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Effect of silicone treatment on hand value of cotton handloom fabrics

M N Pattanaik[1] & Sadhan Chandra Ray[2,a]

[1]College of Engineering & Technology, Bhubaneswar 751 003, India
[2]Department of Jute and Fibre Technology, University of Calcutta, Kolkata 700 019, India

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Cotton handloom woven finished fabrics have been treated with silicone softener in order to improve the hand value by overcoming the inherent drawbacks, such as harsh feel of handloom fabrics, so as to make them suitable for readymade garments. Evaluation of the hand values of handloom fabrics in terms of bending stiffness, surface roughness and softness have been conducted by using simple and cheaper instruments/techniques, like Shirley stiffness tester, digital image processing methods and fabric feel tester. It is observed that with the increase in concentration of silicone softener there is an improvement in the softness as well as smoothness of the fabrics. Consumers experience a better feel when they touch the silicone treated handloom fabric or the garment by their hand.

Keywords: Bending length, Digital image processing, Fabric feel tester, Hand value, Softening treatment, Surface roughness

1 Introduction

Fabric hand refers to the total sensations experienced when a fabric is touched or manipulated with the fingers. In a retail shop, when a customer wants to purchase a particular textile product, a fabric or a garment, the first step he or she takes is to touch it with the fingers to get an impression of the hand value of the product. They feel softness or harshness and smoothness or roughness, which may be the fundamental aspects that determine the success or failure of the product for sale. The colors, design and price of the fabric or garment comes in the next step. The concept of hand value or handle property was first given by Peirce[1]. The term 'handle' depends strongly on the type of fabric being assessed, for instance the smoothness of a worsted suiting is different in nature from that of cotton sateen. Because of the subjective nature of these properties, attempts have been made over the years to devise objective tests to measure some or all factors that measure the fabric handle[2]. Fabric stiffness and drape are measured objectively with the help of stiffness tester and drape tester in terms of bending length and drape coefficient value respectively. The increase in the softness due to treatment of silicon softener on stiffness property has been studied by Roy Choudhury *et al*[3]. who found that the bending length decreases with the increase in softener concentration, indicating a reduction in the stiffness of fabric. The findings of the studies conducted by Chattopadhyay and Vyas[4] have revealed that silicone softener treatment on fabrics decreases bending length, which is the indication of improved softness of a textile material. The magnitude of crease recovery angle is an indication of the ability of a fabric to recover from creasing and it is measured by crease recovery tester. Behera and Pattanayak[5] observed a strong correlation between fabric bending rigidity and drape parameters. Behera and Shakyawar[6] have investigated the influence of softeners on hand value of woollen fabrics produced from Indian wool and its blends and found that their stiffness values decrease by 5-10% compared to untreated fabrics. Shakyawar and Behera[7] during their investigation on the influence of alkyl quaternary ammonium-based silicon cationic softeners on hand value of woollen fabrics observed that the stiffness values decrease by 5-10% compared to untreated fabrics. Fabric weight, thickness and shearing strength are measured by different instruments like weighing balance, thickness gauge and tensile tester respectively. Formability (compression behaviour) is derived from bending stiffness of the fabric and its modulus of compression. Frictional properties are measured in terms of frictional coefficient by using varied types of apparatus based on inclined plane principle. The study of Kawabata and Niwa[8] is found to be the most thought provoking and informative in this field. The revolutionary development for the measurement of total hand value made by Kawabata is known as the KES-FB system. It consists of four specialized instruments, namely FBI, FB2, FB3 and FB4. These instruments measure a total of 16 parameters

[a] Corresponding author.
E-mail: Sadhan53@yahoo.co.in

related to the tensile, compression, shear, bending, surface roughness and friction properties of fabrics. Another similar system of objective measurement of hand value is called 'Fabric Assurance by Simple Testing' (FAST), as designed by CSIRO, Australia. FAST is comparatively simpler than the KES-FB system[2]. Semnani *et al*[9]. have evaluated the surface roughness of weft knitted fabrics by using a high resolution scanner and found that fibre, yarn and fabric parameters influence fabric roughness. They have compared the results obtained from the image analysis with the SMD (geometrical roughness) values measured by the Kawabata method where a good correlation of -0.903 has been noticed between the two methods. Xin Wang *et al*[10]. have successfully measured the texture characteristics of a woven fabric, such as weave repeat, yarn counts and the surface roughness by using computer vision techniques. Bandyopadhaya and Sur[11] have studied the changes in appearance, objectively of jute based fabrics due to progressive abrasion with the help of digital image processing method and found that the changes in appearance are much faster than that of cotton based fabric under similar condition. Hasani and Behtaz[12] have measured the surface roughness of weft knitted fabrics by analyzing the surface signals obtained from image processing with the help of high resolution scanner and Matlab software. The results showed a good correlation between the wavelengths of obtained signal extracted from fabric images and the measured roughness by KES surface tester.

