Fabric Surface Smoothness Measurement via Newly Developed Smoothness Tester

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Abstract

An instrument has been designed and developed to measure the smoothness behavior of finished fabrics. The instrument is based on pendulum principle. The weight (hang on string) comprises a frictionless wheel movable along arc shaped platform. The platform acts as a sample holder. When the weight is subjected to push, it swings back and forth in the platform. The amplitude of the swing reduces due to friction of the fabric. The amplitude is inversely proportional to the friction or roughness of the fabric.

Various types of finished fabric samples were tested on the developed instrument. The results were found to be satisfactory. These results were also compared with the bending length and crease recovery behavior of the particular fabric sample. From the results it was found that lesser the bending length more will be the smoothness. If the crease recovery angle is high, the fabric will be smoother. Statistical analysis was also carried out to co-relate the relationship between smoothness behavior of fabric and bending length as well as crease recovery behavior.

KEYWORDS: bending length, crease recovery, finishing, pendulum, smoothness

Introduction:

Fabric smoothness-roughness has been considered as one of the most important factors of clothing comfort. It is also a significant factor in today's consumer buying decision. Fabric smoothness behavior is directly linked to the fabric surface friction behavior. Fabric friction, which is defined as the resistance to motion, can be detected when a fabric is rubbed mechanically against itself or tactually between the finger and thumb. Friction is considered to be one property of cloth which has considerable importance in the fields of both technological and subjective assessment.

Subjective assessment, which specifies the fabric handle, is undoubtedly influenced by the static and dynamic friction between the cloth surface and the thumb or finger, although other properties are also involved in the assessment. The human finger is a sensitive instrument capable of detecting small differences in the frictional behavior of fabrics. The results of hand tests are expressed in subjective terms such as ‘clingy’, ‘greasy’, ‘mushy’, ‘oily’, ‘rough’, ‘scratchy’, ‘sheer’, ‘sticky’, ‘waxy’ etc., depending upon the sense of touch. So it is important to assess the fabric friction quantitatively as well as the factors that may affect it.

Objective measurement of the frictional properties of fabrics helps in clear communication and the optimization of a particular process. It is well known that there are always disputes between buyer and manufacturer regarding feel of fabric as there is no quantitative method is available which can spell out the feel of the particular fabric.

Though fabric friction has gained much significance, there is no suitable instrument in the textile industry to measure fabric friction. Kawabata developed the KES-FB4 for the measurement of surface friction and the surface roughness of the fabrics. This instrument is however not available to all due to its very high cost. Most researchers have used the Instron tensile tester with some attachments to measure the inter-fabric or fabric-to-metal friction, which again become costlier and complicated. Due to this it is not being used in the industry.

Hence, an indigenous cost effective instrument is required to be developed to address the above problems i.e. to determine the smoothness characteristics of fabric and can give indication on change in surface characteristics after the various pre-treatment and finishing processes. By this instrument finisher can change finishing recipe or process to meet the required smoothness characteristics of the fabric.

2 Material and methods:

2.1 Description of instrument The instrument is based on pendulum principle. The weight (hang on string) comprised to a frictionless wheel movable along are shaped platform. This acts as a sample holder. When the weight is subjected to push, it swings back and forth in the platform. The amplitude of the swing reduces due to the friction of the fabric. The amplitude is inversely proportional to the friction of the fabric. Line diagram of instrument is given in Fig.1. Whole assembly is in chamber in which air flow is constant. The picture of the developed instrument is shown in Fig. 2.

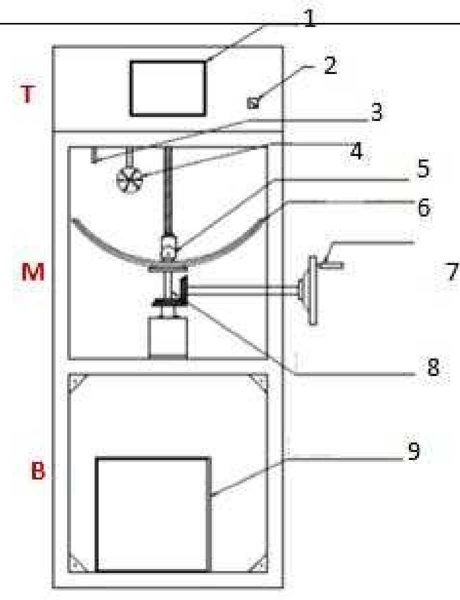

Fig.1: line diagram of smoothness tester

Fig. 2 Picture of NITRA Fabric smoothness tester

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The apparatus includes three chambers namely top, middle and bottom chamber. The chambers will be detailed out one after another herein below:

2.1.1 Top chamber (T)-This chamber accommodates display unit(1), on/off switch (2), geared motor with electromagnetic clutch, press button to actuate pendulum, rotor encoder in order to measure angle/amplitude and programmable logic controller (PLC) to control various parameters such as humidity, temperature etc. The display unit reflects information pertaining to humidity, amplitude, time of completion of cycle, air velocity etc. The on/off switch is provided to switch on or off said apparatus. The geared motor with electromagnetic clutch controls oscillation of the roller hanging from the roof of the middle chamber with a rod.

