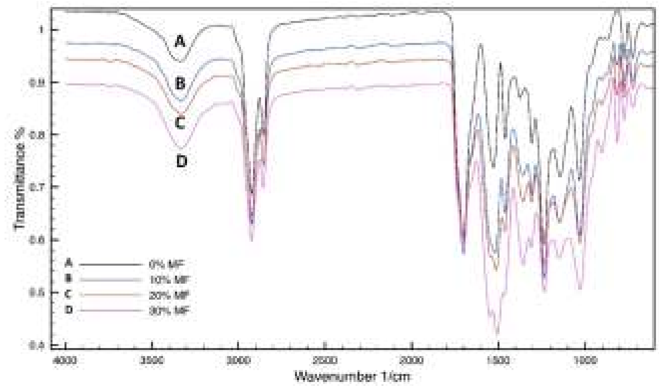
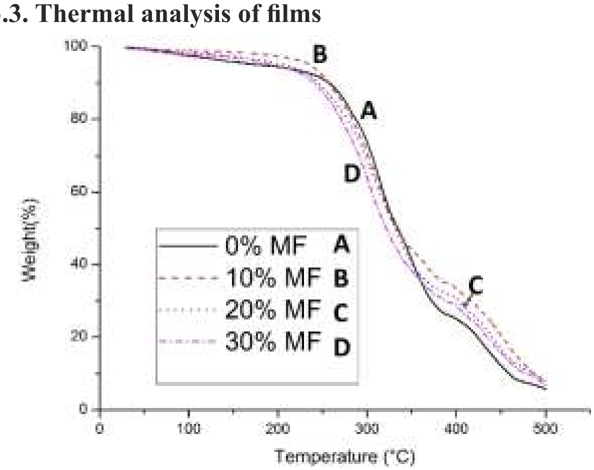


Figure 1. FTIR spectrum of cured polyurethane films

Wavenumber (cm^{-1})	Associated functional group
3200-3600	-OH stretching vibration band and amino group -NH stretching vibration band
2902 1702 1505-1515	-CH_3 stretching vibration films -C=O stretching N–H (primary amine) stretching
1550-1650	C=N stretching
814-820	triazine bending

After evaporation of water, films get cured homogeneous films with polyurethane and crosslinker solutions that show excellent smooth and transparent film-forming ability. Figure 1 shows that an absence of a peak at 2270 cm−1 assigned to the NCO group at all the MF concentrations indicated that the isocyanate's NCO groups had reacted entirely. The peaks assigned to -NH (stretching), -C=O (stretching), and –NH (bending), at 3353, 1703, and 1530 cm^{-1} were observed, respectively, it proving the formation of polyurethane chemical structure. The isocyanate group also showed the typical peaks at 2922 cm^{-1} and 2855 cm^{-1} due to C-H stretching of CH_2 and CH_3 groups. With the increases in melamine resin content, the relative intensity of –NH stretching, C=N stretching and, triazine bending resultant increased the absorption. This FTIR interpretation confirmed that the melamine has reacted and crosslinked during the thermal curing.

3.3. Thermal analysis of films



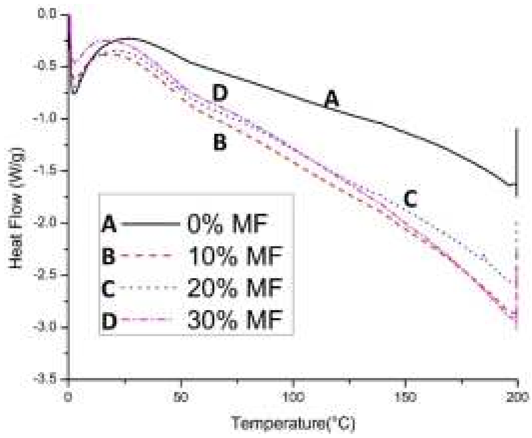


Figure 3. DSC of cured polyurethane films

The thermal degradation of crosslinked and non-crosslinked polyurethane binder materials illustrated in figure 2. The thermal stability of polyurethane depends on the concentration of soft and hard segments and its segment length. The crosslinker also affects the thermal stability and the final film morphology[31].

The castor oil-based polyurethane showed higher thermal stability than the other melamine crosslinked films. The typical two-stage thermal degradation of polyurethane occurred in all the films. The first stage degradation of MF/PUD shifted to lower temperature as melamine resin content increased[32][33]. The significant weight loss happened at 220 to 400°C temperature range for all the blend films. The second stage of degradation beyond 370°C decreased compared to the first stage of degradation of films. Towards the end of degradation above 450°C, the degradation became very low.

The DSC curves of non-crosslinked and crosslinked films shown in figure 3. The glass transition temperature (Tg) increased from 47.67 to 52.43°C as the crosslinker concentration increased. The higher amount of melamine-formaldehyde condensate in films led to the backbone crosslinking and hydrogen bonding between polyurethane and crosslinker, restricting the polymer chain movement. Crosslinked films are not showing any exotherm curve in the DSC graph up to 200°C. Above thermal DSC and TGA analysis concluded the complete reactions of melamine formaldehyde and polyurethane polymer backbone and network formations.

3.4. Effect of crosslinker concentration on Colour and K/S values

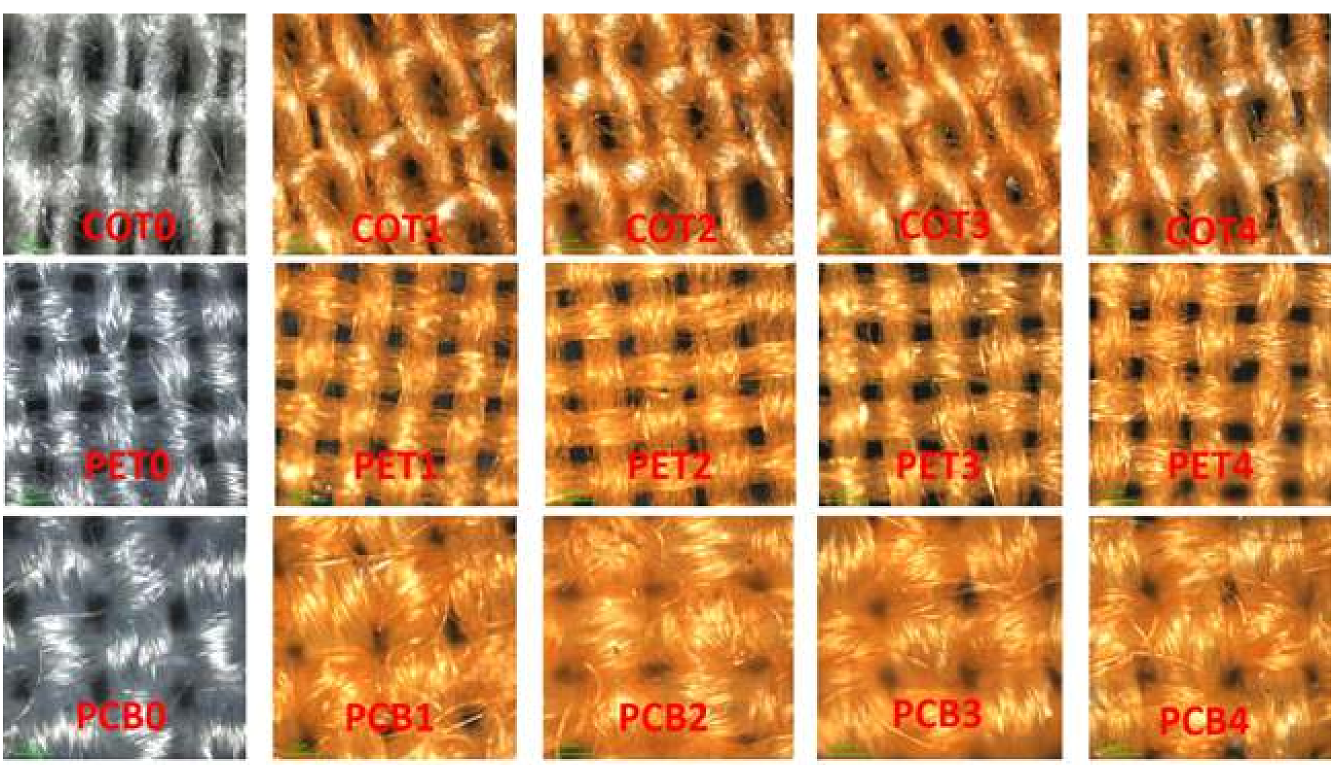


Figure 4 Microscopic images of the printed fabric

Table 3.1. Evaluation of Colour Strength

Sample	L*	a*	b*	K/S
PET 1	67.059	24.511	20.353	46.046
PET 2	67.617	24.191	20.674	49.677
PET 3	68.236	25.411	20.937	57.099
PET 4	68.912	24.734	21.312	60.835
COT 1	74.035	24.005	21.431	28.584

Sample	L*	a*	b*	K/S
COT 2	74.731	24.642	21.772	35.39
COT 3	75.143	25.016	21.987	36.965
COT 4	75.255	24.88	21.982	39.167
PCB 1	72.706	28.655	22.787	44.463
PCB 2	72.065	27.55	22.52	44.721
PCB 3	73.431	28.084	23.179	48.304
PCB 4	73.50	27.548	23.226	50.866

In figure 4 were analysed the even distribution of printing paste and complete immersion on the printed surface irrespective of substrates. The K/S and colour value of printed fabric measured at an integrated wavelength, and the results shown in table 3.1. The colour values and absorption strength of printed fabric depend on printed paste on the textile substrate's surface, total solids and other additives present in printed films. A Colour strength of printed fabric measured in K/S at integrated wavelength. A melamine-formaldehyde content in printing paste improves the depth of the printed surfaces irrespective of the substrate. A polyester fabric showing a higher colour depth compare to blended and cotton fabric. Castor-based polyurethane films are duller than the crosslinked fabrics; as crosslinker concentration increases in the printed surface, it becomes brighter prints. As the crosslinker concentration increases in paste simultaneously, the fabric becomes yellower and redder in colour values. Colour strength measured in K/S shows that the melamine crosslinker substantially affects colour strength as the crosslinker increases a K/S on the higher side[18].

3.5. Effect of crosslinker concentration on bending properties

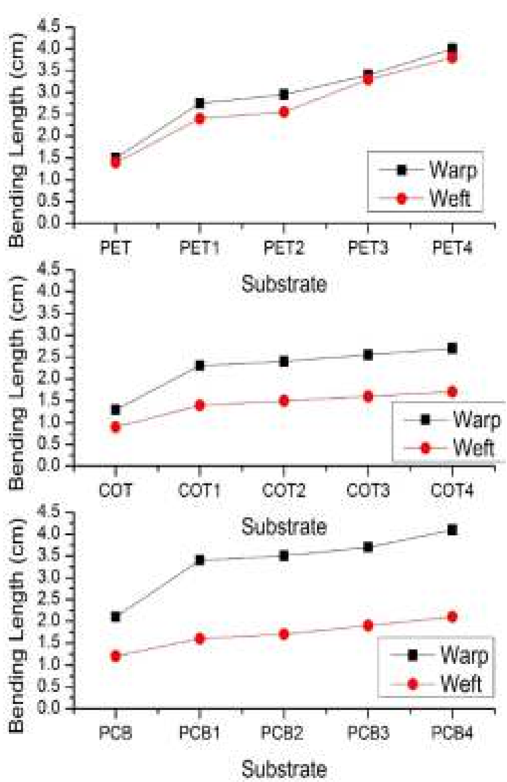


Figure 5 Bending length of the printed fabric

The bending length of printed fabrics shown in Figure 5. The bending length of all the substrates increased in both warp and weft direction, making the stiffer fabric. A typical woven fabric had a lower bending length at the weft direction than warp direction due to higher yarns density. The addition of a crosslinker increases the bending length irrespective of warp and weft directions. Cotton, polyester, and blend fabric initial bending length entirely depends on its construction and linear weight of fabrics. As the crosslinker increases into a print paste, the bending length of warp and weft fabric simultaneously increases; the rise in the stiffness was highest with 30% melamine formaldehyde irrespective of a substrate. Crosslinker was adversely affecting the bending length of fabric, which indicates the stiffness of the fabric. Bending length one of the primary indicators of fabric handle properties.

3.6. Effect of crosslinker concentration on rubbing fastness and wet scrubbing fastness

Table 3.2. Effect of the crosslinker agent on rubbing fastness and wet scrubbing properties of printed samples (Rating Parameter 1-Poor and 5-excellent)

Sample	Rubbing fastness		Wet Scrubbing fastness (50°C for 50 cycles)
	Dry	Wet	Greyscale rating
PET 1	4	3-4	3
PET 2	4-5	4	3-4
PET 3	4-5	4-5	4
PET 4	5	4-5	4
COT 1	3-4	3	2-3
COT 2	4-5	4	3-4
COT 3	4-5	4-5	4
COT 4	4-5	4-5	4
PCB 1	4	3-4	2-3
PCB 2	4-5	4	3-4
PCB 3	4-5	4-5	4
PCB 4	5	4-5	4

Rating:1-Poor and 5-excellent

In table 3.2. shows the rubbing fastness and scrubbing fastness properties of printed samples. The rubbing fastness depends on binder elasticity, adhesion on the textile materials and uneven dispersion of the pigment in the print paste.

However, wet rubbing fastness was inferior to dry rubbing fastness as the coefficient of friction is higher than dry rubbing tests. As a crosslinker content in printed sample increases, wet rubbing and wet scrubbing fastness show a significant improvement in fastness properties. The improvement in wet rubbing and scrubbing is higher in polyester fabric, followed by blend and cotton fabric.

3.7. Effect of crosslinker Concentration on colour fastness to washing and perspiration

Table 3.3. Colour fastness to washing

Sample	Washing Fastness						
	Grey Scale	Staining Scale					
	Change in colour	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
PET 1	4-5	5	5	5	5	5	5
PET 2	4-5	5	5	5	5	5	5
PET 3	4-5	5	5	5	5	5	5
PET 4	4-5	5	5	5	5	5	5
COT 1	4-5	5	5	5	5	5	5
COT 2	4-5	5	5	5	5	5	5
COT 3	4-5	5	5	5	5	5	5
COT 4	4-5	5	5	5	5	5	5
PCB 1	4-5	5	5	5	5	5	5
PCB 3	4-5	5	5	5	5	5	5
PCB 3	4-5	5	5	5	5	5	5
PCB 4	4-5	5	5	5	5	5	5

Rating:1-Poor and 5-excellent

Table 3.4. Colour fastness to perspiration

Sample		**Perspiration fastness**						
		Grey Scale	Staining Scale					
		Change in colour	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
PET 1	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PET 2	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PET 3	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PET 4	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
COT 1	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
COT 2	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
COT 3	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
COT 4	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PCB 1	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PCB 3	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PCB 3	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5
PCB 4	Acidic	5	5	5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5

Rating:1-Poor and 5-excellent

The washing and perspiration fastness properties of the printed fabrics gave excellent colour fastness properties shown in table 3.3. and 3.4., irrespective of the crosslinker content in pigment printed samples. The pigment printed sample does not show any cross staining on the adjacent multi-fabric.

1. Conclusion:

Based on the results and discussion shown above, the following conclusion could draw:

The castor oil-based waterborne polyurethane dispersion study showed good stability and performance and homogenous transparent film properties. The castor oil-based polyurethane dispersion shows good colouration properties with good adhesion to natural, synthetic, and blend fabrics for pigment printing. The addition of a crosslinker improves the wet rubbing and wet scrubbing properties of the printed sample but inversely affects the textile substrate's physical properties. The addition of a 10% crosslinker improves rubbing and scrubbing fastness with minimal, adverse affecting handle properties. Colour fastness properties like washing and perspiration make waterborne castor oil-based polyurethane a promising material for future green industrial printing material and be a viable substitute for fast fashion garment materials.

Acknowledgements

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Encapsulated Kapok fibre for Detection and Removal of Mercury from Wastewater

Aprajita Singh Tomer & Dr. Ashok Athalye*
Department of Fibres and Textile Processing Technology, Institute of Chemical Technology, Mumbai

Abstract
Mercury is considered as a lethal metal due to its health hazards like neurological poisoning in organisms caused by its consumption. Various reasons like natural calamities and industrial pollution cause mercury contamination of water bodies. This work attempts to create a dual-purpose system consisting of a filtration unit packed with optical sensors for the detection and decontamination of dissolved mercury ions. The filtration membrane is made of chemically modified fluorescent kapok fibre encased within alginate fibre loaded with Gold nano-clusters to enable the decontamination and detection of dissolved mercury ions via photoluminescence. The entire arrangement is expected to have three fold decontamination of the waste water. The materials and process are entirely sustainable.

Keywords: *Kapok Fibre, Mercury adsorption, Optic Sensor, Sustainable Solution, Waste Treatment*

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1. Introduction

Mercury is a naturally occurring metal that is found either in the organic or inorganic state dissolved in water. It is its organic form (methylmercury) that is considered to be lethal as it is not possible to eliminate or metabolise once it enters an organism's body. Moreover, after entering the food chain, it undergoes biomagnification and hence the toxicity level due to mercury in the body of an apex predator is ten times higher than that in the body of an organism that first consumed it. [1,2] Studies have shown that high mercury levels in the body of humans tend to cause health ailments such as cell damage, inhibition of enzyme activity, impairment of pulmonary function and kidney performance, chest pain, and central nervous system damage. So far the only cure for acute mercury poisoning is chelation therapy but it cannot be carried out for poisoning in children, pregnant women, and people with pre-existing heart conditions. Moreover, it has adverse side effects on the patients. [3]

The primary sources responsible for the emission of mercury in water include effluents discharged from industries like oil refineries, chloro-alkali chemical facilities, paper and pulp industries, mines, electroplating and paint industries, pharmaceuticals and battery manufacturing. [4] In India, the permissible limit for mercury in water in any form is 0.001 mg/L for drinking water and 0.01 mg/L for effluents. But the ground reality of the extent of mercury contamination in our water resources surpasses this limit by manifolds. In recent surveys, mercury contamination levels of 0.058-0.268 mg/L have been observed which are extremely lethal. [5]

A number of techniques have cropped up in recent times to mitigate the accumulation of mercury both in effluents and marine environments. Out of these methods, adsorption is a widely used technique employed for the removal of mercury. In this study, surface modified kapok fibres are used to adsorb dissolved mercury ions. One of the primary objectives of this study is to ensure that the entire process of creating as well as disposing of the unit is sustainable. For this reason, dopamine solution was used for the surface modification of Kapok fibres.

