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Effect of Pretreatment on the Smoothness Behaviour of Cotton Fabric

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Abstract

Before dyeing, woven cotton fabrics have been passed through different pretreatments like desizing, scouring, bleaching and mercerising to enhance quality. In every treatment cotton fabric is treated with different chemicals and mechanical processes. After these treatments, the feel of the fabric has been changed. The change in feel or in terms of the hand value of treated fabrics were analysed by determining the bending length, crease recovery angle, SEM, FTIR, surface roughness and smoothness properties. Other physical properties viz. the tear and tensile strength were also evaluated. Fabric surface roughness and smoothness were determined using the Kawabata Evaluation System (KES) and digital image processing method. Using MATLAB software, digital image processing techniques were used to evaluate the roughness index. The study revealed that the pretreatment process alters the fabric surface. Statistical analysis (ANOVA) was carried out using SPSS software in order to establish the relationship between the pretreatment process effect on the bending length, smoothness and crease recovery angle.

Key words: *dyeing, pretreatment, desizing, scouring, bleaching, statical analysis.*

Introduction

At the present time the garment industry and fabric producers are confronting a great deal of issues with respect to the hand feel of material. There is no standard method available using which the smoothness of fabric can be measured. Just subjective evaluation is completed to judge the feel of the fabric. When a fabric or garment of clothing is purchased, the consumer constantly attempts to pick it based on his own evaluation technique for a specific end use [1].

The surface of any wearable material can be modified by chemical or mechanical procedures. Fabric smoothness is specifically related to the fabric surface friction. Fabric surface smoothness behaviour depends upon the yarn qualities, weave points of interest, and finally on the sort of chemical treatment. The use of chemical treatment makes a fabric rough or smooth. Chemical or mechanical treatment modifies the surface properties of fabric. The chemical treatment of cotton to alter the physical properties of fibres without changing their shape is a common practice in the textile industry [2].

Material

In this study plain weave (1/1) cotton fabric of 128 g/m^2 mass and 120 and 70 ends and picks per inch, respectively, was procured from surya processors in the grey stage. All the chemicals, like sodium hydroxide, sodium carbonate, hydrogen peroxide etc., used in the study were of commercial grade. For desizing purposes a commercial desizing enzyme was used.

Pretreatment

The cotton fabric was pretreated by desizing, scouring, bleaching & mercerisation as per the sequence given in *Figure 1* using a standard recipe, shown in *Table 1*.

Singeing and desizing

Singeing removed loose and unwanted fibres from the fabric surface to get a smooth surface. Enzymatic desizing was done after singeing.

Scouring

Desized fabric was treated with alkaline solution to scour it. This process improved the absorbency of the fabric by removing impurities.

Bleaching

Woven cotton fabric was bleached using hydrogen peroxide to remove the natural colouring [3].

Mercerisation

Chain mercerisation was used to mercerise the cotton fabric. The concentration of sodium hydroxide was 52° Tw [4].

This work centered around the treatment of cotton with various pretreatments: the cotton texture was successively pretreated as shown in *Figure 1*, utilising the standard formula given in *Table 1*. After every pretreatment process the treated sample was tested for its quality using standard test methods viz. the Tegewa test drop test method, spray test method, and whiteness index.

Analysis of fabric samples

The cotton fabrics (woven) were pretreated (singed, desizing, scouring, bleaching and mercerisation) as per the standard recipe. The test standards used for the study are given in *Table 1*.
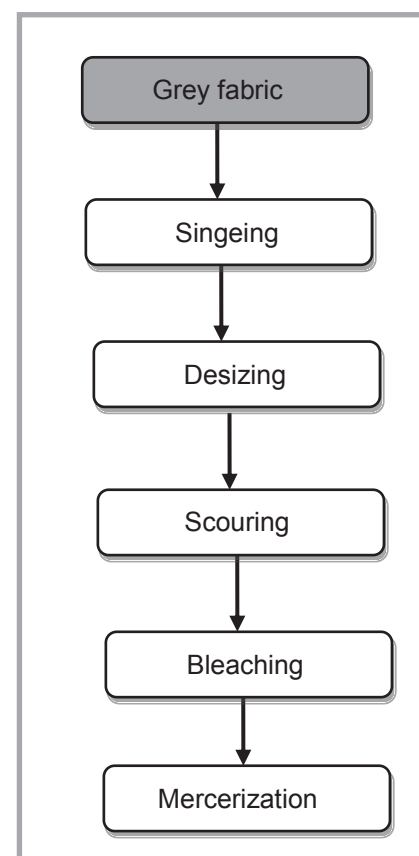
Figure 1. Flow chart of process sequence.