Indian handloom industry occupies an important place at the national and international level with regards to its rich cultural heritage and unique designs (e.g. tie and dye effect of Odisha handlooms), which cannot be produced by powerlooms. But the socioeconomic conditions of Indian handloom weavers are deteriorating day by day. One of the important reasons responsible for such trend is the apathy of the handloom weavers for value addition and product diversification through chemical treatments. On the other hand, presently readymade garment (RMG) market is one of the booming sectors. The apparels made of handloom fabrics are mostly rejected by the consumer at the first sight when they touch it, due to harsh or rough feel. They are rejected even though 100% cotton handloom fabrics offer unique feature of comfort, particularly for summer wear in tropical countries like India. The present study is therefore undertaken for value addition in handloom woven fabrics in order to make them suitable for readymade garment by overcoming the inherent drawbacks of handloom fabrics like roughness and harsh feel, and for the evaluation of the hand values in terms of bending stiffness, surface roughness and softness of handloom woven fabrics by using simple and cheaper instruments/techniques like Shirley stiffness tester, digital image processing methods and fabric feel tester instead of using costly and complicated Kawabata or FAST instruments.

2 Materials and Methods

2.1 Materials

Three 100% cotton handloom woven finished fabrics suitable for shirting were collected from the handloom houses (Table 1). The selection of specific handloom samples was based on the statistics available in Govt. of Odisha w.r.t. the increasing order of sales turnover of handloom fabrics produced for the dress materials by the handloom sector of the state during last three years. Three more powerloom (mill-made) made fabrics were also collected for comparing the surface characteristics of the same with those of handloom woven fabrics.

Fabric softening agent (silicone softener) was collected from M/s. Clariant Chemicals. Laboratory grade $MgCl_2$ and acetic acid were used as catalyst and *p*H regulator respectively during the treatment with fabrics.

2.2 Methods of Softening Treatment

All the fabric samples (parent samples) were desized in boiling water with material-to-liquor ratio

Table 1—Specification of fabric samples

Sample	Warp count Ne	Weft count Ne	Weave	Ends/inch	Picks/inch	GSM	Thickness mm	Cover factor
				Handloom woven shirting				
1	50	49	Plain	61	57	95.25	0.355	14.26
2	48	44	Plain	70	72	77.18	0.300	17.04
3	44	40	Plain	58	**60**	81.92	0.378	15.27
				Mill-made shirting				
1	55	51	Plain	88	66	85.6	0.31	17.19
2	49	45	Plain	74	57	87.2	0.29	15.86
3	41	36	Plain	84	74	93.2	0.28	19.67

of 1:40 for 45 min. Then the samples were dried at 35 ^{0}C. Softening treatment was done by pad–dry-cure method. Softener solutions of different concentrations, i.e. 20, 40, 60, 80 and 100 g/L were prepared as per the following procedure.

Required amount of water for maintaining material-to-liquor ratio of 1: 20 was taken in a container and heated up to a temperature of 40^0 C. Silicone softener (20g/L) was added slowly to the solution and stirred gently. The *p*H of the solution was maintained at 5.5 by adding acetic acid drop by drop. The above desized cotton fabric samples were ironed properly to remove all creases, immersed in the solution and then stirred for 15 min. Then fabric was padded at 1kg/cm^2 pressure in an automatic padding mangle machine to achieve at least 80% expression in order to get optimum pick up of 0.8 on the weight of material.

The above-mentioned procedure of treatment was repeated separately by taking 40, 60, 80, and 100 g/L softeners, so as to get silicone finish solution of different concentrations.