The roller hanging from the roof by means of rod causes whole assembly to oscillate about the equilibrium position by swinging back and forth. This oscillation takes place with the help of geared motor. The electromagnetic clutch plays role to shift the roller assembly at the maximum angle on one side. When this roller assembly attains the maximum angle, it is released by means of a release button. Upon release of the assembly, it starts oscillating about the equilibrium position swinging back and forth. Said rotary encoder is provided to measure angle/amplitude of the roller assembly.

2.1.2 The middle chamber (M) embodies temperature and humidity sensor (3),Anemometer (4), revolving roller assembly (5), Arc type sample holder (6) and screw arrangement and height adjustment (7& 8) . The above will be described herein below:-

2.1.3 Bottom chamber (B): This chamber houses steam generator (9) to generatesteam for changing humidity. Beside the above three chambers, an air conditioning unit is also employed with the apparatus to maintain required temperature in the course of the testing.

2.2 Evaluation of various properties of fabric samples

To study the smoothness behavior of fabric samples, cotton fabric with plain weave is taken. Grey cotton fabric is signed, desized, scoured, bleached, mercerized and then finishing (silicone softener). These fabric samples were analyzed for mass, thread density (EPI X PPI), tear and tensile strength, crease recovery angle and bending length of the fabric samples were tested as per IS 1964, IS 1963, ISO 13937-1, ISO 13934-1, IS 4681 and IS 6490 test methods respectively. Finally all the six samples were subjected to test smoothness behavior using newly developed instrument. For analysis of smoothness property, 20 specimens (15cm X 15cm each) per sample (10 specimens warp wise and 10 specimens weft wise) were cut and well ironed to remove wrinkles. These specimens were conditioned for 2 hours in 65±3% RH at 27±2^{o}C. After conditioning these were mounted on the sample holder fitted on the instrument, one by one. A constant load of 0.4 Kg was applied on the specimen with the help of load cell during the test. After adjusting load, test was started by pushing start button. This initiated the movement of pendulum arrangement. The test is completed once the pendulum movement was stopped completely. Once the pendulum stop, time taken to stop the pendulum in millisecond is displayed on the screen of instrument.

2.3 Statistical Analysis

Experimental data were analysed using SPSS(version 20). One-way ANOVA was used to compare means. The null hypothesis (H_o) is that there is no relationship between types processing treatment given on the fabric & bending length, processing treatment & crease recovery angle, processing treatment & smoothness property. In the alternative hypothesis, there is a relationship between types processing treatment and various properties. The H_o will be rejected when the p-value turns out to be less than a pre-determined significance level,i.e. 0.05.

3.0 Results and Discussion

The various fabric construction and durability properties like mass, EPI/PPI, bending length and crease recovery angle, tear & tensile strength along with smoothness properties of all the six samples are given in Tables 1.

3.1 Bending length: The bending length is very important factor which determines the flexibility of the fabric. The bending length in both the warp and weft direction of the fabric is important in determining the flexibility of the fabric. The values of the bending length of treated and untreated cotton fabrics are given in Table 1. Untreated fabric i.e. grey shows maximum bending length (warp wise: 2.45 cm and weft wise: 1.75 cm). The variation of bending length in both directions of desized, scoured, bleached and mercerized samples is very less as shown in the table 1. This study indicates that grey cotton fabric is more stiff compared to finished cotton fabric in both warp and weft direction. This is due to fact that grey cotton fabric is having sizing chemicals as well as natural impurities. The greater bending length along the warp direction of the fabric reveals that the fabric is stiffer in warp direction than the weft direction. This can be due to the result of fabric density which is more in the warp direction than the weft direction (Table 1). Greater stiffness of the fabric has less bending elasticity along warp direction than the weft direction. It is clear from the Table-2 that p value is <0.05 for both warp and weft direction of bending length with fabric type (fabric after various treatments), and therefore null hypothesis is rejected. It indicates that various treatments have direct influence on bending length of the fabric.

3.2 Crease recovery: Crease recovery is the important property of the fabric, generally caused by a fold due to pressure on the fabrics. The tendency to crease depends on the structural characteristics of cellulose fibres. With a high degree of orientation, a pronounced tendency to crease diminishes. Crease recovery is the removal of crease determined by crease recovery angle was determined by using Shirely crease recovery angle tester. For this purpose rectangular test specimen (14mm x 15mm) were cut both in the warp and weft direction. Before testing sample was conditioned as per the standard test conditions. The value of recovery angle of untreated and treated cotton fabrics are given in table 1. It is evident from the table 1 that the crease recovery angle is increasing from grey to finished sample. Untreated fabric shows minimum crease recovery angle which is periodically increased after the treatment such as desizing, scouring bleaching, mercerization and finishing with softener. It is clear from the Table 1 that the crease recovery (dry state)of different treated samples is higher than untreated or grey fabric sample. This is may be due to swelling of fibre in the fabric. It appears that the treatment has developed the ability of fabrics to recover from deformation. The materials, which have good crease recovery properties, exhibit excellent soft handle, draping and appearance as well as a lack of flabbiness as washing proceeds. The grey fabric materials have less crease recovery angle tend to more limp and flabby on washing. Table 3 indicates that p value is <0.05 for both warp and weft direction of crease recovery with fabric type and therefore null hypothesis is rejected. It indicates that various treatments have direct influence on crease recovery of the fabric.