Table 1. Test standard.

S. no.	Test name	Test standard
1	GSM	IS 1964:2001
2	Thread density (EPI/PPI)	IS:1963-1981(reaffirmed:2004)
3	Count	(IS 3442:1980)
4	Crease recovery	IS 4681-1968
5	Bending length	IS6490-1971
6	Tear strength	ISO-13937-1
7	Tensile strength	ISO 13934-1

The change in fabric surface roughness or smoothness after the pretreatment process was determined using the 'Digital Image Processing (DIP)' method using MATLAB software and the Kawabata Evaluation System (KES-F), a scanning electron microscope from 30 Kv = JEOL (JAPAN) model JSM-6360. These methods are described below.

Digital image processing method

The DIP method is based on the theory of surface height variation measurement. In accordance with this method, fabric samples were scanned using a 600 dpi digital image processing scanner [5]. After scanning, the images obtained were cropped so as to have a uniform and regular figure. Using Matlab software, the simulation and surface roughness were plotted. The images obtained were first inverted so that the lighter areas represented the densely populated part of the fabric and the dark parts – the sparsely populated region [6]. The images were transformed to gray scale and then loaded into Matlab. To remove noise, Gaussian filters were applied. The degree of smoothening was determined by the standard deviation of the Gaussian, which is generally taken as 5 [6]. A surface plot is three dimensional, connecting a set of data points. The images were then converted to a sur-face plot in Matlab. The colour of individual pixels was plotted as the height in the graph. As there is a difference between the colour of different regions of the fabric, this causes a variation in the height of the plot. This difference is used to determine the surface roughness. An appropriate computer programme was written with due consideration of the various parameters of the three dimensional surface plot of the scanned fabric images, and simulation was finished utilising Matlab programming to obtain the fabric surface roughness index [6].

Kawabata evaluation system

Coefficients of friction (MIU) were determined using the Kawabata system. MIU was determined in the warp and weft directions for fabric samples on the sides that would be in contact with the skin during wearing [7].

The frictional coefficient MIU is calculated by averaging the output over the distance between 0 to 20 mm using an integrator [8].

The frictional coefficient is defined as:

$$MIU = F/P$$

Where F – frictional force, N, P – sensor load, N.

Statistical analysis

Experimental data were analysed using SPSS (version 20). One-way ANOVA and Multivariate Anova were used to compare means. The null hypothesis (Ho) is that there is no relationship between the types of processing treatment of the fabric and the coefficient of friction (smoothness), bending length and crease recovery when using a digital image processing system. In the alternative hypothesis, there is a relationship between the types of processing treatment of the fabric and the coefficient of friction (smoothness), bending length and crease recovery of fabrics when using a digital image processing system. Ho will be rejected when the p-value turns out to be less than a pre-determined significance level, i.e. 0.05.

Result and discussion

The physical properties of fabric like the mass, ends per inch/picks per inch, bending length, crease recovery angle and tensile strength along with the surface smoothness in terms of the coefficient of friction (MIU) and surface roughness in terms of the peak height, using a digital image processing system for all 6 fabrics treated along with gray fabric, are assessed in *Tables 2* and *3*.

From the table it is clear that the mass of the samples varies from 118 to 128 g/m². The mass of the grey fabric (128 g/m²) is found to be higher than the others due to the presence of the sizing agent. Ends/inch and picks/inch of the treated fabric samples i.e. samples having undergone mercerisation treatments, were found to be higher than those of the grey due to wet shrinkage during processing. The increase in ends/inch and picks/inch also increase the tear strength of the treat-

Table 2. Physical properties of fabric.