2.3 Stiffness Testing of Fabric

The bending length was measured by Asian make 'stiffness tester' following IS 6490:1971(BIS 2000) standard. Samples along warp and weft directions were cut according to the size of the template (25 × 200 mm). The samples were conditioned in the hot air oven at 95^0 C for about 30 min. Then, each sample was mounted on a horizontal platform in such a way that it overhung like a cantilever and bent to a constant angle under its own weight. The bending length of the specimens was measured for both warp and weft directions. Each specimen was tested at each end and again with the strip turned over.

2.4 Digital Image Processing Method

The improvement in the softness handle of the fabric due to this silicone treatment was studied by 'digital image processing (DIP)' method using MATLAB software. This method is based on the principle of surface height variation. The detailed procedures of image processing method used during this study are summarized below.

2.4.1 Surface Roughness Measurement

These treated fabric samples were scanned using a 600 dpi digital image processing scanner. As the samples were dark in colour, the back side of the reflecting surface of the scanner was covered with white paper. After scanning, the images obtained were cropped so as to have a uniform and regular figure. Simulation and plot of the surface roughness were done by using Matlab software. The obtained images were first inverted so that the lighter areas represent the densely populated part of the fabric and the dark parts represent the sparsely populated region. The images were converted to gray scale and then loaded in Matlab; Gaussian filters were applied on the image to blur it and remove noise. The main justification for using Gaussian filters as a smoothing filter is to remove high spatial frequency components from the image. The degree of smoothening is determined by the standard deviation of the Gaussian, which is generally taken as 5.

A surface plot is three dimensional that connects a set of data points. The images were then converted to surface 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 difference in the height in the plot. This difference is used to determine the surface roughness. A suitable 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 done using Matlab software for obtaining the fabric surface roughness index.

2.5 Measurement of Softness

The objective evaluation of the feel of the fabric was done by using fabric feel tester[13], designed by IIT, Delhi and manufactured by Texlab Industry, Ahmedabad. The basic principle of objective measurement of fabric feel characteristics through this machine is based on the computerized nozzle extraction method that measures the extraction force while extracting a fabric sample through a nozzle.

The fabric samples were made free from wrinkles and crease by ironing, cut into circular shape (diam. 240 mm) and then are attached to sample holder in the instrument. Then the samples were drawn through a conical shaped nozzle (52mm height×60mm length ×60mm width). The nozzle is made up of steel and chrome plated to minimize the frictional force between the fabric and the metal while it is being extracted. The nozzle is slit through the center and made in to two equal halves which are mounted on the base plate with the help of a metal piece. Two load cells are connected to the back of these halves such that they form a closed nozzle loop when joined. As the clamp moves upward, it extracts the fabric specimens through the nozzle. The force required for extracting the fabric specimens through the nozzle changes, as the increasing portion of the

Table 2 —Bending length (cm) of handloom and mill-made fabrics

Sample	Untreated	Treated					Mill- made
		20 g/L	40 g/L	60 g/L	80 g/L	100 g/L	
1(warp way)	3.01±0.04	2.95±0.03	2.9±0.04	2.84±0.03	2.74±0.03	2.75 ±0.03	2.70±0.05
1 (weft way)	2.98±0.03	2.9±0.04	2.85±0.04	2.71±0.05	2.66±0.05	2.64±0.04	2.60±0.05
2 (warp way)	3.10±0.03	3.04±0.02	2.98±0.04	2.93±0.03	2.89±0.03	2.86±0.04	2.78±0.04
2 (weft way)	3.00±0.03	2.94±0.04	2.87±0.03	2.85±0.04	2.81±0.03	2.80±0.04	2.7±0.06
3 (warp way)	3.14±0.03	3.10±0.03	3.07±0.04	3.0±0.03	2.97±0.04	2.97±0.03	2.8±0.05
3 (weft way)	3.12±0.04	3.07±0.04	3.00±0.04	2.90±0.04	2.90±0.03	2.91±0.04	2.84±0.04

fabric is introduced in to the nozzle. The fabric specimen gets folded, sheared, rubbed, compressed and bent (multiple directions) during extraction. A typical force displacement curve is generated which is displayed on the monitor of the fabric feel tester and the values are recorded.