***Corresponding Author:**
Dr. Ashok Athalye
Department of Fibres and Textile Processing Technology,
Institute of Chemical Technology,
Nathalal Parekh Marg, Matunga (East),
Mumbai – 400 019
ar.athalye@ictmumbai.edu.in

Kapok being a natural fibre, found in abundance became the principal choice due to its numerous advantages. It is a highly undervalued fibre whose chief usage is limited to stuffing in beddings, furniture, upholstery, life preservers or other marine life-saving devices.[6] Moreover, upon reaching maturity it has been observed that the kapok fibre drifts away and becomes a cause that adds onto to the issue of air pollution. Therefore, any utilisation of kapok fibre proves to be extremely useful as it helps in mitigating multiple issues. Kapok's inherent structure makes it an excellent adsorbent. It has a characteristic hollow structure with a wax coating on its outer surface. The wax coating renders it the property of hydrophobicity while its hollow structure is responsible for its exceptional ability of adsorption. Moreover, the fibre consists of multiple modifiable hydroxyls which enable easy modification of the surface of the fibre. This allows the utilisation of this fibre for the elimination of various contaminants from the water. Dopamine solution was chosen to modify the surface of kapok fibre as it extensively increased the mercury adsorption capacity. The reason for this is the fact that dopamine undergoes self-polymerisation in 3-D structure which then induces functional groups on the surface of the fibre. These groups then bind the mercury ions thereby eliminating them from the concerned sample. [7]

The distinctive part of this project involved the inclusion of a sensory function that enabled detection of the presence and extent of mercury contamination in the sample. Further, gold nano-clusters were utilised as they exhibit bright photoluminescence. These clusters form the basis of mercury detection as they interact with the ions through metallophilic bonding of their 5d10 electrons which cause quenching of the photoluminescence of the unit, thereby depicting the presence of mercury contamination. The path chosen for the production of these nano-clusters was a protein-based synthesis. The reason being that this process results in really bright photoluminescence, has negligible toxicity, exhibits great biocompatibility and chemical stability and is a relatively easier process to synthesise.[8] Chicken Egg White (CEW) was utilised as a sustainable green reducing agent in the protein synthesis of gold nano-clusters. It is aimed to create a system that has the adsorption unit as its core surrounded by the photoluminescent sensor embedded within a framework having a UV light attached to it. The core is created using kapok fibres whose surface have been modified using dopamine solution When this arrangement is subjected to mercury enriched water sample, and as the mercury ions are adsorbed by the kapok core, the sensory unit exhibits red fluorescence in the presence of UV light.

2. Materials and Methods

2.1 Materials

Raw Kapok Fiber, Dopamine (DA), Mercury Sulphate, Tris-hydrochloride, Fresh chicken eggs, Tetrachloroauric (III) acid (HAuCl4.3H2O, N99%), Sodium Hydroxide (NaOH, ≥98%), Hydrochloric acid (HCl 1M), Calcium chloride (CaCl2, N 96%), Sodium Alginate**.**

2.2 Methods

2.2.1 Preparation of aqueous solution of Mercury:

Take mercury sulphate and dry it at 120^0 C for two hours. Take the dried mercury sulphate and dissolve it in distilled water. Move this solution to a one-litre volumetric flask. Dilute the above solution and shake well. Prepare different concentrations of mercury ion aqueous solution using this (preferably, 1N, 5N, 10N and so on).

2.2.2 Surface modification of Kapok Fiber:

Dissolve 2 gm dopamine into 0.1 ml/l of tris-hydrochloride buffer solution at pH of 8.0. Upon complete dissolution, 100 ml of this solution is taken and 0.2 gm of the kapok fibre is submerged in it. This arrangement is constantly stirred for about a day post which the dipped kapok fibre is found to be coated with polydopamine. This is then washed using deionised water and finally dried at1 60^0 C in vacuum.

After modified Kapok fibre is obtained its surface is compared with a raw and unaltered kapok fibre with the help of a field emission scanning electron microscope (FE-SEM) and a Fourier Transmission Infra-Red (FTIR) spectrophotometer to study and compare the deposition of dopamine on the modified kapok fibre.

2.2.3 Preparation of Fluorescent Fiber:

The first step in this part is to separate the egg whites from chicken eggs and mix 10 ml of it with 5 ml of an aqueous solution of 0.01 M Chloroauric acid (HAuCl4). The mixture is continuously stirred for about 5 minutes and further mixed with 2 ml of an aqueous solution of 1 M Sodium Hydroxide, stirred for 5 minutes and then incubated for 24 hrs at 37^0 C. after complete incubation. The sample is then lyophilised (freeze dried) for one day to obtain a composite powder which exhibits a red fluorescence at 365 nanometres under ultraviolet radiation.

2.2.4 Preparation of AuNCs@CEW-loaded Alginate Fibre:

This is created by first dissolving 2 gm of sodium alginate in 50 ml of deionized water. Then adding 0.4 gm of gold nano-clusters obtained from chicken egg white in Part A. The mixture is allowed to stabilise for 4 hrs to ensure that any air bubble present in it is eliminated. Take 10 ml of this mixture to a syringe and inject into the coagulation bath consisting of a 5% solution of calcium chloride. The spun gel fibres thus obtained are then thoroughly washed to get rid of the calcium ions. The fibres are then dried.

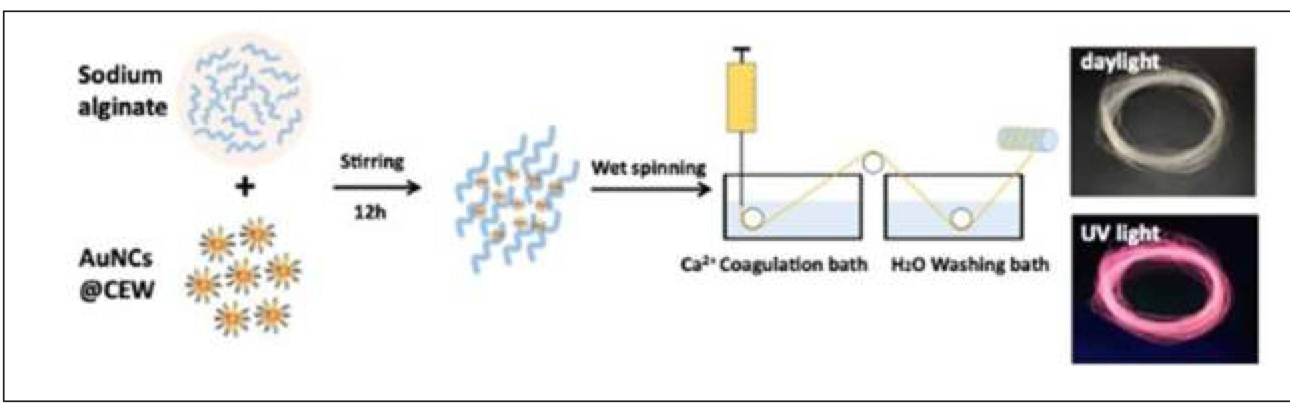

Figure 1: Schematic diagram of preparation of AuNCs@CEW-loaded alginate fluorescent fibre

2.2.5 Combining the Two Fibres:

A mesh is created with the Gold nano-cluster sodium alginate fibres around a layered arrangement of modified kapok fibre, as shown in the figure below. Red signifies Fluorescent Fibre (FF) while blue is for Dopamine modified Kapok fibre (DKF).

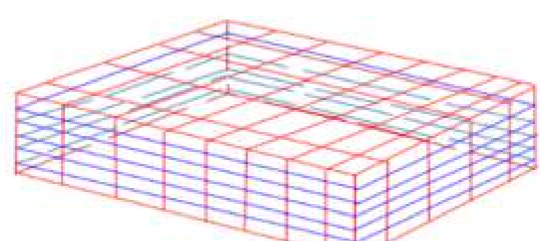

Figure 2: Schematic representation of the DKF-FF arrangement

2.2.6 Adsorption Study:

The study of mercury ion adsorption by dopamine modified kapok fibre (DKF) and comparison with the raw kapok fibre is done by taking 100 ml of mercury sulphate solution in a flask and placing 0.1 gm of fibre. The solution is stirred for 2 hrs at room temperature using a flask shaking incubator. The solution is then analysed for the presence of mercury ion using atomic absorption spectrophotometer (AAS).

2.2.7 Sensing Performance of Fluorescent Fibres:

The alginate FF fibres are kept for 2 days in a container consisting of ultrapure water to determine the fluorescence stability of the alginate fibres which is vital to study before we look into the sensing ability of these fibres. Then the FF is placed in a quartz vial consisting mercury ion solution for 10 min and dried at room temperatures. The FF is then exposed to a radiation of wavelength ranging from 535 nm to 900 nm and the photoluminescence spectrum is recorded. Based on these recordings, the fluorescence intensities that were measured were 666 nm.

2.2.8 Determining effect of pH:

In this part of the study different mercury ion solutions are prepared with each having a different pH. The pH of the samples is adjusted between 2 to 10 using varying concentration of hydrochloric acid (1M) and sodium hydroxide (1M). The initial concentration of mercury is noted to be 70 mg/l before adsorption, after which the arrangement is lowered in these samples. The arrangement was removed after two hours and the remaining water was analysed for mercury ion concentration.

2.2.9 Reusability of the Unit:

In order to check the reusability factor of the DKF-FF arrangement, it is thoroughly rinsed using deionized water once the adsorption process reaches equilibrium. Then to desorb the mercury ions that have been eliminated by the fibre matrix arrangement it is treated with 100 ml of 1M HCl at room temperature and the flask is shaken for 2 hrs. Then it is dried and reused to adsorb mercury ions. The extent of adsorption is observed and the aforementioned process is carried out again. This cycle is repeated up to 8 times.

3. Results and Discussion

3.1 Characterisation of DKF:

The DKF has a rough and uneven surface attributed to the process of 3-D polymerization that Dopamine solution undergoes upon coming in contact with the surface of Kapok fibre. This is expected to have a 2 fold mechanism as it consists of an intermediate form which is 5,6-dihydroxyindole. Apart from this certain functional groups also contribute to the structural change of the surface of Kapok fibre. Of these, a quinone structure is observed which is formed due to the oxidation of catechol groups present in dopamine. This enables further reaction with amines and other quinones / catechols which is the primary cause for the formation of an adherent polydopamine film on the surface of the Kapok fibre. This film can be considered as an inter as well as an intra- polymer network. Such type of network also referred to as IPN forms a fishnet structure that is responsible to easily entrap the mercury ions present in the samples.[9] When the FTIR Spectra of raw and DKF was compared, the peaks at wavenumbers 3341 cm^{-1} and 1035 cm^{-1} were heightened. The reason for this could be attributed to the successful introduction of dopamine on the fibre's surface. Moreover, due to this introduction, the process of self-polymerization took place which enabled multiple groups like carbonyl, aromatic rings, C-N and C-O bonds onto the surface of the Kapok fibre. This resulted in increased wavenumber peaks of the dopamine modified Kapok fibre as compared to Raw Kapok Fibre (RKF) in their FTIR spectra.

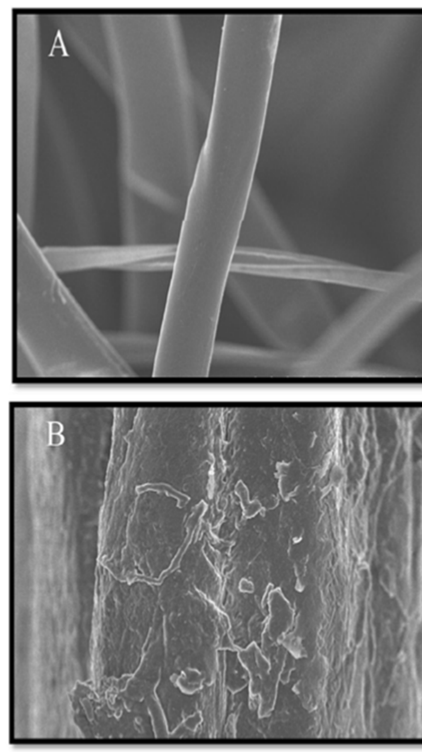

Figure 3: SEM image of raw kapok fiber B. Dopamine modified kapok fiber

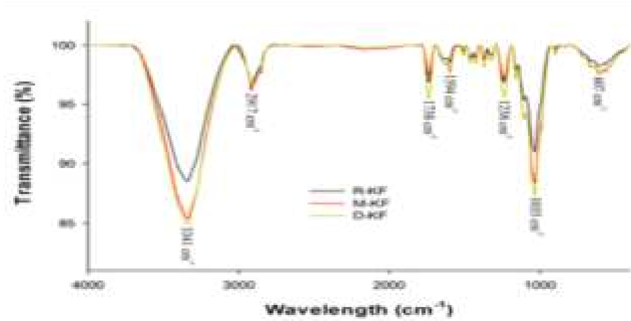

Figure 4: FTIR spectra of R-KF, M-KF, and D-KF after baseline collection

3.2 Sorption study of Mercury ions on DKF :

The kinetic studies of the mercury ion adsorption of DKF using FTIR is shows significant reduction at 3341 cm^{-1}. This indicates chemisorption of mercury ions due to the presence of dominating hydroxyl groups which were results of dopamine coating on the surface of kapok fibre. This arrangement was able to adsorb about 99 % of mercury present in the water samples. As represented in the schematic diagram below, most of the adsorption of mercury ions on the surface was homogeneous and these ions were observed to have a bidentate reaction with the hydroxyl groups on the surface. This bidentate reaction was due to the 3-D polymerisation of dopamine via chelating bonds. There occurs an instantaneous oxidation reaction of catechols present on the surface which converts them into quinones. [10] This causes reduction of the entrapped, in situ mercury ions (Hg^{+2}) to their metallic state (Hg^{0}). In the case of raw kapok fibre, this phenomena is not experienced which makes dopamine modified kapok fibre more environmentally friendly and effective.

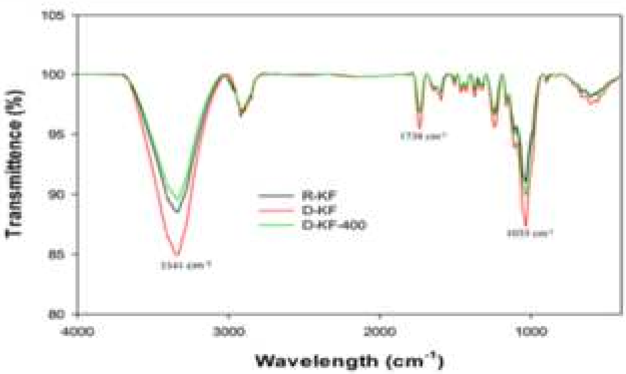

Figure 5: FTIR spectra of R-KF, D-KF, and D-KF-400 after baseline correction

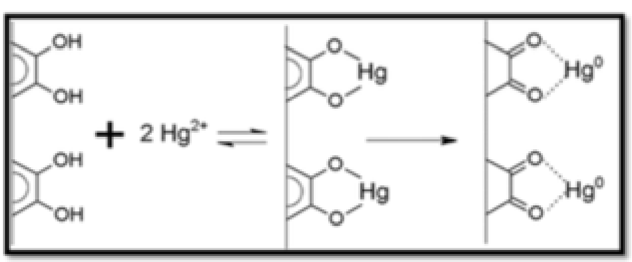

Figure 6: A schematic of the bidentate adsorption of mercury ions with DKF

3.3 Effect of pH:

It is observed that there was only a specific pH range in which our arrangement (DKF-FF systems) proved to be most effective. This range starts from pH 5 through pH 9 and the sorption process is strongest at a pH of 8. At lower pH, there is a competition between the hydrogen and mercury ions present in the samples which cause the efficiency of the DKF to reduce drastically. At pH of 8, the hydrogen ions present in the sample are neutralised by the hydroxyl groups present on the surface of the fibres. This causes the efficiency of the mercury adsorption process to reach its maximum. pH of above 9 is detrimental to the surface of the DKF as it cause destruction of the sites present on the surface which in turn would lead to a decrement in the efficiency of the adsorption process.

3.4 Recyclability of Adsorbent:

The recyclability test showed that even after 3 times of usage efficiency of the entire arrangement (DKF-FF system) retained about 90 % efficiency.

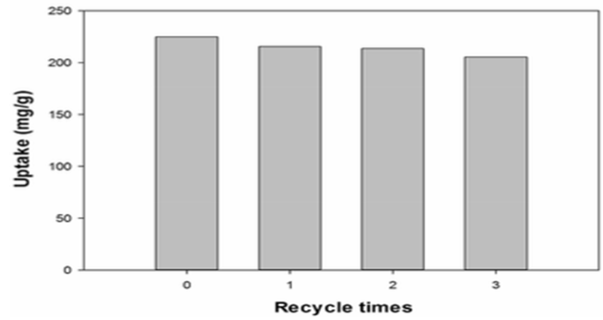

Figure 7: Mercury adsorption after recycling of DKF-FF

3.5 Sensing of Hg^{+2} Ions:

The DKF-FF assembly showed crimson red fluorescence in the presence of UV light even underwater which got quenched in presence of mercury ions in the sample. This is because it depicted a possibility of a sensing unique ability through which initially when the arrangement is lowered in the sample that is rich in mercury ions it does not show any fluorescence but eventually, as the ions are adsorbed by the DKF part of the arrangement crimson red fluorescence is observed under UV rays the intensity of which increases with decrease in the concentration of mercury ions present in the sample.