Sample code	Mass, g/m²	Ends per cm	Picks per cm	Tensile strength, N		Tear strength, g		Crease recovery angle (warp + weft) degree	Bending length, cm		Coefficient of friction-Kawabata	
				Warp	Weft	Warp	Weft		Warp	Weft	Warp	Weft
Grey	128	48	28.8	576	259	1138	569	106	2.45	1.75	0.15	0.152
Singed	124	48.8	28.8	560	270	1112	536	110	2.40	2.80	0.158	0.161
Desized	118	50.4	31.2	520	230	1150	720	140	1.58	1.46	0.167	0.171
Scoured	124	51.2	32	580	240	1064	676	144	1.55	1.42	0.156	0.158
Bleached	126	53.6	32.8	700	271	897	640	146	1.56	1.40	0.153	0.152
Mercerised	127	54.4	32	681	258	977	670	156	1.40	1.38	0.149	0.136

Table 3. Roughness index measured by DIP method.

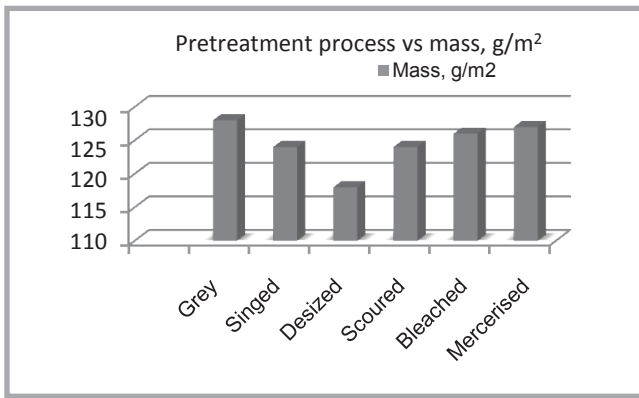| Fabric sample	Grey	Desized	Scoured	Bleached	Mercerised	Maximum decrease in roughness index, %
Maximum height of peaks	28	30	50	60	16	42%

Figure 2. *Effect of pretreatment on GSM.*
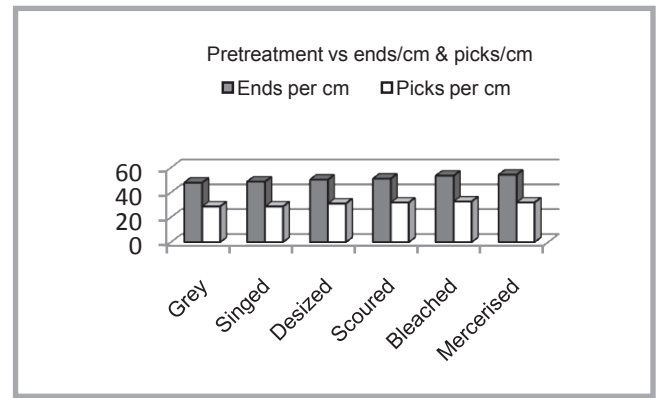

Figure 3. *Effect of pretreatment on EPI/PPI.*
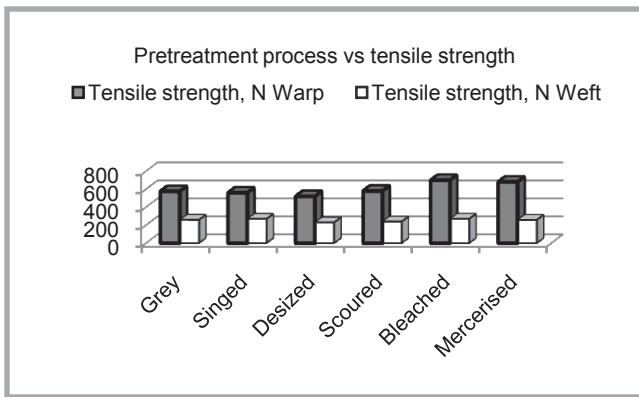