3 Results and Discussion

3.1 Bending Length

Table 2 shows the results on bending length of untreated and mill-made cotton fabrics along with the handloom cotton fabric samples treated at different concentrations of silicon finish. It is observed that the mill made cotton fabrics show a lower bending length value than that of untreated handloom fabrics, indicating that the handloom fabrics are stiffer than that of mill-made cotton fabrics of almost similar specifications. Table 2 reveals that the bending length of all the handloom fabric samples treated at different concentrations of silicon finish shows a gradual reduction in both warp way and weft way directions up to 80 gpL treatment level. These results are in agreement with the findings of Roy Choudhury *et al*.[3] and Chattopadhyay *et al*.[4]. The reduction in bending length indicates reduced rigidity/stiffness, and hence improved softness of the fabric. So, the reduction in bending length of the fabric due to silicone treatment reveals that the samples have become softer due to the silicone finish treatment. The reason for the improved softness may be due to the formation of polymer films on fibres, leading to the lubricating action imparted by silicone between the fibres in the yarn and between the yarns in the fabric. The softening capability of silicone comes from the siloxane backbone's flexibility and its freedom of rotation along the Si-O bonds. Low bond energy and low bond rotational energy contribute to a high degree of rotation of Si-O-Si back bone. This freedom of rotation leads to a unique flexibility of siloxane molecules.

However, there is not much variation between treatments with 80 and 100 g/L concentrations. Hence, considering the cost aspects of chemicals, it is advisable to optimize the treatment of silicone finish at 80 g/L concentration.

Table 3 —Anova analysis of bending length of handloom fabrics

Source	SS	df	MS	F	Prob> F
Warp way					
Columns	0.12204	5	0.02441	2.96	0.0575
Error	0.09907	12	0.00826	-	-
Total	0.22111	17	-	-	-
Weft way					
Columns	0.15983	5	0.03197	3.04	0.0532
Error	0.1262	12	0.01052	-	-
Total	0.28603	17	-	-	-

The regression coefficient (R) values in the range of 0.97 - 0.99 for warp and 0.93 - 0.98 for weft indicate a very strong relationship between increase in concentration of silicone and reduction in bending length of the silicone treated fabrics.

3.1.1 ANOVA Analysis

Statistical analysis (One-way ANOVA) for the above results was carried out by using Matlab software in order to know, whether there exists a significant difference due to the application of softeners at different concentrations on the bending length parameters of handloom fabrics. As per the results obtained by ANOVA analysis (Table 3), the probability value (p) is found out to be 0.0575 (warp way) and 0.0532 (weft way), which implies that there exists a significant difference between the treatments at different concentrations on all the samples at 95 % level.

3.2 Surface Roughness of Fabrics

3.2.1 Surface plots

The surface plots obtained by digital image processing methods for the mill-made fabric samples and untreated handloom fabric samples are shown in Fig. 1. It is observed that the untreated handloom fabric samples are having more numbers of peaks and the average height of the peak is also higher than that of mill-made fabric samples. This indicates that the surfaces of the hand woven fabrics are rough than the