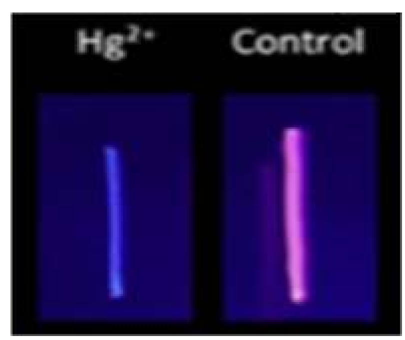

Figure 8: Flourosence of DKF under UV light

4. Conclusion

The menace of aquatic toxicity due to presence of mercury ion and the resultant impact on the food chain is a major concern. Use of a modified kapok fibre based adsorption system will not only mitigate the mercury contamination but can also detect its presence and level simultaneously. The efficiency as well as repeated usability of such fibre assembly system is expected to provide a cost effective and sustainable method to address this eco concern. Moreover, the adsorbed mercury can be easily recovered by adequate desorbing technique.

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Innovations in Silkworm Rearing and Importance: Recent Advances

Tanvi Singh, Arti Nigam & Rachna Kapila*

Institute of Home Economics, University of Delhi, New Delhi, India

Abstract

Silk is a fibrous animal protein produced by silkworm to spin its cocoon and the mass production is called sericulture. Sericulture sector is a labour-intensive sector that provides employment to mass population, both men and women and offers chance for the upliftment of social economic status to rural groups. This sector also has been greatly useful for mankind therefore, innovations in technology are required for success of this sector. Novel developments in technology and their dissemination have helped in emergence and implementation of modern sericulture activities both at farm and industry level, thus increasing the silk output. Innovation has come up as a technological solution to the sericulture problems along with being easy to learn, maintain and being cost effective. Investments in technology, advancements in training, promoting technologies contribute to improving overall competence of sericulture industry. This review paper discusses the recent innovations in sericulture, their adoptability status and the importance of innovation in this sector.

Keywords: *Employment, Innovation, Sericulture, Silk, Technology*

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1. Introduction

Silk is produced by silkworm for spinning its cocoon. It is a fibrous protein, which is light in weight, soft to touch, has high durability, natural sheen and integral affinity for dyes. All these exceptional characteristics of silk make this fibre 'Queen of textiles' [1]. The process of mass scale rearing of silkworms to obtain silk is called sericulture [2, 3]. A large number of interdependent and process specific procedures are involved in sericulture. Asia contributes to more than 95% of the total global silk output and therefore is considered as the main silk producer globally. China, India, Japan, Brazil and Korea are the main bulk producers of Asia [4].

In India, sericulture is an age-old practice and has mingled with the culture and life of Indians. India holds a prosperous and intricate history of silk production [5]. Moreover, India is the only country in the world that produces all known varieties of silk; Mulberry silk (79.23%), Tasar silk (tropical and oak Tasar) (6.8%), Eri silk (13.32%), and Munga silk (0.54%) [1, 3, 6]. In 2019-2020, the raw silk production of India was 35820 MT [7] and India, next to China, owns second place in the world in silk production [1].

The textile sector of India is majorly embraced by silk textile industry and sericulture [4]. Sericulture, in India covers 172,000 hectares of land and is spread in about 22 states. This industry runs in 54,000 villages, operates 29,340 power looms and 25,800 handlooms and provides employment to over 8.51 million people [3]. Sericulture is the most labour-intensive sector occupying an essential and key place in providing employment and extra income to economically weaker sections [8, 9]. It is an environmentally friendly movement that offers chance for the upliftment of social economic status to rural groups [3]. This agro-based industry has two sectors; one, farm sector which comprises of cultivation of food plants for silkworm, production of cocoons and eggs by rearing silkworms, and second, industry sector which involves reeling, spinning, dyeing, printing and finishing procedures [10]. It is efficient in providing livelihood to rural people and can even check migration of people from rural to urban areas by providing sufficient employment [3]. This sector not only produces silk fabrics but also has been greatly useful for mankind [6] therefore, innovations in technology are required for success of this sector. This paper focusses on innovative methods that are used in sericulture in the last five years and the importance of innovation in this sector.

Corresponding Author:

Dr. Rachna Kapila,
Institute of Home Economics,
University of Delhi,
New Delhi- 110016, India,
Email: rachna.kapila@ihe.du.ac.in

2. Technological innovations in Sericulture

Sericulture forms a major sector that holds immense potential for employing both men and women, as it comprises of both the farm and non-farm activities. Higher silk output and thereby better income to farmers and industry workers is achieved due to the development in technology. Novel developments in technology and their dissemination have helped in emergence and implementation of modern sericulture activities both at farm and industry level, thus increasing the silk output [11].

In sericulture, monitoring the health of silkworm along with the environmental parameters like humidity, rain and temperature becomes a complicated process. In a report by Rokhade et al. [12], technological innovation has resulted in accomplishment of improving silk quality by controlling environmental parameters along with successful accumulation of cocoons. The authors have used Arduino aided Internet of Things (IoT), image processing technique and smart sensors which helped sericulture practitioners with real-time data. The innovation has come up as a technological solution to the sericulture problems along with being easy to learn and maintain and being cost effective [12].

In another innovation, observation of silkworm development and recognition of phases of their life cycle was done using Internet of Things (IoT) empowered Wireless Personal Area Network (WPAN) system, the model also involves sensors to monitor environmental parameters according to different stages of development and camera to capture photos and their examination to confirm the progression of sericulture [13]. Several other studies have proposed models based on Internet of Things and using automation to develop smart sericulture technology to improve silk harvest [14, 15, 16, 17].

In order to increase the land yield and labour productivity, mechanization is extremely important [18]. The major problem faced by the farmers cultivating the food plants for sericulture, is cutting the leaves and carrying the leaves to shed where silkworm rearing is done. This requires more manpower as well as it is time consuming. Kumar et al. [19] have come up with a solution through the project “Farmer's friendly mulberry plant cutter”. This has an arm or holder which is movable, to hold the plant and a cutter which is rotating, to cut the plant. A storage space is also provided to store the cut plants. The holding as well as cutting is automatic whereas the cutter is to be moved manually to desired location of plant. Chanotra & Bali [18] have reviewed the use of different equipment in sericulture and the importance of mechanization, which has been summarised in Table 1.

Sericulture sector	Mechanization
Host plant cultivation	Pit making machine
	Irrigation machine
	Intercultural operation machine
	Power operated sprayer
Silk worm rearing	Chawki leaf chopper
	Semi-humidifier cum heater
	Disinfectant dusting machine and battery-operated duster
	Silkworm picking equipment and matured silkworm separator
Post cocoon	Cocoon harvester and defloser
	Tray washing machine
	Cocoon cutting machine
	Reeling machine

3. Adoption status of technological innovations

The technology plays an important role in production of good quality cocoons and increased silk production, also, the progression in technology has significant contribution in improving sericulture. But adopting the technologies for increased production, constancy and sustainable sericulture is of great importance [20]. The study conducted by Ahmad et al. [21] ascertains that the adoption of technology is of utmost importance for improvement of this sector. Several studies have been conducted to know the level at which improved sericulture technologies have been adopted by farmers. Beula Priyadarshini & Vijaya Kumari et al. [11] have reported that bi-model method involving various strategies of extension needs to be developed as uni-model based on farmer's education or experience cannot result in adoption of technology of desired level.

Cluster Promotion Programme (CPP) was launched by Central silk board a decade ago, with an aim to uplift India in international market related to production and upgrading of quality raw silk [22]. Several studies have been conducted to access the effect of this scheme on implementation of novel techniques and socio-economic status of sericulture farmers. The studies have reported that the execution of CPP has resulted in increased leaf production of food plants, cocoon yield, price of silk cocoon and revenue. The practice has altered the living standard of farmers and workers and also refined their socio-economic standard. Thus, this scheme has brought a model shift in silkworm rearing and noticeable development in production of gradable raw silk, thereby making sericulture a venture of secured and lucrative farming [22, 23, 24, 25, 26].

Though the adoption and transfer of technologies is very crucial in obtaining the best benefits for the sericulturists, however, accepting novel techniques is relatively slow in farmers. Jadhav et al. [20], in their study, reported that only 12.5% of the farmers have adopted the model rearing houses equipped with the modern facilities. The farmers are hesitant to consult civil engineers and planners for updating the designs of their sericulture houses or before undertaking construction [20]. Similar findings on non-adoption of technology by farmers were reported by Rathore et al. [27].

4. Importance of innovative sericulture

Entrepreneurship development: Sericulture, being the greatest labour-intensive segment of Indian economy, offers source of livelihood to major part of population by providing profitable self-employment to farmers and their families. This sector involves low investment, short development period, high and guaranteed returns, opportunities to increase income and employment to entire family throughout the year and thus is suitable for the small scale and marginal land holders [4]. Sericulture clusters have been developed by Government of India as an effort to provide a push to this industry. Lalzuitluangi, & Ramswamy [5] have reported the stimulation of sericulture activities by agripreneurs due to land availability, contribution of family labour, suitable climate and government assistance by Cluster development initiatives. Nandhini et al. [28] have reported the importance of awareness and training on technology upgradation for improving entrepreneurial behaviour of sericulture farmers. Innovations can further facilitate opportunities for high employment with less requirement of capital and high returns. Sericulture has become attraction to not only farmers but also for the planners and policy makers as source of socioeconomical development of Indian economy. This facilitates opportunities for millions and meant for its high employment potential, low capital requirement with higher return. By considering all these things of industry with its on-farm and off-farm activities it becomes the point of attraction for all the policy makers and the planners to recognize the industry, as the source of socioeconomic development of economy of India [1].

Women empowerment: Indian women have been regarded generally, as home- makers, however, they also work outside for living and to sustain their families. In fact, women constitute more than half of total labour population of Indian agriculture. In spite of working for around 18 hours a day, at home and outside, their importance by the family has not been valued and respected. This results in low self confidence in women, low level of leadership ability, inability to make decisions. The need for rural women to be self-dependent economically, has been made possible by the sericulture industry, as an initiative by science and technology. Of the total employment provided by sericulture, around half is taken up by women. The qualities of women like caring attitude, persistence, determination, patience and adaptiveness to novel techniques have made them dominant in this industry [4]. Several studies have analysed and reported women workers' dominance in sericulture, resulting in their empowerment [4, 29, 30].

Products and by-products**:** Innovations in sericulture aim to increase the production thereby increasing the applications of products and by-products, directly or indirectly. Application of sericulture products as alternative or regenerative medicines, drug dispensing system, maquillage, food preservatives and additives, biomaterial engineering and medical textiles. Pupa of silkworm has the pertinency as therapies, dietetics, animal food, cosmetics, fertilizers [6]. Sericulture wastes are an important source of biofuel generation. Production of biogas, livestock food, activated carbon, mushroom culture are the potential products of sericulture wastes [6, 31]. Silk worm rearing produces numerous fodder resources like waste or surplus leaf, residues of silkworm rearing beds which are by-products of Seri farming and are potential fodder resources. This sericulture waste has been proved to be very suitable as cattle and sheep fodder, resulting in increased milk yield, the remarkable process of silk milk farming. This contributes to extra income to sericulturists [22, 32].

5. Conclusion

Sericulture, being the most labour-intensive sector, which provides opportunities for employment, need to be made stronger and bigger. Technological innovations play an important role in achieving this target. Further, this can be possible by changing the ideas, focussing on farmers linked sericulture and further developments in sericulture technology. Managing the challenges and daring innovations can add up. Acquiring information on novel technologies by the farmers and adopting the technologies enthusiastically, could produce quality cocoons. The technologies should reach to the farmers so that they can upgrade themselves with the traditional methods leading to reduced cocoon output and reduced income. Investments in technology, advancements in training, promoting technologies will improve overall competence of sericulture industry.

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Optimization of Washing Process Parameters for Ultrasonic Cleaning

Dr. Sabina Sethi*

Department of Fabric and Apparel Science, Lady Irwin College, Delhi University, India

Abstract:
Washing of Garments is one of the primary household tasks; this however is a laborious chore. Conventional wet cleaning process is harsh, laborious and fiber unfriendly. Efforts have been made in the past decades to reduce the physical burden by developing efficient washing machines both for households as well as for the laundry industry. The recent researches in this domain are primarily focusing on identifying ways to make laundry practices more eco friendly. In line with these efforts an attempt was made in the present work, to use ultrasonic energy as an alternative to conventional methods of providing agitation for cleaning soiled areas of the garment. Washing process parameters have been studied in detail for the conventional aqueous cleaning of textiles while use of ultrasonic cleaning has been explored for hard surface cleaning. The work reported in this paper was undertaken to integrate the two and study the wash process parameters for wet cleaning of textiles in presence of ultrasound.

Keywords: *Cavitations, Green laundry practices, Ultrasonic Cleaning, Washing parameters*

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1. Introduction

Detergent concentration, wash temperature, time taken for washing and mechanical agitation time are the variables that are easily controlled in the laundering process and are known to affect soil removal from fabrics. Each of these factors influences molecular activity within the wash system, one expects the response function for one factor is not independent of the levels of the other factors [6]. For effective cleaning, it is important to optimize washing process parameters.

"Ultrasound is high frequency sound wave inaudible to humans ranging from 18 kHz-10MHz. In practice, three ranges of frequencies are reported for distinct uses: low frequency or power ultrasound (20-100 kHz), medium frequency (300-1000 kHz) and high frequency or diagnostic ultrasound (2-10 MHz)" [3]. Ultrasonic vibrations travel in the form of a wave similar to the way light travels but unlike light waves which can travel in vacuum, ultrasound requires an elastic medium such as a liquid or solid with elastic properties for propagation.

There are several phenomenon involved that are responsible for the physical and chemical effects produced by ultrasonic waves. However the predominant of these responsible for ultrasonic cleaning is cavitations. Cavitations are the formation, growth and collapse of gas or vapor filled micro bubbles or cavities under the influence of pressure variation in medium. The cleaning action is mainly due to transient cavitations. There are additional phenomena, such as streaming and stable cavitations, which also contribute to the dispersion and removal of the contaminant particles from the surface, when ultrasonic energy is employed for cleaning purposes [5].

Corresponding Author :
Dr. Sabina Sethi
Associate Professor, Department of Fabric and Apparel Science,
Lady Irwin College, Delhi University, Sikandra Road,
Mandi House, New Delhi, Delhi – 110 001
Email : sabina.sethi@lic.du.ac.in

Ultrasonic cleaning of textiles is a heterogeneous solid/liquid system where various physical and chemical phenomena resulting from interplay between the ultrasound waves, reagent molecules, and liquid media are responsible for enhancement in cleaning.

For effective cleaning, it is important to optimize washing process parameters for ultrasonic cleaning. The present paper in successive sections outlines the methodology and findings of experiments to optimise washing parameters for ultrasonic cleaning of textiles namely – Detergent concentration, Temperature, Time. Further, a comparison has been made of use of ultrasonic energy to provide agitation for effective cleaning with conventional form of agitation i.e. mechanical agitation. To avoid interference with results, optimization experiments were done only to compare ultrasonic agitation as a pretreatment condition; these were not subsequently followed by machine washing.

2. Methodology

Various factors of cleaning for ultrasonic assisted washing of textiles, namely Detergent, Time, Temperature and Agitation were optimized.

Fabric

100% grey cotton (plain woven) fabric was used for the experiments. Cotton forms the major class of fabrics in the laundry, that is why it was used for test samples.

Detergent

For washing, standard reference detergent conforming to AATCC specifications (available under the brand name Extran® in India) and for comparison commercially available washing detergents was also used initially, however for subsequent experiments, only the most efficient commercial detergent identified during the preliminary trials was used for the work reported here.

Chemicals

Carbon Tetra Chloride, Coconut oil (refined and bleached), refined mineral oil, Lanolin (anhydrous), HOWCO (CG3) [10% Graphite by mass in refined mineral oil having a viscosity of 86-98 at 60°C].

Pre Preparation of Fabric

Enzymatic de-sizing of fabric was done as per IS: 199:1989 using enzyme Diastase. Combined scouring and bleaching was done in a bath containing 1g/l wetting agent (detergent), 2-3% Sodium Hydroxide crystals, 1-2% Hydrogen Peroxide, 0.5-1% Sodium Carbonate at 1:50 M.L.R. The treatment was carried out at boil for 2 hours.

Artificial Soiling of Samples

Soil recipe was prepared as described in IS: 5785:2005. The pretreated cloth was cut length wise into strips of suitable width, as per the size of the rollers. The fabric was soiled by passing it through padding rollers, using multiple dip and nip method. After soiling the whiteness Index value of samples was taken.

Ultrasonic Cleaning Unit

To check the viability of using ultrasonic energy for cleaning highly soiled textile substrate, preliminary work was carried out on a commercially available ultrasonic dental scalar used for removing deposits from teeth. It had one transducer emitting 36 kHz frequency, having a limited, one liter capacity (Figure 2.1).

Figure 2.1: Ultrasonic Cleaning Unit (Dental Scalar)

The set up had following specifications:

Frequency	-	36 KHz
Power	-	44 watts (Average)
Temperature	-	35-40°C
Surface Tension	-	72 dynes/cm (water)
		App. 32 dynes/cm (detergent solution)

Measurement of Reflectance and Whiteness Index of Soiled and Washed Samples

Instrumental analysis of soiled and cleaned samples was done using spectrophotometer interfaced with computer color matching system (CCMS). Whiteness index was measured as per Hunter's lab scale using CCMS. The illuminant used was D_{65} with 10° observer. The search unit of spectrophotometer was fitted with option to include/exclude spectral component, SCE/SCI. To eliminate the effect of optical brighteners present in detergent, the measurements were taken with SCE (Spectral Component Excluded) so as to eliminate ultraviolet wavelengths. The whiteness index of unsoiled fabric, soiled and washed samples was measured. A total of 36 readings were taken for each variable. Percentage change in whiteness index value was used as a criterion for evaluating cleaning efficiency. These have been tabulated analyzed and presented in the next section.