Figure 4. *Effect of pretreatment on Tensile strength.*
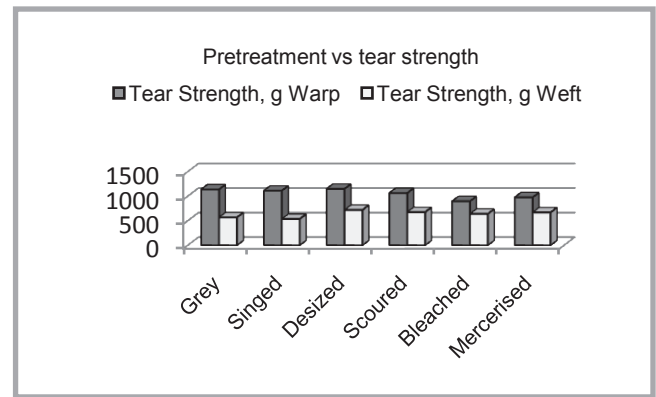

Figure 5. *Effect of pretreatment on tear strength.*
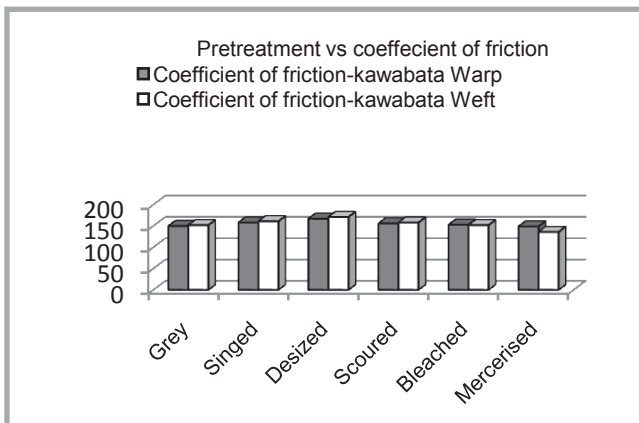

Figure 6. *Effect of pretreatment on coefficient of friction.*
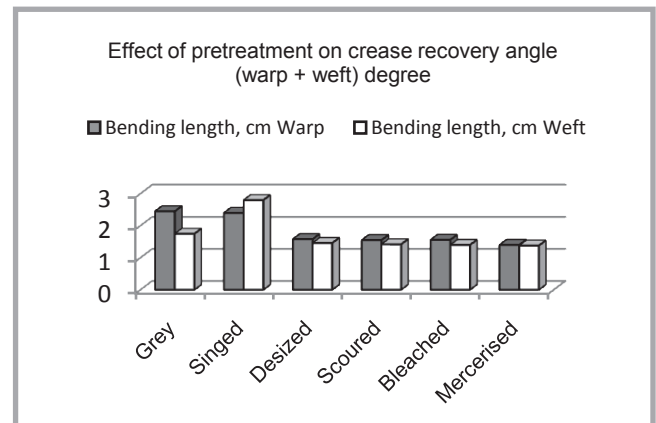

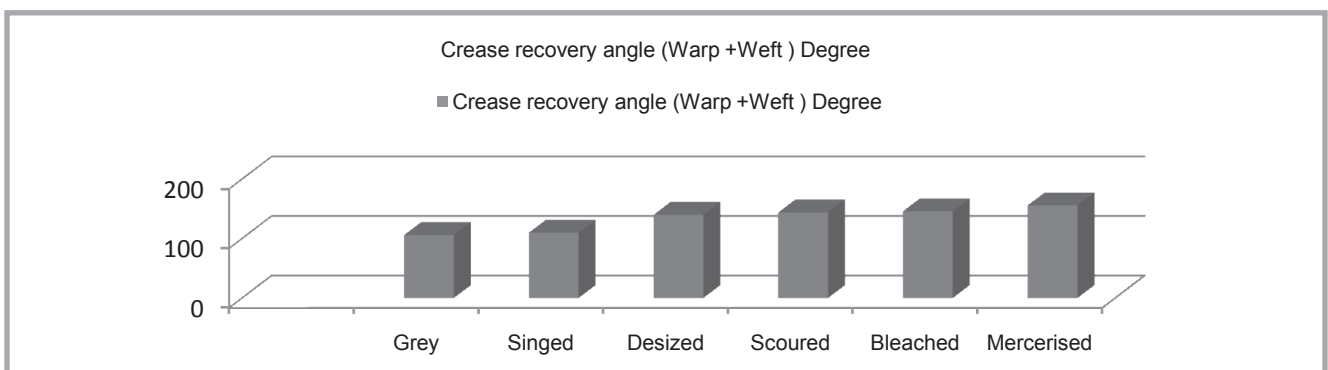**Figure 7.** *Effect of pretreatment on bending length.*