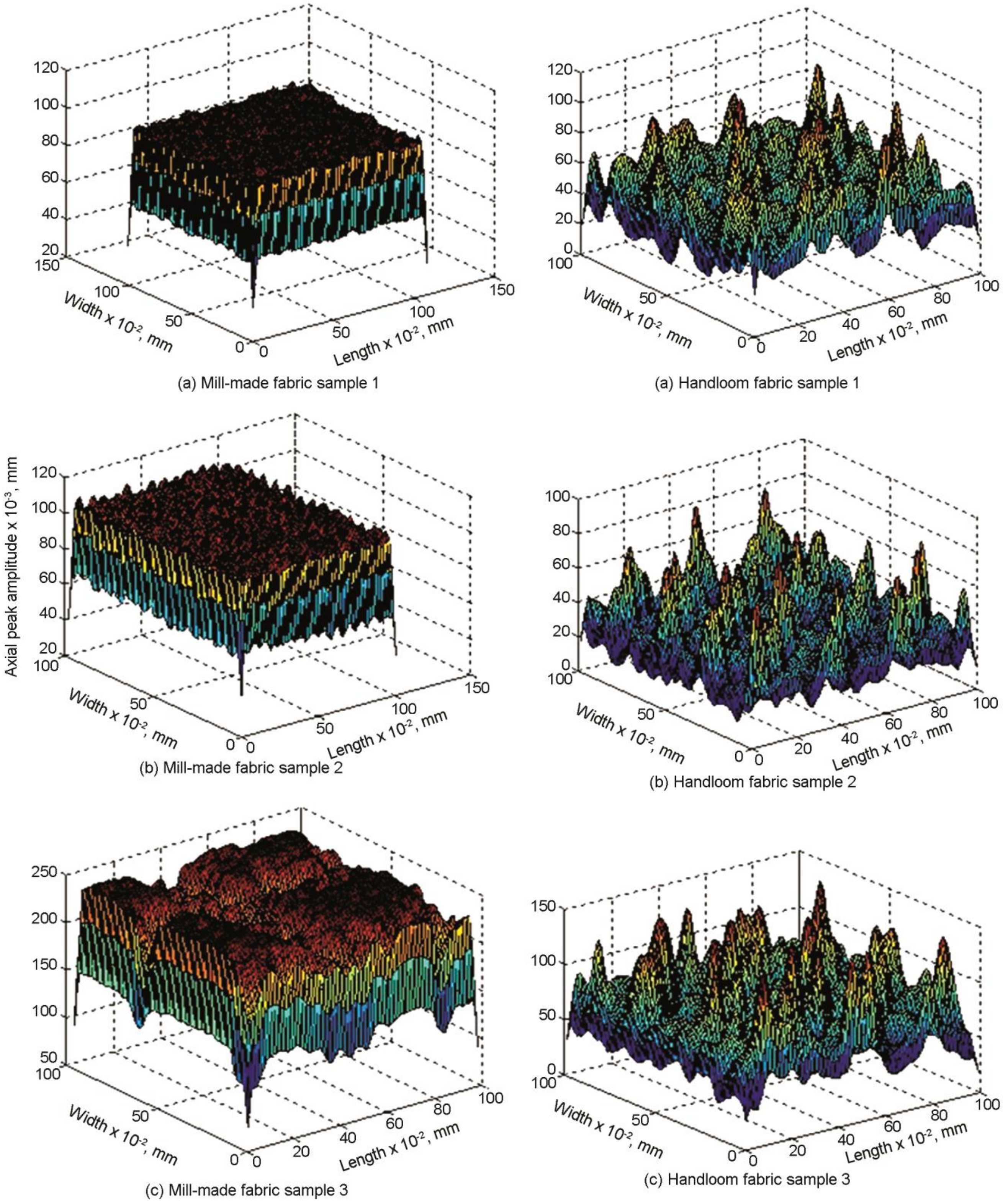

Fig. 1—Surface plots obtained by DIP methods for both mill-made and handloom fabrics

mill-made fabrics. Comparing the surface plots obtained by DIP for the untreated and treated handloom fabrics with silicone softener at different concentrations, it has been observed that the untreated handloom fabric samples has the largest number of local maxima, indicating the roughest surface, which gradually decreases with an increase in the concentration of silicone treatment. There are least number of maxima found on the fabrics treated with 80 g/L finish suggesting that the smoothness improves with the level of silicone treatment up to 80 g/L (Fig. 2). However, the smoothness decreases in samples treated with 100 g/L concentration of silicone finish.

3.2.2 Surface Roughness Index

The roughness index values of all the handloom fabric samples both silicone treated and untreated obtained by digital image processing method (DIP) are shown in Table 4. It is observed that the untreated samples have higher roughness index value than the treated ones. This roughness gradually decreases with increase in the concentration of silicone treatment. The decrease in the surface roughness or increase in smoothness of the fabrics due to silicone treatment is in the range of 68.71 – 90.82 %, which is very much encouraging. The maximum improvement in terms of surface smoothness has been observed for Samples 2 & 3 at the treatment level of 80 g/L whereas the improvement has been continued up to 100 g/L concentration for the Sample 1. The results are in line with the findings of Semnani *et al*[9]. who have noticed that increase in softener concentration reduces the surface irregularities of weft knitted fabrics and consequently SMD values. The one-way ANOVA analysis of the surface roughness index values at variable concentrations of silicone treatment demonstrates that the improvement in surface smoothness is significant at 95 % level for all the fabric samples.