3. RESULTS AND DISCUSSION

3.1 Effect of Detergent Concentration

Work was carried out at concentrations of 3-18 g/l with previously identified suitable commercial detergent and standard detergent. Results revealed that variation in detergent concentration resulted in corresponding changes in cleaning achieved for both standard as well as commercial detergent. For control samples, cleaning improved with increasing concentration of commercial detergent from 3-18g/l but with standard detergent, no clear trend could be seen. At all concentrations exposure to ultrasonic showed marked improvement in cleaning as compared to the control sample. It was four times better with standard detergent and more than double with commercial detergent. Better cleaning was noted with commercial detergent than standard detergent, probably due to presence of additional constituents and alkaline pH of commercial detergent (TABLE 3.1A).

For ultrasonic samples cleaned with standard detergent no clear trend could be seen from the results. Cleaning improved from 3 to 9g/l, but marginally declined at 12g/l , it improved again at 15g/l followed by a decline at 18g/l. Best cleaning results were observed at 15g/l for standard detergent. With commercial detergent also variation in cleaning due to change in concentration was observed, the interactions however did not point at clear trend. Decline in cleaning was observed from 3g/l onwards till 12g/l followed by an improvement in cleaning at 15g/l and then again decline at 18g/l was noticed (Figure 4.1).

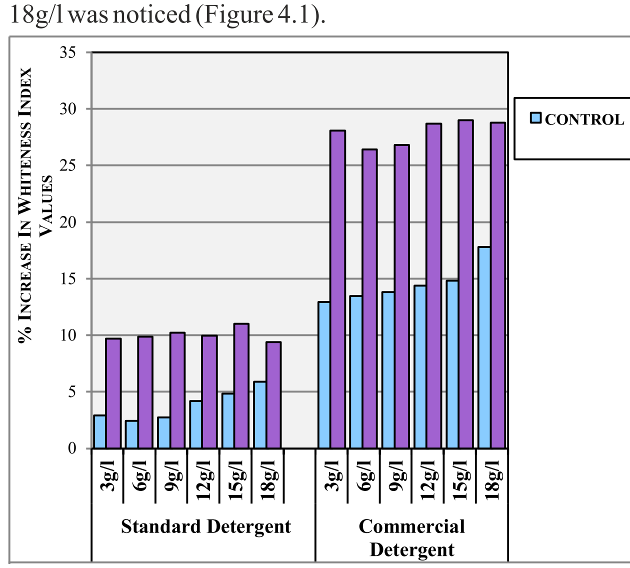

Figure 4.1: Effect of detergent concentration on cleaning

For better understanding statistical analysis was also done and Variation analysis ANOVA corroborated that detergent concentration affected level of ultrasonic cleaning for both standard as well as commercial detergent, significance value was below .001.

Results show that there is significant difference in cleaning obtained at 15 g/l compared to other concentrations with standard detergent where as for commercial detergent the difference between 3g/l and 15g/l is not significant at .01 level of confidence. It would not have been economically and/or environmentally prudent decision to use five times the concentration for statistically insignificant improvement in cleaning, therefore, 3g/l was considered as the optimum concentration for further work.

3.2 Effect of Time

The success of a cleaning application depends on the interrelationship of thermal, chemical, mechanical energy and time. Time will not only increase the effectiveness of all three energies, but it will also increase or decrease production rates in the particular step of the process. Experiments were carried out for time durations varying from 1-11 minutes at previously optimized concentration of 3g/l with both standard and commercial detergent. Whiteness Index values before and after washing as well as increase after wash were tabulated, analyzed and presented here. Percentage increase in whiteness index for control and ultrasonic sample for both detergents was tabulated and plotted in bar diagram to see a general trend (Figure 4.2).

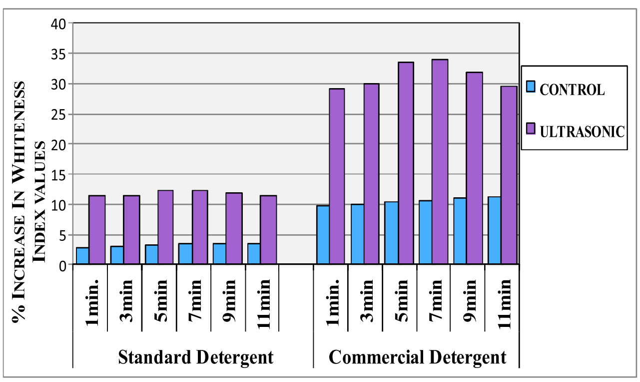

Figure 4.2: Effect of treatment time on cleaning

Results show that for control sample there was marginal improvement in cleaning with time whereas when samples were cleaned in presence of ultrasonic waves, a bell shaped curve was observed. This curve was less prominent for standard detergent but was more emphatic for commercial detergent. In the first phase rapid increase in cleaning efficiency up to 5 minutes was seen followed by a phase of no change from 5-7 minutes and then decline from 7 minutes onwards. This improvement in cleaning with time is consistent with findings of other researches [4], [2]. The detectable decline in cleaning efficiency after initial rise with time has also been reported and explained [7].

The possible reason for effective cleaning in such a short duration could be due to enhancement in the laundry process with use of ultrasonic. Ultrasonic has been reported to augment the mass transfer in textiles and thereby helps in the cleaning.

Statistical analysis was also done to corroborate these findings. Variation analysis (ANOVA) indicated that change in time of exposure for ultrasonic agitation made a highly significant difference to the level of cleaning achieved with both standard as well as commercial detergent.

The findings indicated that cleaning achieved at 5 and 7 minutes were significantly better than 1 minute for both detergents but with commercial detergent increase in whiteness Index was more substantial. These results clearly indicate that textile cleaning is not just a function of time; the type of detergent used will also affect the amount of cleaning achieved. So it was proposed that instead of increasing the time for ultrasonication, additional time can be given to presoak the garments in commercial detergent followed by ultrasonic cleaning so that the ingredients present in commercial detergents like enzymes and other surface active agents can act upon the soil particles and loosen them and bring them into the wash water

3.3 Effect of Temperature

Role of temperature is critical, as it will have an impact not only on cleaning but also energy costs, environmental harm etc. FIGURE 4.3 shows the effect of temperature variation on soil removal during ultrasonic cleaning. For the purpose of comparison it also shows the extent to which cleaning was done in the absence of ultrasonic energy (control samples). In control samples with increase in temperature improvement in cleaning was seen, which is in consonance with the findings of previous authors [1], [6]. A comparison of cleaning at various temperatures showed, maximum cleaning is achieved between 40°C and 50°C, beyond 50°C there is no improvement in cleaning. As the temperature was increased further to 60°C, there was a decline in efficiency of cleaning this could be because of the sensitive nature of enzymes. Not only are enzymes substrate specific; they are also very temperature sensitive. When cleaning was done at high temperature, the enzymes present in detergent, probably became ineffective and therefore the reduced cleaning/ whiteness index values were observed. In case of ultrasonic cleaning done with detergent similar trend was observed.

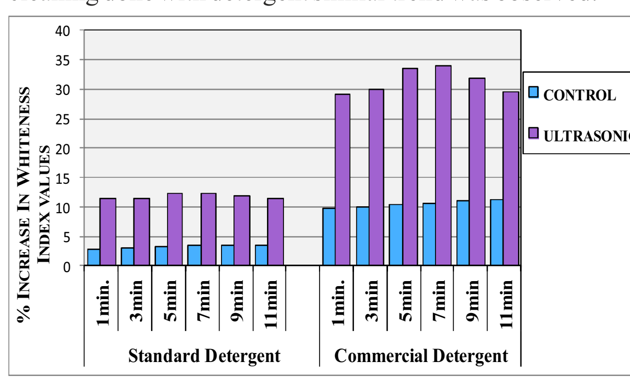

Figure 4.2: Effect of treatment time on cleaning

Results show that for control sample there was marginal improvement in cleaning with time whereas when samples were cleaned in presence of ultrasonic waves, a bell shaped curve was observed. This curve was less prominent for standard detergent but was more emphatic for commercial detergent. In the first phase rapid increase in cleaning efficiency up to 5 minutes was seen followed by a phase of no change from 5-7 minutes and then decline from 7 minutes onwards. This improvement in cleaning with time is consistent with findings of other researches [4], [2]. The detectable decline in cleaning efficiency after initial rise with time has also been reported and explained [7].

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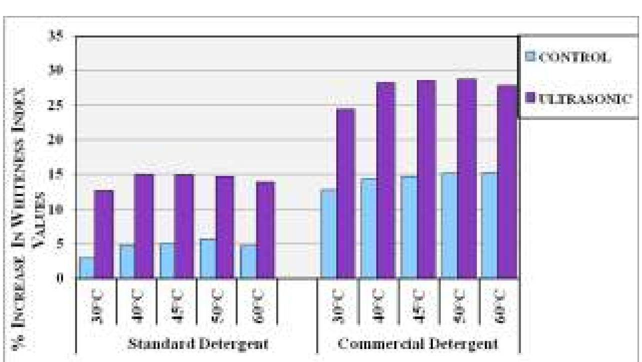

Figure 4.3: Effect of temperature on cleaning

For further validation of the trend observed, statistical analysis was done by comparing % increase in whiteness index values. ANOVA results confirmed that variation in temperature resulted in corresponding variance in cleaning achieved, which was highly significant for both standard as well as commercial detergent. To find where the inequalities existed in different group means, Tukey test was also applied and also Students t test for unpaired means was applied on all possible 10 pairs.

Outcome of the t test confirmed that 40-50°C is the optimal temperature range for ultrasonic cleaning. For further work, lower temperature of 40°C was considered optimum. This temperature is way lower than the temperature generally recommended for washing of cotton fabric by conventional methods. This means that use of ultrasonic can possibly result in energy saving also.

4.4 Effect of Agitation

Comparison of ultrasonic agitation with mechanical agitation was done by tabulating the before and after whiteness index readings of samples and % increase in whiteness index for various agitation methods including control was tabulated and plotted. Figure 4.4 clearly shows that in absence of mechanical action, control samples gave only 1/3rd cleaning compared to other two methods of providing agitation, though all other factors of cleaning were constant. Apparently ultrasonic agitation was comparable treatment to conventional method of brushing for cleaning heavily soiled clothes with both standard as well as commercial detergent. Better cleaning results were seen for commercial detergent compared to standard detergent in line with all the previous optimization experiment findings.

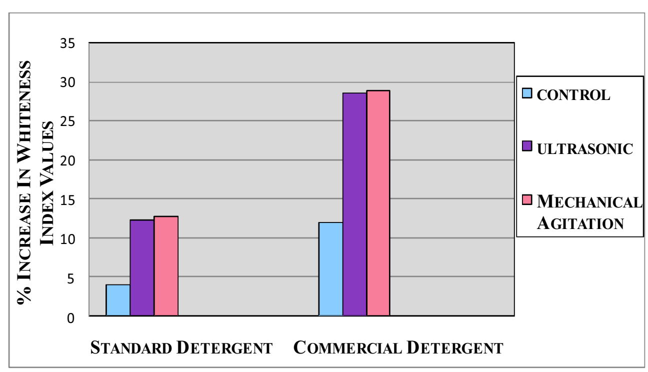

Figure 4.4: Comparison of various forms of agitation

These findings were further supported with statistical analyses. ANOVA confirmed that due to agitation there is highly significant difference in resultant cleaning. Further Student's t test (for unpaired samples) confirmed highly significant difference in cleaning obtained with control vis-à-vis samples exposed to agitation; p value of .000 with both standard as well as commercial detergent was noted. The findings clearly indicate that there is no significant difference between ultrasonic agitation and mechanical agitation. p value of .315 for standard detergent and .579 for commercial detergent was noted. Thus, with 99% confidence we can say that the cleaning obtained with ultrasonic agitation was comparable to popular methods used to provide mechanical agitation for cleaning soiled garments.

Warm or hot water melts fats or oils so that it is easier for detergent to dissolve and pull it away, but neither detergent nor soap accomplish anything except binding to the soil, until some mechanical energy or agitation is added to the cleaning process as in hand or machine washing. "Swishing the soapy water around allows soap or detergent to pull the grime away from clothes and bring it into the larger pool of rinse water. Rinsing washes the detergent and soil away" (Bhattacharya, 2009). Agitation therefore is a critical factor and any change in its nature and/or intensity would correspondingly affect laundry process effectiveness.

4. Conclusion

The aim of this research was to optimize the parameters for ultrasonic washing. Fundamental parameters which affect the cleaning efficiency viz. Time Temperature and Detergent concentration were investigated; the results were presented, tabulated and discussed. Two- way Anova repeated statistical analysis, Students t test for unpaired means and Tukey test were employed to further verify the findings. On the basis of the experimental work the optimized washing conditions for ultrasonic washing are - Detergent Concentration 3g/l, Time for presoaking in detergent 5 minutes, Ultrasonic treatment Time 1 minute and Temperature for Presoak and Treatment 40°C.

The optimization was done keeping in mind the effectiveness of cleaning as well as economic and environmental impact. To summarize, use of ultrasonic energy as an effective alternative to presently used methods of cleaning soiled apparel was established. Optimal integration of all factors of cleaning in concert with ultrasonic agitation led to further enhancements in cleaning efficiency. Ultrasound waves provided the mechanical agitation which expedited the cleaning process; reduced the amount of cleaning chemical required to achieve the same level of cleaning as achieved in conventional methods.

Identifying and optimizing energy efficient and eco-friendly alternatives to present laundry practices are the need of the hour. Green laundry practices that are effective as well as efficient and at the same time user as well as environment friendly are worthy of future explorations and adoption by the industry and individuals.

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Product Diversification and Enhancement of Kotpad Textiles through Printing with Natural Dyes

A. Dutta[1] & S. Roy Maulik[2]*

[1] J.D. Birla Institute (Affiliated to Jadavpur University), Kolkata, India
[2]Department of Silpa-Sadana, Visva-Bharati University, Sriniketan -731236, India

Abstract:
The varied, rich textiles of India are a significant part of the diverse heritage of the country. The tribal weaves have also contributed immensely. Raw material, motifs, and techniques have developed according to regional, geographic and climatic conditions. Religious beliefs and culture play a significant role as well. The tribal weavers of Mirgan caste from Kotpad in Koraput district of Odisha, have earned an important place for themselves in the Indian Handloom Industry while weaving the indigenously Aal dyed yarns. The sensitivity towards their beliefs and customs are symbolizing through the motifs created by these weavers. As the colour palette is limited only to Aal root bark dye and motifs are typical, other natural dyes can also be explored for value-addition of Kotpad textiles through block printing, batik work, and hand painting to give a new lease to Kotpad weavers.

Keywords: *Aal* dye, Kotpad, Motifs, Natural dyes, Printing, Value-addition

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1. Introduction

Textile has always occupied a prominent place in the lives of people around the world since time immemorial. Amongst the archaeological excavations are carvings like the well-known Mohenjo-Daro stone sculpture piece of a high priest figure with a decorated shawl with a raised trefoil pattern covering the left shoulder and passed under the right arm. The trefoil pattern was once filled with colour in it. This indicates that motifs along with weaving as well as dyeing / printing were well developed by the third millennium B.C. Motifs have been found in burial jars of Indus Valley, Mauryan, Gandhar, Amaravati, Nagarjunakonda sculptures, costumes painted in Ajanta cave paintings, Mughal miniatures and many other sources.

People of different geographical and climatic conditions used naturally available material from their environment. Over the period, weaving became art and flourished in the hands of weaver artisans. Enrichment of fabric began according to the surroundings and requirement of the society. The raw material used in creating a fabric indicates the geo-climatic conditions of the place of its origin. The piece of fabric also often exposes trade links and influences. The techniques used in the manufacturing of the fabric reveal the status of civilization. The motifs talk about the beliefs and surroundings of the society and the way of life of its creator [1]. Traditional artisans took inspiration from what they believed, saw, and experienced. They learnt from their ancestors but brought variations in forms and style according to their present. The essence of their folklores, mythologies, and beliefs are symbolizing as motifs. The motifs display their power of observation, unique sensitivity, and understanding of techniques. They survived historical, socio-economic, and political changes. Even today, in contemporary times, textile designers fall back on these traditional designs for inspiration.

***Corresponding Author :**
Dr. S. Roy Maulik
Department of Silpa-Sadana, Visva-Bharati University,
Sriniketan - 731236, India
E-mails: s_r_moulik@yahoo.co.in
sankar.raymaulik@visva-bharati.ac.in

Indian handloom textiles are known for their textures and motifs. Different rulers and traders have brought in their influences integrated with the existing ones to form new indigenous motifs. These integrated motifs have become to be known as characteristics of traditional textiles of India.

The contribution of tribal textiles to the Indian handloom is no less. There are 705 individual ethnic groups notified as Scheduled Tribes in India according to the 2011 census [2], out of which Odisha has 62. Each one of these tribes has distinct identities and unique textiles.

One such ethnic fabric comes from Kotpad, a small tribal handloom cluster situated in Koraput district of Odisha. The tribal weavers of *Mirgan* caste have earned an important place for themselves in the Indian Handloom Industry while weaving the indigenously *Aal* dyed yarns. These fabrics are woven out of hand-spun cotton or wild tussah and are free from pesticides. Weaving is done on a rudimentary pit loom, and the exquisite loom embroidered motifs are created manually by using an extra weft called *'nan'*. The motifs created are art forms by themselves, on the loom.

On the other hand, India has a rich tradition of decorating textiles through printing and painting using colourants extracted from natural resources since the ancient time [3]. Researchers are also continuously tried to explore different natural resources for dyeing and printing of textiles with colourants obtained from them [4-8]. There is an opportunity to add value to the Kotpad textiles utilizing different types of yarns, printing with colourants extracted from locally available vegetable resources, surface ornamentation through batik work, hand painting etc.