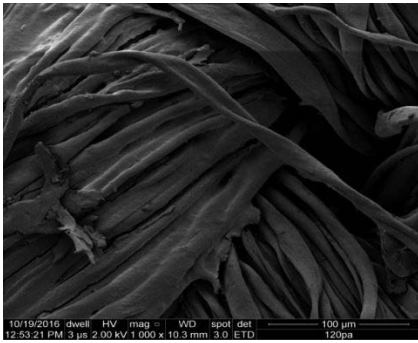**Figure 8.** *Effect of pretreatment on crease recovery angle.*

Figure 9. SEM micrograph of untreated.
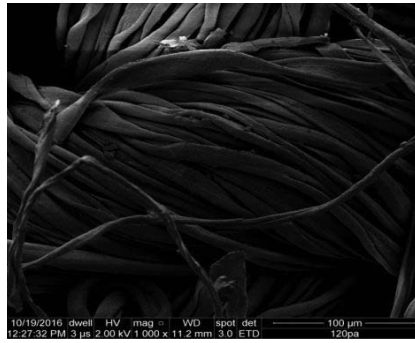

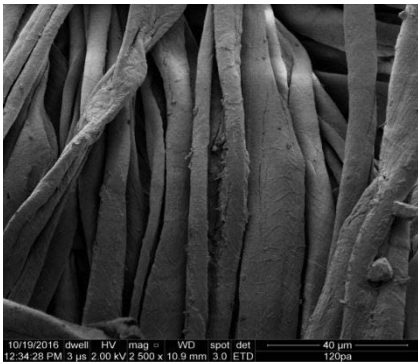*Figure 10. SEM micrograph of scoured woven cotton fabric woven cotton fabric.*

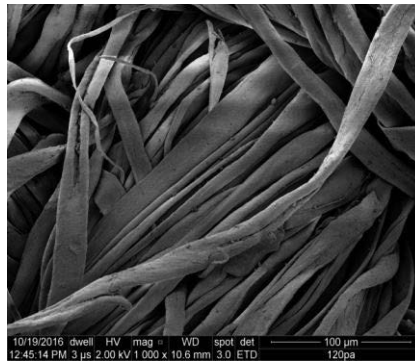*Figure 11. SEM micrograph of bleached samples.*

Figure 12. SEM micrograph of mercerized sample.

ed fabric. On the other hand, the tensile strength of the mercerised fabric was found to be higher than that of the fabric treated with various pretreatments.

Tensile strength

The tensile strength of mercerised fabric samples increased due to the swelling of cotton fibres in the presence of alkali. The mercerisation process removes convolution and false twist (causing weak spots). Thus fibres acquire a more uniform cross section. As weak spots are removed, the strength of the fibre increases [4].