3.3 Objective Measurement of Softness

Besides the above methods of measurement of the softness property of silicone treated fabrics at different concentrations of silicone finish, another method of objective measurement of softness was also conducted, i.e. evaluating the feel of the fabric objectively by using 'fabric feel tester'. All the above fabric samples (untreated and treated at different concentrations) were tested by this instrument for 60 s each. At the end of each test, a graph showing maximum pulling force in gram was automatically plotted on the monitor of fabric feel tester, which is recorded.

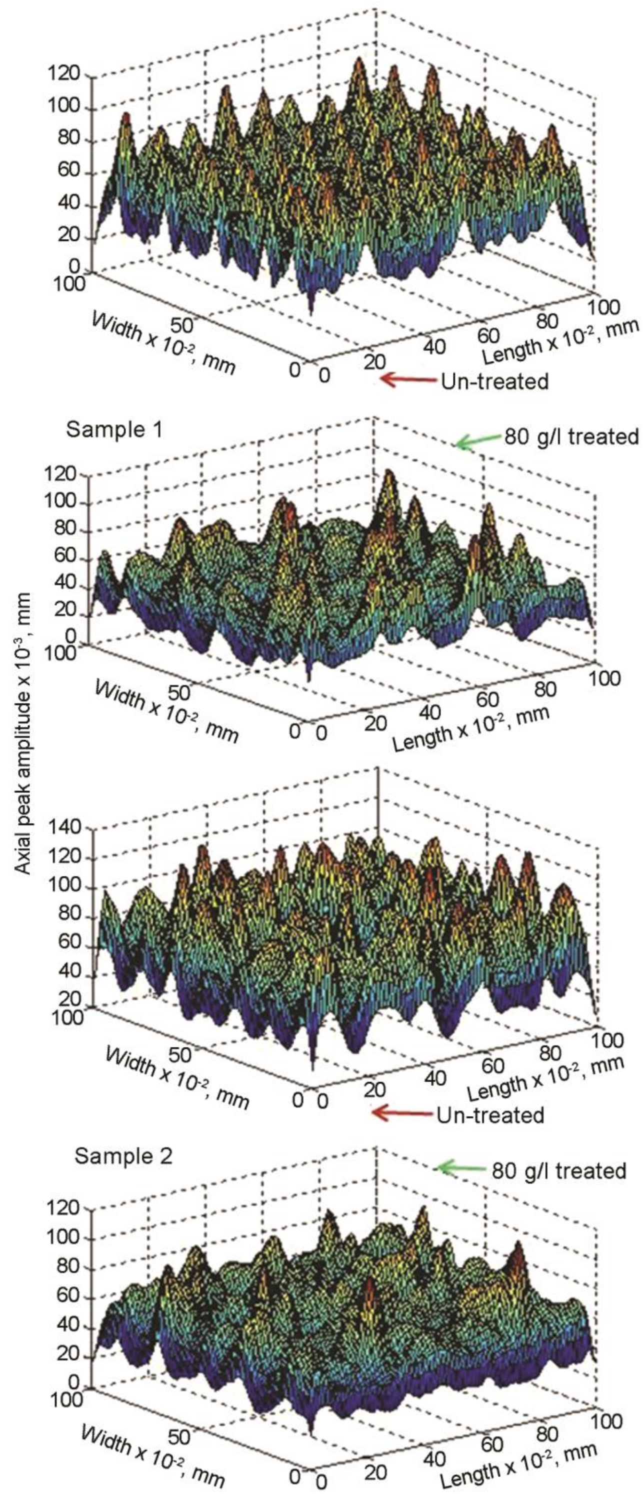

Fig. 2 — Surface plots obtained by DIP method for untreated and 80 g/L silicone treated handloom fabrics (Samples 1 and 2)

Table 4—Roughness index ($\times10^{-4}$) measured by DIP method

Handloom fabric sample	Untreated	Treated					Max. decrease in roughness index, %
		20 g/L	40 g/L	60 g/L	80 g/L	100 g/L	
1	16.28	13.01	12.88	11.86	05.03	02.59	84.09 (100 g/L)
2	29.78	16.64	15.34	15.01	09.32	10.33	68.71 (80 g/L)
3	22.25	12.92	07.67	06.35	02.04	06.88	90.82 (80 g/L)