This value addition without disturbing their culture may improve the livelihood and enrich the aesthetic appeal of the end product. The main objectives of this work are to introduce locally available natural dye resources to Kotpad fabric through block printing, batik work and hand painting as an alternative surface enrichment process, survival of Kotpad weaves from extinction, modifying or developing the different motifs used in weaving to increase variety and adaptation to suit contemporary taste, and diversifying the use of the textile through the non-traditional application. All these attempts may conserve and preserve the rich art of Kotpad.

2. Kotpad Weaves

Kotpad is a town located in Kotpad Tehsil in Koraput district of Odisha and according to the 2011 India Census, 68.89% of the Kotpad population consists of Schedule Tribes (ST), while 11.94% belong to Schedule Caste (SC). Male literacy stands at 61.15%, whereas female literacy is 33.39%. This town of Kotpad has 18 weavers and 12 families of dyers, amongst its total population of 1,466. They have continued the leg acy of the unique heritage textile, which is appreciated for its eco-friendly *Aal* dyed yarns. The process involved in dyeing is distinctive as no chemical is used at any stage during the dyeing process. The women of *Mirgan* caste called the *Panikas* are the ones responsible for this unique dyeing process. They dye the yarns in varying shades ranging from red to black, using the bark of the roots of *Aal* tree.

There are philosophical meanings attached to the *Pata (saree),* a rectangular piece of cloth that the lady of the house drapes around her. She is considered responsible for the peace, prosperity, happiness and welfare of the entire family. Nature inspired, aesthetically abstract motifs used in her *saree* have symbolic significance and are associated with their social and religious beliefs. They remind her of the virtues like tolerance and humbleness and also protect her from evil.

3. Kotpad Motifs

Motifs keep returning with variations in form and style in various periods with their varied visual interpretations, themes and symbols and stories according to the requirements and preferences of the changing society. Observation says that relatively, very few motifs can be termed as absolutely new.

A novelty in design is brought about by varied techniques, innovative distribution or placement, or combinations. Colour variation also has a role in bringing a difference. Keeping this in mind, the weaving design motifs were adapted to block printing, batik and hand painting processes with the help of different natural dyes. Below are symbolic connotations of some motifs used in Kotpad weaves.

Bilai khoj (Cat's paw)

A cat walks silently without making any noise. Similarly, a young girl with good values must have the virtue to quietly serve her family and fulfil their needs without boasting or making noise about it.

Peepli (Butterfly)

A butterfly is beautiful and delicate, yet it never sits idle and keeps moving from one flower to another for collecting nectar. A young lady must imbibe this attribute.

Machha (Fish)

The fish is always agile and never static. It is compared with the virtuous of a woman who is aware of her duties and striving towards the comfort of her family. A child in the womb is floating in the water and is also compared with fish. It thus symbolizes birth. A fish always tries to return to its birthplace. This represents that a woman should be aware of her roots. Fish also symbolizes prosperity.

Machha chakshu (Fish's eye) and Rami chirde (Eagle's eye)

The eyes of a fish or that of the eagle is always observant. Nothing remains hidden from it and is considered omnipresent. It is similar to the geometric shape of a diamond and often referred to as a star. The fish eye symbolizes the alertness that a woman must possess to safeguard her family.

Kankra (Crab)

Virtues of a crab that can walk forward and sideways and withdraw into its shell when required are compared to a woman who needs to be malleable according to the circumstances.

Kachim or Kachua (Tortoise)

A tortoise is a symbol of the reincarnation of Lord Vishnu. When required, its ability to pull itself into its shell is compared to a virtuous woman who must have this skill to look after her family. It is also relished as a delicacy for the tribes of the region.

Mayur (Peacock)

Peacock has a great significance in Hindu culture. It is associated with courtship, fertility, festivity, immortality, and beauty. It is believed that it has the power to protect the newly wedded from the evil eye.

Hamsa (Swan/Duck)

Another common motif used in weaving is a swan. Neck and gait of a beautiful lady is comparable with that of a swan / duck. A swan can swim, fly and walk, and thus one can say that it has conquered the air, water and earth and is yet dignified and humble. A swan / duck thus symbolize victory with dignity and humbleness.

Mruga (Deer)

The eyes of a deer are beautiful, innocent and full of love for its fawn. A deer is agile and very quick to respond. It is non-violent. A virtuous woman should have similar virtues. Her love for her children should be exemplary.

Hasti (Elephant)

Despite its enormous size, an elephant is very careful while it moves. Even a tiny creature like an ant does not get killed under its feet. It is powerful and has no fear but is non-violent. Thus, a virtuous woman, in spite of having strength, should be caring and have softness.

Simha (Lion)

The king of animals' lion has excellent strength and power yet has a skinny waist. The waist of a beautiful woman is compared with that of a Lion's waist.

Handi/ Mathia/ Kalasha/ Kumbha or Earthen Pot (The holy ceremonial water jar)

The earthen pot symbolizes a womb and means to carry water and nectar (*Amrit*). It also symbolizes abundance and good fortune.

Bor paan (Beetle leaf) and Peeper paan (Peepal leaf)

These leaves are considered auspicious as they are used for puja especially for Vishnu puja.

Amongst the motifs derived from nature, *Phul* (flower), *Chiria* (bird), animal motifs, *Jhar* (tree) motifs are popular. Flowers like lotus are commonly used as motifs. Common birds like a crow, dove, *mynaa* and even the mythological *Jatau* find their place as motifs in Kotpad *sarees*. *Bhaisa* (Ox), *Boyela* (cow), *Billi* (cat), and *Unth* (camel) are common animal motifs. The fascination for tigers and leopards from stories of *shikarah* by the ancient *Rajas* continues, and tiger motifs are still made. *Jhitpiti* (lizard) is considered auspicious and is used as motif.

Objects used both during rituals and their day-to-day life, like *Patawaar* (oar) used for rowing the boat for fishing, *Teer* (arrow) for hunting animals for food, *Angi* (chopper) used for sacrificing animals during rituals*, Chata / Chatri* to protect farmers during rains find place amongst Kotpad motifs. Motifs inspired from day-to-day life like farming or pumping of tube well etc. are also common. Motifs associated with mythology, festivals, rituals and celebrations like *Dhemsa* dancers performing, drummers beating his drum, or woman going for puja are also famous. Human figures performing various activities are loom embroidered with ease.

4. Pictorial Motifs

Pictorial motifs, though rare, are found. These motifs are complex in terms of space visualization. Here the weaver is representing objects at different planes. This visualization brings the weaver to the same platform as a visual artist. The motifs are created on the loom without any drawing or reference.

The creativity of the weaver is such that he turns whatever he sees as a motif. The creativity and mastery of the technique of the weaver while creating motifs are commendable. The sense of proportion is exemplary, and copying from any graph or old piece of weaving is not required. Due to this reason, some of the weavers have created their distinct style, and one can recognize them through their creations. Figure 4.1 shows the distinct style of motifs by weavers. Thus, a Kotpad weaver can truly be compared to an artist.

Various factors of cleaning for ultrasonic assisted washing of textiles, namely Detergent, Time, Temperature and Agitation were optimized.

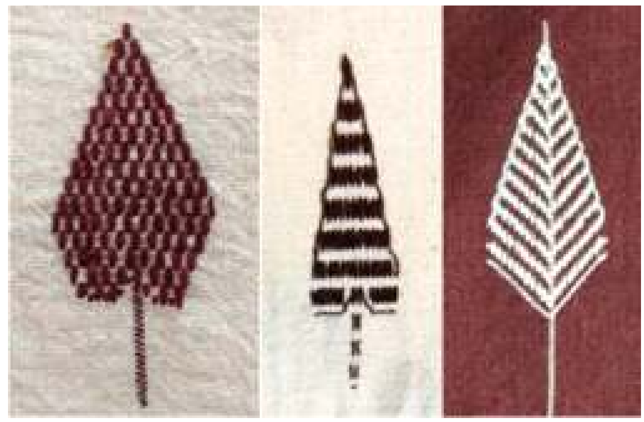
Fabric

100% grey cotton (plain woven) fabric was used for the experiments. Cotton forms the major class of fabrics in the laundry, that is why it was used for test samples.**Detergent**

For washing, standard reference detergent conforming to AATCC specifications (available under the brand name Extran® in India) and for comparison commercially available washing detergents was also used initially, however for subsequent experiments, only the most efficient commercial detergent identified during the preliminary trials was used for the work reported here.

Chemicals

Carbon Tetra Chloride, Coconut oil (refined and bleached), refined mineral oil, Lanolin (anhydrous), HOWCO (CG3) [10% Graphite by mass in refined mineral oil having a viscosity of 86-98 at 60°C].



Borpaan1 *Borpaan2* *Borpaan3*

Figure 4.1: *Borpaan*

Borpaan 1: Weaver Artist
Jagatbandhu Samrath, Age: 60+

Borpaan 2: Weaver artist
Baidyanath Samarth: Age: 60

Borpaan 3: Weaver Artist
Khatpati Panikar: Age: 35

5. Traditional Kotpad *Tual* (a rectangular piece of fabric used by men) and *Pata (sarees)*

Originally the *sarees* that the tribal wore were short in length and was called *Pata,* and the fabric used by men was called T*ual*. *Pata* or *saree* is an unstitched rectangular fabric with a field or body, *dhari* or border and *jada / pallu or end piece*. The body is the central portion of the *saree*. *Butis* (motifs) distributed at regular intervals enhance the body. The border, a relatively heavier part than the body, runs through the entire length of the *saree* along the selvedge. Different coloured yarn may be used for border while warping. Kotpad weavers generally use three shuttle techniques to create *Kumbh* motif in the borders. The *jada* generally consists of flat stripes and a *jada moh* which is generally a temple motif *(chul)* in the centre of the width of the *saree* facing the body. Rows of *bundgi* are also found in the *jada*. The thickness of the borders varies from 2 *ungli* to approximately 1" to 8". The *Kumbh* varies. It may begin after the coloured yarns for the *dhari* or border end or may be within the border or half within and half protruding. The end piece or *jada* may vary in size, ranging from 8" to 1 m. The ornamentation increased with the *sarees* that were used for various ceremonial occasions and the affluent class. Finer yarn and motifs with detailing are preferred over bold tribal motifs. The width of these *sarees* is 48" and the length 6 m.

6. Motif Development

The motif may be simplified, stylize or modified in some creative manner. They should be redefined to suit the new purpose and the product. Thus, the abstract symbolic motifs of Kotpad were modified to naturalistic, stylistic and geometrical styles (Figure 6.1).

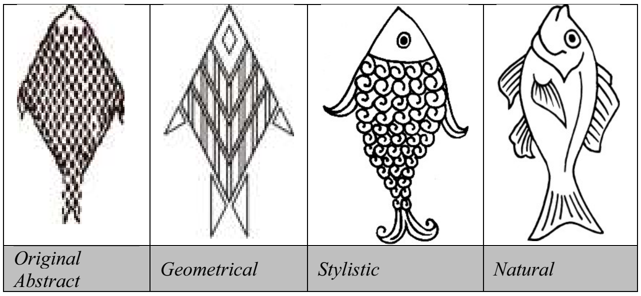


Figure 6.1: Modified naturalistic, stylistic and geometrical motifs

It was then observed that the abstract symbolic motifs were best suited for Kotpad weaves. This would allow them to maintain their identity. Thus, they were modified by further abstraction to suit the contemporary taste and develop the new product range (Figure 6.2).

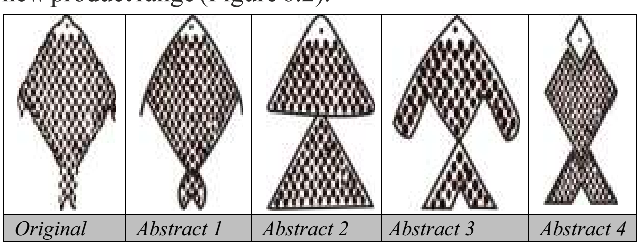


Figure 6.2: Abstraction in motifs to suit contemporary taste

Motifs thus generated were evaluated by the weavers based on ease in weaving and aesthetics. The ones that were selected by the majority of weavers were used in varied repetitions for new products (Figure 6.3).

Figure 6.3: Product developed from selected motif

7. Experimental

7.1 Materials

7.1.1 Fabrics

Plain weave loom state handloom cotton fabric with yarns of 20^s Ne warp and 18^s Ne weft, having 44 ends/inch and 34 picks/inch with an areal density of 112 g/m^2 was directly purchased from the weavers of Kotpad and used in the present work.

7.1.2 Natural Dye

Rubia cordifolia (Manjistha), *Terminalia chebula* (Myrobalan), *Indigofera tinctoria* (Indigo), *Allium cepa* (Onion peel), *Laccifer lacca* (Lac), *Bixa orellana* (Annatto), *Camellia sinensis* (Tea leaves), Alizarin, *Curcuma longa* (Turmeric) and *Morinda citrifolia* (*Aal* root bark) either in crude form, powder form or in paste form were used as natural dyes for dyeing and printing purpose.

7.1.3 Chemicals

Laboratory reagent (LR) grade sodium hydroxide, sodium meta-silicate, sodium carbonate, hydrogen peroxide (30% w/v), acetic acid, aluminium sulphate and ferrous sulphate obtained from M/s Emplura Merck Life Science Pvt. Ltd, Mumbai, and Gum indulka, T R Oil, i.e., sulphonated castor oil, detergent, and non-ionic detergent of the commercial grade obtained from the local market were used in this study.

7.2 Methods

7.2.1 Scouring and bleaching

In order to make the fabric absorbent, all the natural and added impurities were removed through combined scouring and bleaching treatment. This combined scouring and bleaching process was performed by the conventional tub method. This process was carried out with sodium hydroxide (2%), sodium carbonate (2%), anionic detergent (0.2%), Turkey Red Oil (0.5%) and sodium meta-silicate (2%) at a fabric-to-liquor ratio of 1:30. Initially, the liquor was heated up to a temperature of 60°C and at this temperature, the material was immersed and boiled for 1.5 h. At the time of boiling, hydrogen peroxide solution (2%) was added in two instalments and the process was further continued for another 1 h. The scoured and bleached material was then washed thoroughly with hot water, followed by cold wash and neutralized with dilute acetic acid, washed again with cold water and finally dried in air. Figure 7.1 shows the fabric samples before scouring and after scouring. It was observed that the fabric became absorbent.

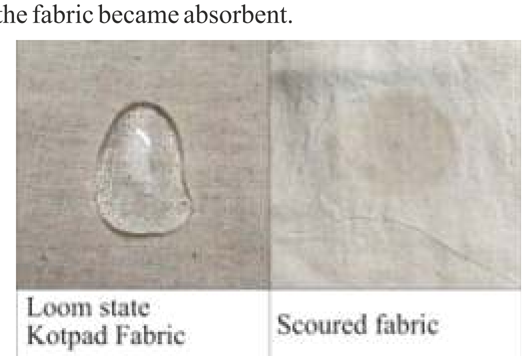


Figure 7.1: Kotpad fabric before and after scouring

7.2.2 Extraction of natural dyes

The extraction of the vegetable matters was performed by adding 100 g of each vegetable matter separately to 1 liter of water. The mixture was heated at a temperature of 90°C for 45 min in a thermostatically controlled water bath, allowed to stand for another 30 min and finally filtered through nylon bolting cloth having 140-200 mesh size. Such filtrate was used for dyeing and printing purpose.

7.2.3 Dyeing with natural dye

Figure 7.2 shows the process of dyeing commonly followed in this study. Scoured and bleached cotton fabric was dyed with the aqueous extract of natural dyes in the presence of mordants such as aluminium sulphate and ferrous sulphate either individually or combination following post-mordanting technique. In case of post-mordanting method, the dyeing was carried out at 90°C for 45 min in the thermostat control water bath. The dyed fabric was then mordanted in a separate bath at 70°C for 20 min. Soaping of all the dyed samples was done with 2g/l non-ionic detergent at 50°C for 10 min, followed by cold wash and finally dried. Some of the dyed fabrics were over-dyed with another dye for achieving different shades.

7.2.4 Printing with natural colour

Printing paste was prepared following the simultaneous mordanting method. In this process, inorganic salts of specified dose levels were mixed with the aqueous extract of natural dyes and kept for 15 min, followed by the addition of gum indulka with the help of a high-speed stirrer to prepare the printing paste. The process followed keeps the printing paste fungus free and allows storage for later use (Figure 7.3). Printing on bleached or dyed cotton fabric was performed with the help of blocks. After printing / painting, the fabric pieces were dried at room temperature, followed by steaming at 102°C for 45 min in a cottage steamer (Figure 7.4). After steaming, the printed / painted fabrics were washed in a solution containing 2 g/l non-ionic detergents at 60°C for 10 min, followed by washing with cold water and finally dried in air. Figure 7.5 shows the different dyed and printed Kotpad fabrics with various motifs.

Figure 7.2: Dyeing process of Kotpad fabric with natural dye

Figure 7.3: Printing paste

Figure 7.4: Steaming process of natural dyed and printed fabrics

7.2.5 Discharge style of printing

The scoured and bleached Kotpad cotton fabric was dyed with *Terminalia chebula* (100g/l) following post-mordanting methods in the presence of ferrous sulphate (10 g/l). The dyed fabric was then printed with a paste consists of oxalic acid, ammonium hydroxide, gum indulka and water, followed by steaming at 102°C for 15 min. The fabric was then washed thoroughly with 2 g/l non-ionic detergents, followed by cold wash and finally dried in air. Figure 7.6 shows the discharge style of printing and the motifs were inspired from *Machha* (Fish) and *Bilai khoj* (Cat's paw).

7.2.6 Batik with natural dye

Batik work is a traditional process of dyeing the fabric by resisting the specified area with wax. Beeswax and paraffin wax were used for resisting the colour. Batik work with natural dyes was performed in the following steps:

Drawing and waxing

The motif was drawn on the fabric as per the requirement. Wax was applied over the areas which needed to retain the ground colour in accordance with the motif (Figure 7.7 and 7.8).