Bending length

Values of the bending length of untreated and treated cotton fabrics are given in ***Table 2*** and ***Figure 7*** above. From these we obtain data of the bending length for both the warp and weft directions of the cotton fabric, respectively. It is evident from ***Table 2*** that the bending length in both the warp and weft directions is going to decrease from the control to the mercerised sample. Untreated fabric shows the maximum bending length (warp and weft), which is periodically reduced after treatment such as desizing, scouring, bleaching and mercerisation.
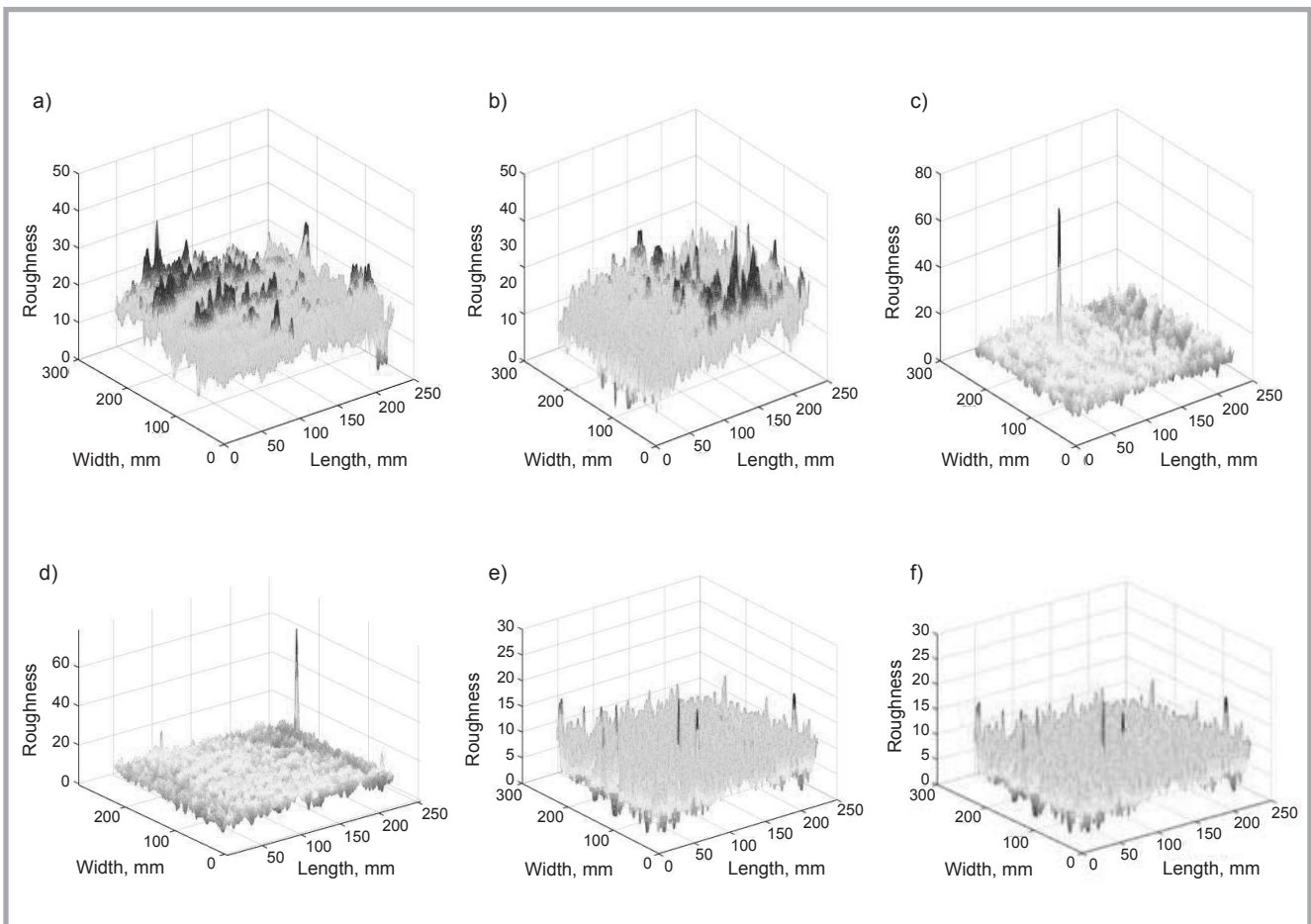

Figure 13. DIP of pretreated cotton fabric: a) grey fabric, b) singeing, c) desizing, d) scouring, e) bleaching, f) mercerisation.

Crease recovery

Values of the recovery angle of untreated and treated cotton fabrics are given in **Table 2** & **Figure 8** above. It is evident that the crease recovery angle is going to increase from the control to the mercerised sample. Untreated fabric shows a minimum crease recovery angle, which periodically increases after desizing, scouring, bleaching and mercerisation treatment.

SEM analysis of woven cotton fabric

SEM images at 1000 x magnification are given in **Figures 9-12** of grey and treated samples. As the samples were treated with different chemicals, there are some clear differences in the respective images. There is a clear difference in the respective chemical treatments for woven cotton fabric. **Figures 9-12** show SEM photographs of untreated, scoured, bleached and mercerised cotton fabrics. When compared to the treated fabrics (**Figure 10** and **11**), the surface of the mercerised fabric sample has a smooth surface, as shown in the SEM photograph (**Figure 11**). It is a well known fact that when cotton fabric is treated with alkali under tension in order to achieve maximum fibre swelling, the fibre surface becomes smoother [2].