Table 5—Maximum pulling force (g) of handloom and mill-made fabrics

Sample	Untreated	20 g/L	40 g/L	60 g/L	80 g/L	100 g/L	Mill-made
1	163.38±2.76	146.92±3.66	137.68±2.9	111.26±6.28	97.74±1.61	95.33±3.29	108.9±3.47
2	183.16±3.24	131.0±3.34	99.78±2.53	94.29±3.65	87.21±2.17	108.15±2.83	90.32±2.22
3	211.90 ±5.54	181.57±3.26	159.92±3.53	159.41±5.01	136.38±3.71	113.13±4.61	146.49±3.28

The maximum pulling force required to overcome a fixed path for the handloom samples treated at different concentrations of silicone treatment and the untreated mill-made fabrics samples are shown in Table 5. The increase or decrease in the softness of fabric by the fabric feel tester is based on the principle of ‘the maximum pulling force required by a sample while passing through a definite traverse path with respect to time. Table 5 shows that the force required to pull the mill-made fabric is much lower than that of the handloom fabric which reveals that mill made fabrics are softer or having smooth surface than that of the handloom fabrics. It is observed that with the increase in concentration of silicone for handloom fabric samples, there is a linear decrease in the value of maximum pulling force required to pull the fabric during the fixed traverse path. The corresponding regression coefficients are 0.98, 0.77 and 0.98 for the fabric Samples 1, 2 and 3 respectively.

This indicates that the softness of all the treated samples increases with an increase in the concentration of silicone finish. However, it is noticed that for all the handloom samples, at the level of 100 gpL concentration, no definite trend is observed, i.e. in some samples either the softnes of the fabrics increases or decreases or remains similar to that of sample treated with 80 gpL silicone finish.

3.3.1 ANOVA Analysis

Table 6 shows the results of one way ANOVA analysis of the measured data obtained from fabric feel tester as mentioned in Table 5. The probability value (p) is found to be 0.0193, which implies that there exists a significant difference at 95 % level between the treatments at different concentrations on the softness property of all the handloom samples.

Summing up the above results as obtained from the testing of bending length, digital image processing method and testing by fabric feel tester, it can be mentioned that a gradual increase in softness has been achieved due to treatment of handloom cotton fabrics with silicone softener concentration from 20 gpL to 80 gpL. However, the fabric samples treated with higher concentration of softener finish (80 gpL and 100 gpL) show either an increase or decrease or no real change, implying that the treated fabrics do not always show an improvement in their softness. This may be caused due to the deposition of softener on the fibre matrix, thus hindering its flexibility and softness. The treatment of silicone finishes on cellulose fabric essentially improves swelling of cotton fibres. Hence, treatment with higher concentration of these chemicals might be resulting in more expansion of the fibres causing ruptures of the silicone films. Since the polymeric film layers do not melt and flow, the cracks in the ruptured film cannot be sealed, which ultimately develops rigidness or tend towards rigidness in the matrix.

Table 6 —One way Anova results of fabric feel test

Source	SS	df	MS	F	Prob> F
Columns	14321.5	5	2864.3	4.21	0.0193
Error	8168.4	12	680.7	-	-
Total	22490	17	-	-	-

3.4 Subjective Evaluation of Garment (Fabric) Softness

In order to assess the consumers’ subjective feeling by hand on the improved softness of handloom fabrics due to the silicone treatment, two similar types of garments (ladies kurti) were stitched from untreated (the readily available) and silicone treated handloom fabrics. Both the garments were displayed before buyers in a reputed shopping malls of Bhubaneswar city and a survey was conducted through a set of questionnaire in order to get the opinion of the consumers. The feedbacks of the customers are found quite encouraging. All the forty seven customers, participated in the survey, have commented that the silicone treated garment feels better than the untreated garment and expressed their preference for purchasing the silicone treated garment even by paying extra amount.

4 Conclusion

4.1 The commercial handloom fabrics possess higher stiffness and surface roughness than mill made fabrics.

4.2 Silicone treatment reduces the stiffness and imparts softness in the handloom fabrics.

4.3 Silicone treatment also reduces the surface roughness of the handloom fabrics to the maximum extent of 90.82%.

4.4 Out of various concentrations, 80 gpL has resulted maximum gain in hand values like softness and surface smoothness and ultimately a better feel.

4.5 For easy and quick assessment of quantitative measurement of the hand value of fabrics, the concept of measurement of fabric bending length, digital image processing technique for fabric surface roughness and fabric feel tester for fabric softness may be used for commercial and academic purposes.

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