Dyeing with Indigo

Indigo is a very popular dye for Batik work (Figure 7.7). The wax-coated fabric was dipped into a solution comprising of *Indigofera tinctoria,* sodium hydrosulphite and sodium hydroxide, and the dyeing process was carried out at room temperature.

Dyeing with natural colour

Waxing was done on a fabric dyed with Myrobalan. The wax-coated fabric was pre-mordanted with aluminium sulphate (10 g/l) for 20 min at room temperature, followed by dyeing with the aqueous extract of Alizarin and kept for another 30 min at room temperature, followed by drying.

Wax removal

As natural dyes are very sensitive to alkali, the conventional wax removing process was not possible. It is essential to use non-ionic detergent and emulsifying agent for removing wax. Removal of wax resulted in a contrast between the dyed and resisted portions.

Table 1: Printing paste for block printing and painting

	Colour	Source	Aqueous extract	Mordants	Quantity	Thickener
1	Black	Myrobalan (*Terminalia chebula*)	100 ml	Ferrous Sulphate	10 g/l	Gum indulka
2	Brown	Catechu extract	100 ml	Copper Sulphate	2 g/l	Gum indulka
3	Red	Alizarin extract	100 ml	Aluminium Sulphate	20 g/l	Gum indulka
4	Dark red	Lac	100 ml	Aluminium Sulphate	2 g/l	Gum indulka
5	White discharge	Oxalic acid	10 parts	Nil	100 g	Gum indulka

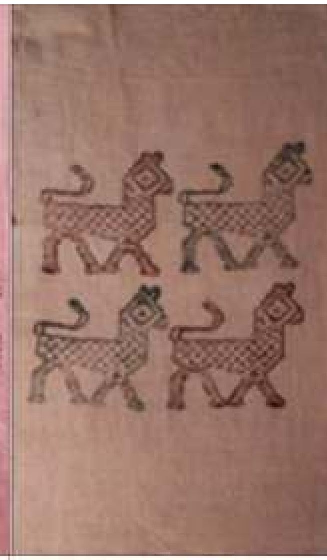
			
Ground colour: Myrobalan, Motif: *Machha* (fish) Block Print i) Ferrous sulphate &Gum indulka, ii) Catechu &Gum indulka	Ground colour: Madder, Motif: *Bilai khoj* (Cat's Paw) Block Print i) Catechu &Gum indulka	Ground colour: Aal Motif: *Bagh* (Tiger) Block Print i) Ferrous sulphate &Gum indulka ii) Catechu &Gum indulka	Ground colour: Madder with Myrobalan topping Motif: *Pipli* (Butterfly) Block Print i) Ferrous sulphate &Gum indulka ii) Catechu &Gum indulka
			
Ground colour: Tea leaf with Madder topping Motif: *Mrudanga Purusha* (Drummer) Block Print Ferrous sulphate &Gum indulka	Ground colour: Turmeric Motif:*Bhainsa Hal* (Agriculture with Bullocks) Hand Painting i) Ferrous Sulphate &Gum indulka ii) Alizarine&Gum indulka, iii) Lac &Gum indulka iv) Catechu &Gum indulka	Ground colour: Annatto, Motif: *DeulGudi* (Temple) Hand Painting i) Ferrous Sulphate &Gum indulka ii) Alizarine&Gum indulka iii) Lac &Gum indulka iv) Catechu &Gum indulka	Ground colour: Onion Peel Motif: *Kela Jhar* (Banana tree) Hand Painting i) Ferrous Sulphate &Gum indulka ii) Alizarine&Gum indulka

Figure 7.6: Discharge style of printing (Motif: Machha and Bilai khoj)

Figure 7.7: Batik work (Ground colour: Indigo, Motif: Tulsi chowra)

Figure 7.8: Batik work (Ground colour: Myrobalan with Aluminium Sulphate followed by Alizarin)

8. Application of Natural Dyes at Kotpad

Commonly available natural sources like turmeric, onion peel, pomegranate rind and annatto seeds have been introduced at Kotpad. The yarn was dyed with the aqueous extract of these colourants, and weaving was executed subsequently. Figure 7.9 and 7.10 describe the process adopted at Kotpad for dyeing of yarn with natural dyes. These yarns were used to weave the fabric (Figure 7.11) to bring in colour and design variations in their weaves and also to add value to the end product.

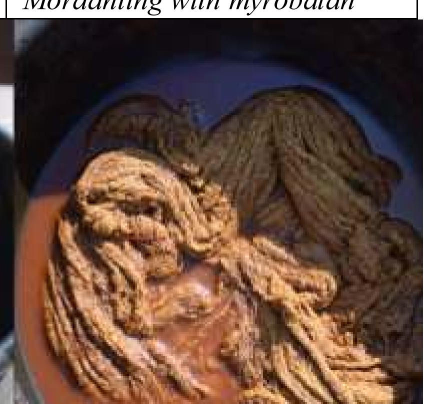
Local Turmeric

Boiling in salt water

Mordanting with myrobalan

Turmeric solution

Rubbing of yarn in the solution



Resting the yarn in the solution for a day in sunlight

Heating till the water is absorbed	*Washing the dyed yarn*	*Fixing the dye with alum solution*

Dyeing of yarn with onion peel	*Dyeing of yarn with annatto seeds*	*Dyeing of yarn with pomegranate rind*

Figure7.9: Process of natural dyeing with turmeric powder in Kotpad

Dyed yarn using onion peel	*Dyed yarn using annatto seeds*	*Dyed yarn using local turmeric powder*	*Dyed yarn using pomegranate rind*

Figure 7.10: Dyeing of yarn with other natural sources in Kotpad

Figure 7.11: Kotpad weave using yarn dyed with annatto seeds and onion peels

9. Conclusion

Kotpad weaves were the first to get GI in Odisha [9], yet many are not aware of it. The weavers are struggling to keep the younger generation involved in their age-old legacy of weaving, as they prefer other odd jobs. The government is making many efforts for the survival of Kotpad weaves. The cotton yarn used is expensive, and the extraction of the dye and the process of dyeing is complicated and time-consuming. The weaving process is rudimentary and thus again requires much time. All these factors make the weaves expensive. Locals have shifted to cheaper and brighter mill made *sarees*. As the motif designs, yarn quality and colours are limited, the demand for these textiles has become stagnant. In the absence of a local market, they sell their produce directly to designers / consumers in bigger cities. Unless appropriate and quick steps are taken, the beautiful Kotpad weaves may become a thing of the past. New designs, colour variations through other natural dyes and better looms will hopefully bring in better survival opportunities and preserve this symbol of cultural heritage. Design development for Kotpad weaves is a small step in this context.

General awareness regarding Kotpad weaves and motifs is very limited. Since the block printing process is the most widely used process for design transfer amongst the handcrafted fabrics of India and is used extensively by the present-day designers, it was felt that if the Kotpad motifs could be transferred on the fabric using block printing, hand painting and batik work, it may gain popularity amongst designers and through them reach a wider market, which may, in turn, generate higher recognition.

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Some Issues in Selecting Shuttleless Weaving Machines

S. Srinivasan

Mr. S. Srinivasan

Mr. S. Srinivasan is a M.Tech in Textile Technology with FCMA (Fellow Cost & Management Accountants) and a MBA. He has a long experience of about 32 years in the Textile Manufacturing in India and Abroad. He has exposure to almost all the sections of the textile units, viz. Spinning, Weaving, Processing, Circular and Warp Knitting, Polyester Melt Spinning, Texurising, Embroidery, Garments and Utilities.

He retired as Director (Operation) in Lagos (Nigeria) from a Textile cum Plastic Manufacturing unit. He has been a Practicing Cost Accountant from 2011 to 2019 and since April 2020, he is "Regional Director (Chennai Region)"of M/s. Pursuitex Advisory Services LLP (India).

M.: 9840398160.
Email: rcpgsrinivasan52@gmail.com

Abstract

Capital Investment in Shuttleless Weaving machines(SWM) is to be taken after setting right the house first in building culture of quality, building goodwill for high priced products, trading for some period and careful selection of the SWM for the product intended and market segment(s) to be served in mind.

A. INTRODUCTION:

Compared to auto-shuttle looms, investment in Shuttle-less Weaving Machines (SWM) is very high. Despite a several fold higher investment vis-à-vis the increase in productivity and quality from the SWMs, many weaving units, switch over from conventional shuttle looms, to SWMs, due to one or more of the following reasons.

1. Inability to train maintenance staff, to adequately maintain the conventional machines,
2. Inability to adhere to the schedule, to clean oil, grease and set right all the parts of conventional machines that are necessary to reduce break downs.
3. Inability to train weavers, to enhance their skill, to improve the quality of fabrics.
4. Inability to contain, flight of trained weavers and mechanics.
5. Non-availability of standard/proper parts that fit properly on looms.

The Management apathy for man-power development, as well as the despicable labour culture of NOT maintaining any asset, are the reasons for the woes. The conventional technology is discarded under the impression that the conventional machines require "too much to do" by the existing work force and so the modern technology is opted, where less human interference is needed. An organisation should first remove the "inabilities" listed above, before embarking on modern technology, to reap the best from the huge investments.

B. HIGHLIGHTS OF SWMs:

The SWMs overcome the problems arising due to dependents on human power for quality, maintenance etc. by having better metallurgy (that reduces wear and tear), machine dynamics & design, centralised oiling unit, scheduling auto-oiling of parts through computerised programmes, repetition of exact settings as per the stored memory in the computer, etc. in addition to higher speeds, much wider widths, controlled auto-let-off, bigger batch size in beams and cloth rolls, suitability for wider range of fabrics etc. These improvements are provided at a high cost, resulting in higher price of the machine.

The mechanism in conventional machines are basically of mechanical in nature, the SWMs have many electrical and electronic gadgets which require a) frequent cleaning of the machine to avoid dust affecting the electronics, b) cool ambience and controlled power supply voltage and frequency. The SWMs also require better quality of input material, like higher yarn strength, less count and strength C.V.s, hairiness, fluffs etc. for getting the required production. Some of these requirements like yarn strength are not required to that level for processing fabric in the post weaving departments like processing and garmenting, and even for the end uses. This means this extra strength is imparted just for weaving on SWM and it is important to note that the "required better quality of various input materials" comes with an additional cost.

C. MARKET ING CAPABILITIES:

The huge investment required for SWMs, necessitates production of high priced fabric. Some weaving units, without considering the inability of selling such high priced fabric, embark on huge investment in modern technology and end up in successfully producing the high-priced fabrics but not in selling them at the envisaged price. A product similar to the best in the market can be made but can NOT be sold that easily. The Company requires good-will among the consumer, the conventional approach to gain it, is through continual delivery of quality (even of the low priced goods) and ensuring quality service. Many units who were basking on seller's market for a long time fail in the latter aspect. This means, before bringing in a culture of "Quality" in all its activities, a Weaving Unit should not venture higher investment.

D. STAGEWISE PROCESS:

The transition to modern technology (that need huge investment) should happen in stages, first with minimum investments to improve the existing conventional weaving machines a) through simpler modifications on looms (like introduction of warp stop motion, semi-auto let off, individual motor drive, clutch mechanism, etc.) and b) by imparting higher skills to the present weavers, and maintenance staff through rigorous training.

In parallel, a sound management policy of a) buying only standard spare parts, b) raw material and c) having effective planning. Once an organisation establishes consistent quality culture in its product and services, the fruits of higher investment will be reaped without undue effort.

Thus, the better approach is, first to utilise the available resources (especially machinery) fully.

E. SWM SELECTION PROCESS:

Once, a unit's culture is ripe to go for modern technology, the basic steps to be followed are:

1. **Product Selection:** To make a thorough market study and trade for a period and decide about the products which the organisation is capable of selling. (This selection restricts the selection of technology most suited for the product). Each technology is most suited for fabrics of certain range only.
2. **Technology Selection:** There may be more than one technology suitable for the same products. It is better to avoid selecting too extreme products in the product-range (like fine voile and heavy denims). A "light and medium" fabrics or "medium and heavy fabrics" or "heavy and very heavy" fabrics are the normally selected combinations in the product range.

   Following table gives a glimpse of the technical details that are to be considered to check the productivity, waste, suitability of the machine for the product to be made. For instance, item 2 in the Table, has an influence on the width of the fabric to be woven and the number of such fabric to be woven on the same machine. The item 3 is about production rate, item 4 on type of selvedge available, item 5 on weft wastage and warp wastage(that has a bearing on (item 6 i.e.) warp beam dia, item 8 & 9 on permitted warp and weft range in terms of raw material, count range, twist etc, item 2 & 13 on the warp and weft density. The remarks column indicates some relevant points to be considered for techno-economic evaluations. For instance, if only fringe selvedge is available for the technology, and if such fringe selvedge is not accepted by the consumers, there is a mismatch between what can (only) be produced and what is required. Similarly, sized-warp is inevitable for non-synthetic warp; Water-jet technology is out of the options available and so on. Each and every technical feature is to be considered to bring about the difference in the cost-benefit analysis.
3. **Make selection:** The next step is to select the best "Make" for a given technology, as each maker produces weaving machines of different technologies and vice versa (i.e. for each technology there are different makers) and consider the best make for the technology opted. For comparison, an index "Investment in Rs. per 100,000 metres of weft inserted" after considering efficiency may be arrived at for each technology & make. It may be noted that the factor "metre" is introduced to take care of number of widths involved.

Table 1. Showing technical features of SWMs

Sr. No.	Particulars	Sulzer	Picanol	Tsudokoma	Tsudokoma	Remarks
1	Technology	Projectile	Rapier	Air Jet	Waterjet	
2	Width (c.m.)					
3	Weft Insertion (mpm)					
4	Selvedge Type					tuck-in , leno, fringe, fused,
5	Waste% (Wp/Wf)					
6	Weaver's Beam Dia.					Saving in beam fall, sizing doff time, Warp waste
7	Cloth Roll Dia.					Saving in doff time, wastage associated with joining the grey fabric
8	Warp Range (Ne)					
9	Weft Range (Ne)					
10	Warp Material					Cotton. Blends, 100% MMF etc.,
11	Weft Material					Cotton. Blends, 100% MMF etc.
12	EPI					
13	PPI					
14	Reed Space loss					Between each width of fabric
15	Fabric weight Range (GSM)					Cover Factor etc.

1. **Width & Lot Size Selection:** It is axiomatic that if two (or more) widths are woven simultaneously on a single SWM, the lot size for the particular fabric has to be more. As against this choice, instead of making a large quantity of the same fabric on ONE multiple width machine, for the same quantity in total, single width machine can produce different fabrics in each of the machine, thus increasing the flexibility of the unit (to serve smaller markets also). This decision will depend on the present and potential customers the organisation wants to serve. Nowadays, the local market and export market requires variety that is often associated with smaller lot. The organisation may opt to serve a large number of smaller customers of various needs and may consciously decide to lose the economics in production rates of wider machines and more than compensate the loss by charging some extra price for the smaller lot. The selection need not be based on economics on cost of production alone but on the net return the organisation gets on the whole. Thus, the decision on the overall width of the weaving machine is very important.

2. **Width & Speed:** The (multiple) width has influence on a) speed (and hence the weft insertion rate), b) rate of warp & weft breaks, c) time to gait beams/warp tying, d) Space and e) to some extent time taken for cloth doffing etc. Wider machines run at a slower speed but the weft insertion rate is higher. Due to this, there is higher weft exhaustion rate per unit time, and due to more number of warp threads, the probability of warp breaks and warp entanglement/fabric defects in a unit time is also higher but the effect of lower speed on breakage rate should be seen together. The supplier's technical assessment should be sought in these areas for the given quality of warp/weft the organisation intends to use. This assessment will indicate the running efficiency achievable.

Every technical specifications of the machine should be considered and where the features cannot be converted into financial terms, they should be mentioned as a foot note. Some of the textile materials related items were listed earlier.

The mechanical related items of the machine that should be considered in the cost benefit analysis are listed below:

- Shedding: (tappets, dobby, jacquard etc.) each of the selection, has effect on the weave that can be woven.
- Weft Cols (2, 4, etc.) has effect on the number of colour thread in weft.
- Special attachments: Back rest for Denim etc.
- Speed affects the production and get influenced by the width and other attachments of the weaving machine and the warp and weft type (like high twist/fancy etc.) and quality
- Recommended Maintenance (for Cleaning, oiling, greasing, settings) frequency and permitted time to attend (which decides the recommended compulsory machine stop for continuous standard performance, thus has a bearing on period of utilisation of the loom):
- HP connected: Motor 1, Motor 2, Motor 3 and % of time each one of them work when the SWM is in operation decides the power consumption.
- The direct labour cost is a function of loom allocation which is determined based on the time for which a weaver is engaged, (plus "allowances") the former is influenced by the yarn quality, speed, weaver's skill in starting the stopped loom etc.

3. **Other miscellaneous details:** Details of other information required are:

- Estimated Spares consumption per 100,000 picks mtr.
- Humidity Requirement
- Space requirement
- Flooring requirement on its strength
- Yarn quality requirement & additional cost for it.
- Weft and warp waste, Fabric Defects level and associated loss
- Lighting requirement etc. is to be assessed and their corresponding running cost should be determined.

4.**Details on one time Investment on the following should be ascertained.**

- Basic machine (care should be taken to know what is included and excluded).
- Accessories
- Humidity plant,
- Cleaning device,
- Beam and cloth handling devise with accessories
- Erection
- Land& Building etc.

A. The present and Future Potentials: The capacity of the organisation in meeting the requirements of the operation of modern machines should be meticulously assessed. The various requirements may be for, production, quality checks and for selling of the intended product(s). Some of them are: a) the skill of various personnel needed, b) availability of such skills now and if not- possibility of getting them within the country, c) training required, d) turnover of trained personnel etc.

B. The Criterion for Evaluation; It may be computed for equal production or for equal number of machines (considering number of width made in parallel on each machine). The former will result in a different number of total widths of all the machines for each option and the latter, in different production levels .Usually, considering the marketing constraint on the quantity to be sold, the "equal production" option is considered. The relevant cost and revenue will vary for entirely a new project and for addition of machines in an ongoing organisation. In the latter case, relevant cost approach is to be made in the evaluation.