Fabric surface peak height and roughness index

Digital image processing methods were used to obtain surface plots for mercerised and softener treated fabric samples. The plots thus obtained are shown in **Figure 13**. It is observed that the scoured and bleached fabric sample has a higher number of peaks with a higher peak height, as shown in **Figures 13.d** and **13.e**, also in **Table 3**. This indicates that the surfaces of the desized, scoured and bleached fabric are rougher than that of grey fabrics. The mercerised fabric sample is smoother than for the other treated or untreated samples. Comparing the surface plots obtained by DIP for the untreated and treated fabrics at different processing stages, it is observed that the bleached fabric samples have the largest number of local maxima, indicating the roughest surface. It was also found that in mercerisation, due to the swelling of fibres, fabric friction will be reduced.

Surface roughness of fabrics

Surface plots

The surface plots obtained by digital image processing methods for pretreated and untreated fabric samples are shown in **Figure 13**. It is observed that the untreated cotton fabric samples have a lower average height of the peak as compared to the desized, scoured and bleached fabric but higher than for the mercerized fabric samples. There are the least number of maxima found in the mercerisation stage, suggesting that smoothness improves with the swelling of fibres in yarn, thereby reducing the yarn crimp compact structure of yarn. The fabric shows a uniform surface, thus reducing the fabric friction.

Surface roughness index

The roughness index values of treated and untreated samples obtained by the digital image processing method (DIP) are shown in **Table 3**. The decrease in the surface roughness or increase in the smoothness of the fabrics due to mercerisation treatment is 42 %, which is very encouraging. It is concluded that in mercerisation swelling in fibres is obtained due to this process reducing the surface irregularities of fabrics and, consequently, SMD values. From the bleached to mercerized fabric, the surface Roughness Index is 73%, from scouring to mercerisation – 68%, from desizing to mercerisation – 46%, and from grey to mercerisation it is 42%.

In the grey stage the starch applied during sizing makes the fabric surface smooth and stiff. It in shown in **Table 2** and **Figure 6** that the coefficient of friction is less compared to the scoured or bleached fabric and that the peak height is also lower than for scoured or bleached fabric sample 7.

During the desizing and bleaching stage, the starch, wax and other foreign matter were removed, due to which, the open space in the fabric increased. The roughness of the fabric also increased, as shown in **Table 3**, as compared to the grey fabric.

In mercerisation the fibres in yarns swell, thereby reducing the crimp. The compact structure of the yarns and fabric would, in turn, present a more uniform surface, thereby reducing fabric friction.

ANOVA analysis

Experimental data were analysed using SPSS (version 20). One-way ANOVA and Multivariate Anova were used to compare means. The null hypothesis (Ho) is that there is no relationship between the type of processing treatments and the coefficient of friction (MIU), bending length and crease recovery of fabrics. In the alternative hypothesis, there is a relationship between the type of processing treatments and the coefficient of friction (MIU), bending length and crease recovery of fabrics. Ho will be rejected when the p-value turns out to be less than a pre-determined significance level, i.e. 0.05.

As per the results shown in **Table 4** for multi-variant ANOVA analysis between types of processing treatment and the bending length, the null hypothesis (Ho) is rejected as the p-value turns out to be less than the pre-determined significance level, i.e. 0.05. It indicates that there is a relationship between the processing treatment and bending length.

The regression coefficient (R Squared) values are 0.97 & 0.68, respectively, indicating a very strong relationship between the processing treatment and bending length (warp & weft).

Table 4. Multi variant ANOVA –between pretreatment process and bending length. **Note:** [a] R Squared = 0.971 (Adjusted R Squared = 0.965), [b] R Squared = 0.739 (Adjusted R Squared = 0.687).

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	bending length – warp	3.529[a]	4	0.882	167.093	0.000
	bending length – weft	0.448[b]	4	0.112	14.163	0.000
Intercept	bending length – warp	73.103	1	73.103	13845.170	0.000
	bending length – weft	56.370	1	56.370	7135.451	0.000
Types	bending length – warp	3.529	4	0.882	167.093	0.000
	bending length – weft	0.448	4	0.112	14.163	0.000
Error	bending length – warp	0.106	20	0.005		
	bending length – weft	0.158	20	0.008h		
Total	bending length – warp	76.737	25			
	bending length – weft	56.976	25			
Corrected total	bending length – warp	3.635	24			
	bending length – weft	0.606	24			

Table 5. *One way ANOVA –between pretreatment process and crease recovery.*

	Sum of squares	df	Mean square	F	Sig.
Between groups	7130.240	4	1782.560	810.255	0.000
Within groups	44.000	20	2.200		
Total	7174.240	24			

Table 6. *One way ANOVA – between pretreatment process and peak height in DIP method.*
Note: ^{a} R Squared = 0.992 (Adjusted R Squared = 0.991).

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	6344.000^a	4	1586.000	634.400	0.000
Intercept	33856.000	1	33856.000	13542.400	0.000
Types	6344.000	4	1586.000	634.400	0.000
Error	50.000	20	2.500		
Total	40250.000	25			
Corrected total	6394.000	24			

Table 7. *One way ANOVA –between pretreatment process and coefficient of friction.*

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	coefficient of friction-warp	0.001^a	4	0.000	5.048	0.006
	coefficient of friction-weft	0.003^b	4	0.001	320.600	0.000
Intercept	coefficient of friction-warp	0.601	1	0.601	11550.481	0.000
	coefficient of friction-weft	0.590	1	0.590	235929.600	0.000
Types of fabric	coefficient of friction-warp	0.001	4	0.000	5.048	0.006
	coefficient of friction-weft	0.003	4	0.001	320.600	0.000
Error	coefficient of friction-warp	0.001	20	5.200E-005		
	coefficient of friction-weft	5.000E-005	20	2.500E-006		
Total	coefficient of friction-warp	0.603	25			
	coefficient of friction-weft	0.593	25			
Corrected total	coefficient of friction-warp	0.002	24			
	coefficient of friction-weft	0.003	24			

To understand any relation between different concentrations of softeners and the bending length and crease recovery, one way ANOVA was applied, the results of which are shown in **Table 5**. From the table it is clear that the null hypothesis (Ho) is rejected as the p-value turns out to be less than the pre-determined significance level i.e. 0.05. This shows there is a relationship between the processing treatment and crease recovery.

The regression coefficient (R) value is 86, indicating a very strong relationship between the concentration of softeners and coefficient of friction (MIU).

From **Tables 6** and **7**, it is shown that the null hypothesis (Ho) is rejected as the p-value turns out to be less than the pre-determined significance level i.e. 0.05. This shows that there is a relationship between the processing treatment and peak height in the DIP method and the coefficient of friction, respectively. The regression coefficient (R) values are 0.99 & 0.98, respectively.

Conclusions

It is observed that the mercerised treated cotton fabrics show a lower bending length value in comparison to bleached or scoured fabric, indicating that the pretreatment process affects the feel of fabric. It is also observed that in grey or mercerised fabric samples, there is a reduction in the bending length. The reduction in the bending length indicates reduced rigidity/stiffness and, hence, improved softness of the fabric. Therefore, there is a reduction in the bending length of the fabric due to the swelling of fibres, thereby decreasing the friction as the samples have become softer.

Scoured or bleached fabric show a minimum crease recovery angle, which is periodically increased after the mercerised treatment. It is clear that the crease recovery of mercerised samples is higher than for the scoured or bleached fabric sample. This may be due to the swelling of fibre in the fabric. It appears that the treatment developed the ability of the fabrics to recover from deformation. The materials which have good crease recovery properties exhibit excellent soft handle. It is seen that the crease recovery angle increases from desized to mercerised fabric samples.

The Kawabata evaluation study shows that the value of the coefficient of friction (MIU) is higher for bleached fabric in both the warp and weft directions than for grey or mercerised fabric samples.

From the digital image processing method, the surface roughness value of the mercerised fabric samples are lower than for the bleached or scoured fabric samples. This indicates that the bleached and scoured fabrics are rougher than the mercerised fabric samples. The maximum decrease in roughness was found when the fabric was treated in the mercerised stage.

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