C. Selection Basis: The selection may be based on least cost to produce some fixed quantity say, 50,000m/day of a reference fabric of specific width. It may be noted that the selling price of the product made and the result viz. contribution or profit derived is not considered in this approach. This approach considers the intrinsic worth of the machine and segregates the other factors like selling capability, good will etc. that contribute to the return. Technical experts prefer this approach, as any production activity is a resource- consuming activity, that considers the price (costs) to be paid to consume the resources, and therefore, any machine that takes less cost is an obvious choice for selection.

Financial experts consider the return or the cash flow from the investment and adopt IRR (Internal Rate of Return) and/or NPV (Net Present Value) i.e. the entire capacity of the organisation in generating the return is considered.

Conclusion:

To reap the best from high investment, the invested asset should be used in the best possible manner and an organisation should first gear up to this requirement. What is best for one organisation need not be best for another organisation.

INTERVIEW with Dr. Mona Suri by RUW

Dr. Mona Suri
PFHEA, Higher Education Academy, U.K.
Academic Vice President,
Royal University for Women, (RUW),
Kingdom of Bahrain
Associate Professor, Fabric and Apparel Science
Former Reader, Lady Irwin College, New Delhi

Dr. Mona Suri, Associate Professor, is the Academic Vice President at Royal University for Women (RUW), PFHEA, Higher Education Academy, UK, with a teaching experience of more than 31 years.

She completed her studies in Fabric and Apparel Science from Delhi University, India. She has been actively involved in research and teaching and has successfully supervised six PhD and 45 Master's students. She has many publications, presentations and awards to her credit.

Dr. Mona Suri was teaching at Lady Irwin College, Delhi University, New Delhi, for twenty years and joined the Royal University for Women in September 2008 and in the last thirteen years, has been contributing the academic and corporate life of RUW. Before taking up the role of Academic Vice President she was the Dean for College of Art & Design for over six years.

She has played a key role in creating linkages of the college with International partners including West Virginia University, Embassies, Industry, visiting professors and Fulbright Scholars. She has been the Conference chairman for RUW biennial Conference on Women and Society since 2016, initiating annual Fashion show Modamist and Design Exhibitions at RUW. She has been part of many National Projects in Kingdom of Bahrain, including projects with the Supreme Council for Women and BAPCO.

Some Experiences of Teaching at Royal University for Women in Kingdom of Bahrain

Q.: You have spent quite some years at RUW! Can you please share your journey with us?

I joined RUW in 2008 as an Associate Professor in Fashion design, before that I had worked in India at Lady Irwin college New Delhi, since 1989. I have six PhD students who completed under me, and more than 45 Masters Students have finished their projects under my supervision. I am also a Principal Fellow of Higher Education Academy, UK. My journey was very exciting especially because I am always surrounded by young and energetic students. There have been challenges but interesting ones. At RUW I joined as pure academic and later was appointed the Dean of College of Art and design and then I became the Academic Vice President. My expertise is in fashion design but more from a technical perspective and I love the subjects related to research or research methods. In last thirteen years there has been ashift as I joined as pure academician and later as AVP was in academic administration. I have enjoyed both roles thoroughly.

Q.; From India to Bahrain! How do you find the culture difference as far as the students are concerned?

For me students are the same whether they are in India or are in Bahrain or in any other part of the world because the 17 years old student's that come from school to the university have same feelings…. they have the same butterflies in their stomach… they are sad to leave their friends but at the same time they're also excited to meet new friends in the university environment. Also, even for parents they share the same emotions.

When I came to Bahrain, I was actually anxious, that there is going to be a cultural change with language barriers, but to my surprise I realized that whether it is the parents or the students they're just the same. I still remember an incident where one of my students and her father came to me and this girl had studied in another foreign university and then she had to complete her studies in Bahrain, and they chose RUW. When I met with the father and the student, and discussed how the student can settle down in a new environment, I could just imagine myself sitting in India and talking to some students there, and believe me, it was just the same feeling. So, to me whether in Bahrain or anywhere else in the world the relationship/bond the students and parents share with one another and with teachers is just the same.

Q.: What aspects should a student consider before she decides to choose a university to study at? Also, can you tell us more about what a student at RUW experiences?

In my view the students who are planning to join the university should consider

1. Quality of education in the University (accreditations/ mappings, international standing)
2. Academic facilities, Infrastructure, extracurricular opportunities, International linkages.
3. Opportunities available at the university, so that they get more chances to bloom they also have various other ways of showing their talent and their other capabilities.
4. Qualifications and Experience of Faculty members, who are more like facilitators and friends who are guiding you and who are supporting you to attain your goals.
5. Where the alumnae are placed (if possible, talk to them) as they can give fair review of the university

In my view since I've been at RUW for almost 13 years I realize that the students who join RUW are actually more mature they are more focused and they have also more skills that they have with them and again as a university RUW gauges these, balances the skills of the students and wherever there is a gap we try to fill that up with various other activities that we offer.

Another difference that I see in the in the in the students who come at RUW is that most of the students that I have seen across are independent learners. They just need to get an idea and then they take it from the concept and they start working on it independently. Just to give you an example that in the past I had one student who was working on a fashion project where she was trying to create a textile design of Arabic calligraphy and while she was working she tried to make sure that she did a lot of prototyping work at her level to see that how these things can be done and finally she fetched for herself from Bahrain and from Dubai to get these fabrics printed on silk and finally she made her ensembles beautifully for her fashion collection.

Similarly, there was another student who was working on a bridal collection and in order to do that her inspiration was from Bedouin jewelry, and she did this whole thing of getting this material embroidered from KSA from Bahrain and then finally creating their own ensembles.

So, I think being independent learners is something which is again a very positive for the students who are with us because ultimately, they want to excel in whatever they have chosen as their career path whether it is Business, or it is art and design or it is law. Again, as a university RUW is facilitates this kind of independence. We also have a lot of facilities which are available to students in terms of well-equipped studios, online portals, clubs etc. Students can actually start their own club in whatever they feel like working (Environment club, debating Club), Gym, competitions etc.

Q.: What is your contribution to the academic life at RUW in general in the past years and specifically in setting up RUW Women's Research Centre?

Well talking about my contribution to royal university for broadly I worked on the curriculum development when we started initially we had our curriculum from the Middlesex University but then every four years we are doing a curriculum review as a periodic cycle through which we try to make sure that the curriculum is updated, current, robust and fit for purpose.

Secondly my role is to make sure that every program has a linkage with the industry. So, we have made our internship program as a mandatory course for all programs at RUW and this enables the students to actually work in the industry and see how they operate and it gives them a hand on experience. Also, the graduation projects are also linked with the industry again when I talk with industry these industry for us could be a bank it could be an NGO, it could be a governmental organization, or it could be any employer in any area of specialization that we have at the university.

Thirdly it is the active international affiliations and partnerships that we have so we have international partners like West Virginia University, Bangor and with various universities through which we are giving an excellent exposure to the students whether it is a summer course or a faculty exchange program or the student exchange. This international dimension also adds a lot of value to the student's holistic development and global citizenship.

With regards to the RUW Women's Research Centre, it is a collective vision of RUW from the past many years. The biennial International conferences that were started planted the idea. The International Conference on Women in Society which was held in 2016 and the second one in 2018 talked about Role of Women in Society and higher education. The third conference was planned in 2020 but because of COVID it didn't happen so we're hoping that now it will be happening in 2022.

This was an idea that we had actually from the last few years and we initiated this idea in the past that how can we actually set up a center at RUW which is a women's Research Center which caters not only to the needs of Bahrain but also to the entire Arab region and I'm very proud to say that with our long standing association with SCW and then with another partnership with ESCWA we're in the process of setting up a women's Research Center at RUW which will be the hub for all women related research in futures to come.

Q.: What kind of achievements the students had at RUW?

Our students at RUW are very energetic they're very driven and they're super talented. We give them opportunities to showcase their talent in

1. INJAZ company competition is what someone such competition where the students have create very well we have been participating in this competition from the last almost 5-6 years and we have won the prize for the best company we have got the prize for the best product for the best social impact not only within Bahrain at a national level but also at a regional level as well
2. Our students have performed very well in the national skills competition and we have got gold medals for interior, fashion graphic design also we participated in the world skills competition and we again got a medal
3. Students have been participating in the Trade Quest competition which organized by Bahrain Bourse and our students have been awarded for second prize and third prize in the past
4. Individually the students have worked very well to get the best microenterprise award, in hackathon so they have all worked very well in the way areas of law fashion graphic interior business and so many other places

Q.: What is your final advice to all students starting their university life?

In my view students should:

- Talk to people around you (parents, friends, and teachers) before choosing your university or program. These 4 years of study is your investment …
- Choose your friends carefully who support you and challenge you to do better.
- Have a clear aim as to what you want to achieve in life and work towards it.

DKTE New Book on Polypropylene Staple Fibre

DKTE Society's Textile & Engineering Institute is in the field of textile education for over three decades. During this period an urgent need of standard and well authenticated text books, especially on man-made synthetic fibres, has been felt. With this lacuna in mind, publishing the following new book;

POLYPROPYLENE STAPLE FIBRE - *Revealing its True Potential-* ISBN: 978-93-5391-986-3

This book is authored by Dr. S. R. Vengsarker & Prof. S. D. Mahajan who are associated with the textile industry for more than fifty years. Dr. Vengsarker has the benefit of working in both polyester and polypropylene fibre manufacturing and marketing for over forty years. He had unique advantage of interacting with several technocrats in this field in India, Europe and U.S.A. He also got opportunity of visiting some prominent polypropylene fibre manufacturing companies. He has tried to incorporate this information in the book in the best possible manner.

The salient aspects covered in the book include:

- Detailed coverage of major man-made synthetic fibres highlighting the 'unique' properties of polypropylene fibres.
- Modes of manufacturing various grades of polypropylene fibre with special reference to raw material (resin) selection spin finish oil application, fibre testing and quality grading of fibre.
- Fibre to yarn conversion on cotton spinning system and also on Dref-2 yarn spinning system.
- The chapter on applications of this fibre brings out the vast potential of the fibre mentioning several products made in India as well as specialty products produced abroad from high-tech fibre grades.
- Four experts are also involved to contribute by sharing their experience in their specialized fields like use of polypropylene fibre in civil engineering, geo-synthetics, and antimicrobial applications and in denim fabric.
- No. of pages – 328, No. of Figures: 118, No. of Tables:70

Thus, the authors have given a very wide coverage to polypropylene fibre in the book to enable the readers to appreciate its full potential. The book is priced at INR Rs.1000/- (One Thousand only) and 30% discount for academicians and students. The book will prove useful to textile institutes, research institutes and equally to man-made fibre industry.

Review by Dr. S. G. Vinzanekar, Former Principal & Head of Textile Technology Dept., V. J .T. Institute, Mumbai,

The Book exclusively deals with Polypropylene Staple Fibre and provides a wide coverage including physical, chemical properties and structural aspects of major synthetic fibres in use in India, clearly mentioning the properties in which polypropylene scores over others. The Book provides valuable information on polypropylene manufacturing techniques with lot of practical operational inputs and associated spin finish application details on the fibres, fibre testing details and fibre test values expected out of various fibre grades. Moreover, polypropylene's exceptional properties are also highlighted in the context of end user applications such as filtration fabrics and sieves, geo-synthetics, carpets, floor coverings for automotive applications, civil engineering applications etc. Special mention is about un-usual wicking property of polypropylene not found in other fibres and advantage taken in inner-wears and sportswear.The authors have taken pains to bring out "niche" applications of polypropylene fibre practiced abroad and the Indian industry should explore these products to expand the market.

There are four Chapters (No. 8 to 12) in the Book contributed by guest authors, experts in their own fields. They cover practical application of polypropylene fibres in civil engineering applications in geo-synthetics (in combination with geo-grids, geo-nets, geo-membranes), in anti-microbial yarns/ fabrics and in Denims. Out of the above, use of polypropylene fibre in geo-synthetics is well established and is growing at a faster rate due to infrastructure development. Field trials taken are well explained with details and colour photographs. There is no doubt that the authors have presented the subject matter very lucidly with illustrations, figures, tables, graphs and photographs. The Book covers most areas of polypropylene fibre-from raw materials to manufacturing to fibre end applications-and will be a reference guide not only to fibre industry but also to technical institutes, research organizations and textile students. It is therefore recommended that the technical institutes can now introduce Polypropylene Fibre and Filament as an elective credit in the synthetic fibres course syllabus.

I wholeheartedly congratulate the authors to bring out this exceptional Book at a time when such informative textile books are needed the most. The Book is printed meticulously in suitable font to make reading comfortable.

For enquiries to contact:
pachougule@gmail.com,
Mobile No: +91 7709958318,

USTER The Double Security Stress-busting Solution for Weavers

Why Uster Q-Bar 2 should be a standard in fabric inspection

What do weavers need? In a word, it's security – for both fabric quality and profit margins. And for this double security, there's only one solution: the Uster Q-Bar 2 formation monitoring system. It's like having an extra operator dedicated to a single weaving machine…

Operators should be everywhere at the same time – checking, fixing, keeping the machines continuously running – no matter in which weaving mill, all around the globe. Operators should be as fast as world record sprinter Usain Bolt, see as good as an eagle and with the knowhow of an engineer and service technician for different kinds of weaving machines. As operators with this skill set are really rare it's a matter of fact that most of them are stressed.

Don't risk profitability

This kind of stress can be a risk to weavers' profitability. For example, a worn-out part might be overlooked, setting off a drama affecting margins. Defects could be repeated, showing up again and again – linear meter by linear meter – for as long as it takes to identify the fault and fix the issue. If only someone could have an eye on things, constantly.

Long-running defects can also arise from dirty parts, or from missing or inadequate maintenance. Whatever the issue, what they have in common is that they spoil lots of good fabric – worst of all in the middle of the web – and yet they can be automatically detected and damage avoided. Q-Bar 2 is the solution, working with various weaving machine types (except water-jet and jacquard).

Uster Q-Bar 2 has its inspection position within the fabric formation area, allowing it to respond quickly when a defect appears and avoid long-running or repeating faults. Alarms and stop signals alert the operator to correct problems immediately. This early detection reduces second quality and material loss.

Q-Bar 2 also monitors critical machine units in the formation zone. If there is a problem here, the system makes it easy to identify and eliminate it, preventing further defects, and again maximizing fabric yield.

Smarter than loom sensors

To err is human – which makes it essential to have machines. Smart weaving machines do point out issues to the operator, but Q-Bar 2 sees what weaving machines can't. For example: the constantly stressed operator fixes a broken warp yarn, picking the yarn and drawing it in the reed position; loom sensors get the signal that the missing yarn is now available and accelerate to full speed within milliseconds. Immediately, an alert starts at Q-Bar 2, with a red light indicating the location of the issue. What happened? The operator picked the wrong reed position. Without the Uster formation monitoring system, the defect stayed undetected; as the operator had already moved on to fix the next issue at another machine.

Time pressure is not the only worry. Complex patterns, fine yarns and a lack of experience can all lead to wrongly drawn-in warp yarns – defects that are hard to recognize with the human eye. Without an automatic solution in place, the problem with wrong draw-ins is usually unnoticed until it's woven into the fabric for some meters of length.

Security for management and shop floor

The best way to avoid off-quality is simply not to make it. A zero-defect standard is what many weavers wish to achieve. Q-Bar 2 is the way forward. Weaving defects can have various root causes, so Uster Q-Bar 2 provides different algorithms to identify specific defects and their causes. With this knowledge, it is possible to prevent defects during the actual weaving process.

Uster Q-Bar 2 monitors the fabric already at the critical stage in fabric formation with automatic, in-line inspection. Identifying problems here brings enormous benefits and enables weavers to deliver constant quality and stay competitive in the market.

Operators would surely vote for Q-Bar 2 as a standard on every weaving machine. They would appreciate Q-Bar 2 as the new colleague in their team, reliably keeping an eye on the web all day long. Whether a single or repeating defect occurs, the integrated LEDs used by Q-Bar 2 would highlight the system status and pinpoint the location of defects with red lights. Wouldn't it be great to empower operators to secure both profitability and quality for the boss!

For more information, please contact:

Edith Aepli
On behalf of Uster Marketing Service
Uster Technologies AG
Sonnenbergstrasse 10
8610 Uster
Switzerland
Phone +41 43 366 38 80

RIETER

Rieter Acquires Three Businesses from Saurer

- **Investment to complete Rieter's ring- and compact spinning systems and in two attractive component businesses**
- **Schlafhorst automatic winder as well as Accotex and Temco will be transferred from Saurer to Rieter**
- **Closing expected during the month of August, implementation to be completed in six to nine months**
- **Changes in the Rieter Board of Directors**

Rieter Holding Ltd., Winterthur/Switzerland, and Saurer Intelligent Technology Co. Ltd., Shanghai/China listed, signed an agreement on August 13, 2021 by which Rieter will acquire three businesses from Saurer Netherlands Machinery Company B.V., Amsterdam/Netherlands, the parent company of Saurer Spinning Solutions GmbH & Co. KG, Uebach-Palenberg/Germany and Saurer Technologies GmbH & Co. KG, Krefeld/Germany.

With this acquisition, Rieter will complete the offering of ring- and compact spinning systems by acquiring the Schlafhorst automatic winder business. Additionally, Rieter invests in two attractive component businesses: Accotex (elastomer components for spinning machines) and Temco (bearing solutions for filament machines).

In total, the three businesses had a combined turnover of EUR 142 million in 2020, the year of the COVID crisis. In 2019 and 2018, the total combined turnover was at a level of EUR 235 million and EUR 260 million, respectively.

The purchase price for the three businesses is EUR 300 million on a cash and debt free basis. Rieter has financed the purchase price by cash and available credit lines.

Rieter and Saurer expect to close the transaction during the month of August. In the first step of the transaction, Rieter will acquire 57% of the shares of Saurer Netherlands. The shares will be returned to Saurer after the implementation of the transaction in six to nine months.

In connection with the transaction, it is envisaged that Rieter will supply automatic winders to Saurer in the future.

Changes in the Rieter Board of Directors

During the course of this transaction, it came to serious violations of the statutory duty of loyalty, the obligation to maintain business secrets and the Rieter Code of Conduct by the two members of the Board of Directors Luc Tack and Stefaan Haspeslagh. They have used information internal to the Board of Directors in order to compete with Rieter through their own offer.

The Board of Directors considers this to be a strong violation of Rieter's interests, to the detriment of all of its stakeholders, and a sustained breach of the relationship of trust within the Board of Directors which makes further cooperation impossible.

Therefore, the Board of Directors of Rieter Holding Ltd. intends to convene an Extraordinary General Meeting at which its members, Luc Tack and Stefaan Haspeslagh, are to be dismissed.

To protect Rieter's interests, the Board of Directors will file a criminal complaint against the two members of the Board of Directors.

The date of the Extraordinary General Meeting will be announced at the appropriate time.

For further information please contact:

Rieter Holding Ltd.	Rieter Management AG
Investor Relations	**Media Relations**
Kurt Ledermann	Relindis Wieser
Chief Financial Officer	Head Group Communication
T +41 52 208 70 15	T +41 52 208 70 45
F +41 52 208 70 60	F +41 52 208 70 60
investor@rieter.com	media@rieter.com
www.rieter.com	www.rieter.com

Professor W. B. Achwal Endowment Oration

Department of Fibres & Textile Processing Technology, ICT featured Prof. Rajiv Padhye, Director, Centre for Material Innovation and Future Fashion, School of Fashion and Textiles, College of Designing and social Context, RMIT University, Australia on **"Saving Lives" – Materials for Protection** during the 5th **Prof. W. B Achwal** Endowment Oration on 3rd June 2021. The Online aired program received overwhelming response from the students, academicians and industry representatives from across the world.

Prof. Ravindra Adivarekar welcomed the audience and briefed about the significance and value of the endowment and the activities performed in the past and planned in the coming year.

Shri Subhash Soudagar - a 1973 batch M.Sc.(Tech) student of Late Prof. Achwal & an eminent industry stalwart shared his fond memories of his beloved Guru recalling him as a strict academic disciplinarian but a helpful kind hearted person. A sport enthusiast and motivator for participation in extra-curricular activities. How Prof. Achwal helped nurture the values and ethics in students which helped him advancing in industrial career.

Dr. Sanjeev Kamat – a well known and respected industry expert and student of Prof. Achwal informed about the recent sad demise of another student of Achwal sir **Shri Vilas Mohite** and paid homage to him.

Prof. Ganapati Yadav, Padmashri Awardee - former Vice Chancellor of the Institute shared his reminisce about Late Prof. Achwal and recalled his academic accolades and narrated incidences which instilled his fond memories, the command and fluency of Prof. Achwal over foreign languages like German and Russian in which he published many Textile related research articles and also his immense contribution to science by writing in a simple, easy to understand Marathi language for the common public.

Shri Abhijit Achwal – son of late Prof. Achwal shared his fond memories and highlighted the discipline, punctuality, focussed systematic work approach and jolly helpful nature. He thanked the textile department for arranging the endowment event and Prof. Rajiv Padhye for accepting the invitation to deliver this lecture.

Prof. Aniruddha Pandit, Vice Chancellor welcomed all to the memorial lecture and thanked Prof. Padhye for selecting a relevant topic on Saving Lives by using protective textiles under the ongoing pendemic condition.

Prof. Rajiv Padhye delivered a highly informative and knowledge sharing lecture on Protective Textiles for saving lives. Given below are excerpts;

After giving brief information about the present status of the Textile industry in Australia and the reasons for the shift from the commodity apparel wear to the specialised value added functional technical textiles. He explained the role and activities of the Centre for Materials Innovation and Future Fashion (CMIFF) within RMIT University. He explained advantages of strategically mixing a natural polyamide fibre like Wool with Kevlar, a synthetic aromatic Polyamide in terms of achieving a multi-layered Ballistic protection along with improved wet performance. The various tests specifications to evaluate the performance efficacy of the blended fabric were provided.

Another example highlighted the development of high strength fabric for combat clothing to mitigate shrapnel Impact. A lightweight material constructed using seamless knitting utilising a 3D CAD system was also mentioned.

The next segment of innovation was in the field of Chemical, Biological and Radiological (CBR) protection. A multi-layered protective apparel system with improved physiological comfort for metabolic stress reduction was explained. The other innovations included protective Vests for Policewomen, development of Next-to-skin sports fabric with high abrasion and penetration resistance, IVA skin suites for space travel, Novel car seat to facilitate reliable Airbag deployment, surgical mesh, etc. Many of these innovative products are presently under the advanced stages of development and considering the aspects of confidentiality the specific composition parts could not be revealed.

Prof. Padhye also touched upon the importance of sustainability and the research directed towards recycling of Mattresses and converting post-consumer textile waste into reusable products. The use of recycled fibre materials for the building insulation and acoustic performance of Soft Pod fibre board's was also highlighted. Textile coloration with Natural dyes and fibre reinforced concrete are some of the on-going research projects.

During the post oration question answer session, Prof. Padhye ably responded to various questions pertaining to the innovative research activities, ideas, concepts, materials and methods.

Proposing Vote of Thanks, **Prof. R. R. Deshmukh**, Registrar thanked the audience for attentively participating in the Prof. Achwal endowment lecture and thanked Prof. Padhye for delivering excellent talk explaining the importance of Saving Lives using Protective Textile material.

Prof. Rajiv Padhye – A brief introduction

Prof. Rajiv Padhye is an alumnus of the department of Fibres and Textile Processing Technology of ICT (formerly UDCT). After graduation, he went to UK and did doctorate from University of Leeds and now he is the Director of 'Centre for Materials Innovation and Future Fashion' at the RMIT University, Australia. He has a unique distinction of having both the industrial as well as academic experience. This has helped him in the application performance oriented research. He specialises in sustainable aspects of Textile colouration and functional Coatings for Protective, Sports and Medical textiles applications.

Prof. Padhye has published 6 co-edited books, 12 book chapters and over 150 research articles and has presented papers at various Conferences. He is a chief research project investigator for Australian Defence and other industry partners. He has three joint Patents and commercialisation agreement on "Soft Ballistic fabric", "Deployable air bags"," Abrasion resistive fabric in sports application" and "Application of sensors in fire fighter's uniform.

Prof. Padhye has won many awards including the 'Australia New Zealand Sports Technology Award' and Capability Improvement Award by the Australian Defence Materials Innovation Centre. He is a Fellow of the Textile Institute UK, Technical Textiles and Non-Woven Association (Australia), Society of Dyers and Colourists for Australia & New Zealand.

TRÜTZSCHLER Proven Results with Innovative Comber Machines

More and more TCO 12 combers are now operating in India – and that success had to be earned. Customers in the Indian spinning industry want to experience real-world results from innovations on the shop floor. The rising popularity of the Truetzschler comber TCO 12 is a powerful indication of how our machines meet these expectations by providing outstanding quality and productivity.

When Truetzschler launched its first comber TCO 12 in India in 2017, it faced some major challenges. Local and international competitors were fighting hard to win market share, while spinners in the Indian market wanted to get real-world and first-hand experience of the Truetzschler technology before they believed in the value of Truetzschler combing innovations like servo drive, twin drive or auto-leveler.

Vardhman Group – one of the biggest textile conglomerates in India is significant addition to a growing group of Indian companies that are using combing machines from Truetzschler. Vardhman has always been keen and proactive in trying the latest technological innovations. In this spirit, Vardhman decided to buy its first Truetzschler comber in 2017.

The customer tested the machine for two years at its site in Madhya Pradesh, comparing the quality and productivity against machines from other providers. Based on this trial, Vardhman was confident about the technology and performance of the TCO 12 – and ordered a complete combing set for its new spinning plant in at Vardhman Fabrics Unit, Budhni.

Another generation of innovative combing

In 2020, Truetzschler boosted its portfolio of combers by launching the next-generation "Type-2" machines. These new combers were developed in response to experience and insights from our customers' sites. They offer a range of new features that improve on the "Type 1" machines launched in 2017.

This includes:

- Simplified changing of the detaching distance, within just a few minutes.
- A new and easy-to-use comb brush setting mechanism.
- A new top comb locking system.
- The option to select a detaching curve, for higher speeds.
- A special handle to lock and open the detaching unit with one hand.
- Modified doors and covers for better accessibility and aesthetics.

The machines have now been running at the Vardhman Fabrics site in Buddhi for more than a year. Technological reports for count Ne 20s to 30s showed that the machine comfortably achieved benchmarks for quality and productivity at high Nip rate of 500 and more.

Mr. T. C. Gupta, *CGM Vardhman Fabrics*

"*The TCO12 is a futuristic design*," said **Mr. T. C. Gupta**, Chief General Manager of Vardhman Fabrics unit. "*It presents special features where manual intervention is significantly reduced.*"

Mr. Harsh Mani Tripathi, Senior V. P., Vardhman Fabrics, added: "*We supported all of these trials and shared our valuable input to make it a success. Vardhman Fabrics appreciates that the machine is good in terms of technology – and is also very stable, even in varying RH/Ambient conditions.*"

Mr. Harsh Mani Tripathi,
Senior V. P., Vardhman Fabrics

Automatic greasing

The Truetzschler comber machines used by Vardhman Group also feature a special auto-greasing device. This automatically applies grease to all of the components that require it, which makes sure all necessary points on the combing head are always greased accurately and at the right time.

"*At Vardhman, we appreciate this unique and innovative design feature,*" said **Mr. S. K. Nagar,** Chief Manager. "*Manual greasing means applying grease to 70 points within the machine. We always saved this time and effort*"

Mr. S. K. Nagar,
Chief Manager, Vardhman Fabrics

More innovations coming soon

The road to success, as the saying goes, is always under construction. In line with this saying, Truetzschler's team is now working hard to develop even more features that add value for customers in this market.

This includes the 1,200-milimeter Jumbo Can, as well as the Auto LAP transportation system and the flexibility to use different technological components. An automatic lap piecing system for the comber is now in development.

The planned new features are part of the company's long story of responding to challenges by creating innovative solutions. And the next chapters in that story could be the most exciting ever…

Lenzing VEOCEL Brand Launches Hydrophobic

Lenzing's VEOCEL™ brand launches hydrophobic lyocell fibers with Dry technology.

The VEOCEL™ branded lyocell fibers with the patented Dry technology are an eco-responsible alternative to fossil-based materials in personal hygiene products by providing hydrophobic characteristics whilst being biodegradable and compostable. The fibers are soft to touch and provide a dry feeling to the wearer when applied within top sheets in personal care products.

In its quest to drive greater sustainability in the personal care and hygiene industry, the VEOCEL™ brand has launched a new offering: VEOCEL™ branded lyocell fibers with Dry technology which are naturally smooth and gentle on skin, ensuring comfort for sensitive skin.

Absorbent hygiene products are an indispensable part of many consumers' lives and are relied upon daily. As these are essential items, it is important that they should offer maximum comfort and relief to the user. This is demonstrated by the new VEOCEL™ branded lyocell fibers which have the capacity to provide a high level of comfort, softness and dryness, when applied in these types of products.

Combining high-performance with sustainability

Increasingly, consumer expectations are extending beyond functional needs, to focus on natural materials and ingredient transparency. However, consumers should never have to compromise between functionality, comfort and sustainability, and it is critical that such intimate products

provide both – as the new VEOCEL™ branded lyocell fibers can offer. While most hydrophobic fibers are fossil-based fibers, Dry technology by Lenzing allows cellulosic VEOCEL™ branded lyocell fibers to achieve similar liquid-controlling properties built on a biodegradable, botanic-derived material. The fibers are also soft to touch and gentle on the skin, thus beneficial for applications that have direct contact with skin, such as in femcare and period care products, adult incontinence products and baby diapers.

“We have observed a growing trend of consumers who are mindful of product ingredients, so we created a product that can offer both sustainability and performance,” said Jürgen Eizinger, Vice President of Global Nonwovens Business at Lenzing. “Our new VEOCEL™ Lyocell fibers with Dry technology are certified biodegradable and compostable – therefore, offering an eco-friendly and quality alternative to fossil-based materials. The VEOCEL™ brand is continually expanding its capacities and innovations for wood-based specialty fibers as a means to reduce the industry's reliance on fossil-based materials in personal care products.”

Eco-friendly solution to better protect the environment

A recent Stifel survey indicates that 83% of consumers believe it is important for companies to act sustainably. This drive comes from the rising number of eco-conscious consumers, who are acutely aware of the environmental impact of disposable products and are searching for products which are better for the environment. In particular, consumers are increasingly favoring products that are eco-friendly in baby and femcare products. To meet this growing demand and lessen the impact on the environment, VEOCEL™ branded fibers are certified biodegradable and compostable under various conditions.

Not only are the hydrophobic VEOCEL™ branded lyocell fibers with Dry technology environmentally friendly, but they also provide great comfort and a feeling of dryness for the wearer, which comes from enabling strategic fluid distribution. This is a particularly useful trait in absorbent hygiene products as it helps to manage bodily fluids, keeping the surface dry and the touch soft even after encountering liquid.

Overall, this contributes to a comfortable personal care experience for the wearer and allows them to feel as if their skin is next to nature.

For more information please contact:

Rita Ng
Global Marketing Services Manager
Phone: +852 3718 5675 Email: r.ng@lenzing.com
Connie Au
Head of Marketing – Nonwovens (Asia)
Phone: +852 3718 5699 Email: c.au@lenzing.com
Miray Demirer Acar
Head of Marketing – Nonwovens (EU&US&MEA)
Phone: +90 532 721 46 18 Email: m.demirer@lenzing.com

Goller Spun Oil Washing Range – A Success Story worldwide

Emerging trend: Open width knit processing

The Indian athletic apparel market grew by a whopping CAGR @ 19% between 2009 and 2017, while the Indian footwear market, which includes sports footwear, grew at a CAGR @ 24% during the same period. India will again be no exception to the growth in this sector.

These growth prospects of athleisure products are encouraging Indian knit processors to consider expansions and diversifications to cater to the needs of this segment. Many investments are therefore being planned to tap the huge potential presented by this segment, especially as there is not much competition so far.

Garment properties like protection, insulation, moisture permeability, stretch, shape retention, optimum heat and moisture regulation, rapid drying, dimensional stability even when wet, durable, easy care, light weight, soft touch, etc., are intrinsic to active wear garments. However, these properties are not readily achievable in 100% cotton, circular knitted fabrics. Hence the need for synthetic circular or warp knitted fabric production and processing becomes inevitable for addressing the opportunities in the active wear segment.

The very first step in synthetic active wear processing or spandex processing is spun oil washing. Goller is a major international player in this segment and as major supplier to high end synthetic fabric manufacturers worldwide.

Goller – a brief introduction

Goller was founded in Germany and manufactured its first open width textile processing range in 1948. Goller became a member of the CHTC Fong's Group in 2006.

The integration of Goller into the CHTC Fong's Group helped it to develop and spread at a tremendous rate its highly engineered textile wet finishing ranges for the textile industry.

Today, Goller is a global market leader in the manufacturing of open width textile processing ranges. Goller's wet processing ranges including those for spun oil washing are widely used to produce high quality woven and knitted fabric in world-wide textile dyeing factories.

Objectives of spun oil washing

Spun oil washing is a treatment of synthetic woven or knitted (circular/warp knit) fabrics with de-oiling chemicals to remove lubricating oils from the fabric structure. These lubricants are needed in spinning and remain on the fabric through the knitting process. The purpose of open width spun oil washing is to pre-shrink the fabric, reduce and even out the oil distribution on the fabric, and to thus ensure uniform dyeing and finishing results in subsequent finishing steps.

If a grey fabric with oils on it is heat set, there is an accumulation of these oils in the stenter. This creates chances of fire in the exhaust pipelines and in the heat exchangers. Oil dripping further creates quality problems in subsequent processing. But after spun oil washing, if the cleaned fabric is pre-heat set, the stenter remains oil-free and safe, eliminating risks of fire and improving fabric quality.

The benefits of Goller spun oil washing ranges:

- Avoids fire hazard in stenter while pre-setting
- Even dyeing results
- Pre-shrinkage of fabric
- Suitable for wide range of fabrics from light to heavy GSMEnvironment-friendly process
- Technical and utility data of Goller spun oil washing range:Fabric type: warp knit/circular knit
- Fabric quality: polyester/nylon with Lycra
- Machine speed: up to 40 m/min
- Chemicals: soda ash, washing agent, acetic acid (optional)
- Water consumption: approx. 4 - 8 L/kg
- Steam consumption: approx. 0.3 - 0.7 kg/kg

Success story

Goller has successfully installed more than hundred high productivity spun oil washing ranges worldwide for processing undergarments, swimwear and activewear, which also includes a modular unit that has been installed in front of a Monfongs stenter at a knit process house in Kolkata.

Investment in continuous open width processing requires a lot of planning. Goller with a wide range of different modules and a team of skilled engineers can custom-build ranges to meet specified needs of customers in the field of continuous open width processing. A long history, worldwide experience, continuous innovations have made Goller a popular choice with the industry for continuous open width processing for both woven and knit goods.

For more details, please contact:
Jasbinder Kaur Panchi
Executive Assistant
Textile Engineering Group
A.T.E. Enterprises Private Limited
M: +91-9869288040 T: +91-22-6676 6104
E-mail: jasbinder.panchi@ategroup.com

சர்தார் வல்லபாய் படேல் சர்வதேச ஜவுளி மற்றும் மேலாண்மை கல்லூரி
सरदार वल्लभभाई पटेल इंटरनेशनल स्कूल ऑफ टेक्सटाइल्स एंड मैनेजमेंट

SARDAR VALLABHBHAI PATEL International School of Textiles & Management

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