3.3 Fabric surface smoothness: From the Table 1 it is seen that fabric smoothness is found to be more in the finished fabric compare to other. The mercerized sample is second highest smoothness behavior as expected. The bleached sample showed lowest smoothness behviour as the sample with hydrogen peroxide bleaching become harsh. One-way ANOVA was used to compare relationship between fabric type and processing treatments. The results are given in Table 4. From the Table 4, it is clear that the p value is <0.05 for both warp and weft direction of smoothness properties (time required to stop pendulum in milliseconds) with fabric type (fabric after various treatments), and therefore null hypothesis is rejected. It indicates that various treatments have direct influence on fabric surface smoothness.

Table.1: Physical property of samples

Sample code	Mass, g/m^2	End /inch	Picks /inch	Tensile strength, N		Tear Strength, g		Crease recovery angle (^{o}) (Warp +Weft)	Bending length, cm		Smoothness, Time required to stop pendulum device in milliseconds	
				warp	weft	warp	weft		warp	weft	Warp	Weft
Grey	128	120	72	576	259	1138	569	106	2.45	1.75	680	690
Singed	124	122	72	560	270	1112	536	110	2.40	2.80	658	676
Desized	118	126	78	520	230	1150	720	140	1.58	1.46	736	740
Scoured	124	128	80	580	240	1064	676	144	1.55	1.42	814	837
Bleached	126	134	82	700	271	897	640	146	1.56	1.40	783	797
Mercerised	127	136	80	681	258	977	670	156	1.40	1.38	890	954
Finished	126	136	72	428	167	1404	821	184	1.12	1.10	1050	983

Table.2: Anova analysis between type of fabric and bending length

Tests of Between-Subjects Effects						
Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	Warp Bending	4.641[a]	6	.774	4922.465	.000
	Weft Bending	4.898[b]	6	.816	27.042	.000
Intercept	Warp Bending	61.955	1	61.955	394256.030	.000
	Weft Bending	57.669	1	57.669	1910.459	.000
FABRICS	Warp Bending	4.641	6	.774	4922.465	.000
	Weft Bending	4.898	6	.816	27.042	.000
Error	Warp Bending	.002	14	.000		
	Weft Bending	.423	14	.030		
Total	Warp Bending	66.598	21			
	Weft bending	62.989	21			
Corrected Total	Warp bending	4.643	20			
	Weft bending	5.320	20			
a. R Squared = 1.000 (Adjusted R Squared = .999)						
b. R Squared = .921 (Adjusted R Squared = .887)						

Table.3: Anova analysis between type of fabric and crease recovery

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	12626.571[a]	6	2104.429	2104.429	.000
Intercept	410760.429	1	410760.429	410760.429	.000
FABRICS	12626.571	6	2104.429	2104.429	.000
Error	14.000	14	1.000		
Total	423401.000	21			
Corrected Total	12640.571	20			
a. R Squared = .999 (Adjusted R Squared = .998)					

Table.4: Anova analysis between type of fabric and smoothness (time required to stop pendulum in milliseconds)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Smoothness warp wise	329939.143[a]	6	54989.857	54989.857	.000
	Smoothness weft wise	266436.000[b]	6	44406.000	44406.000	.000
Intercept	Smoothness warp wise	13492851.857	1	13492851.857	13492851.857	.000
	Smoothness weft wise	13812141.000	1	13812141.000	13812141.000	.000
typeoffabric	Smoothness warp wise	329939.143	6	54989.857	54989.857	.000
	Smoothness weft wise	266436.000	6	44406.000	44406.000	.000
Error	Smoothness warp wise	14.000	14	1.000		
	Smoothness weft wise	14.000	14	1.000		
Total	Smoothness warp wise	13822805.000	21			
	Smoothness weft wise	14078591.000	21			
Corrected Total	Smoothness warp wise	329953.143	20			
	Smoothness weft	266450.000	20			

	wise					
a. R Squared = 1.000 (Adjusted R Squared = 1.000)						
b. R Squared = 1.000 (Adjusted R Squared = 1.000)						

Conclusions

Fabric smoothness behavior is directly linked to the fabric surface friction behavior. Fabric friction, which is defined as the resistance to motion, can be detected when a fabric is rubbed mechanically against itself or tactually between the finger and thumb. Friction is considered to be one property of cloth which has considerable importance in the fields of both technological and subjective assessment. Subjective assessment, which specifies the fabric handle, is undoubtedly influenced by the static and dynamic friction between the cloth surface and the thumb or finger, although other properties are also involved in the assessment. The human finger is a sensitive instrument capable of detecting small differences in the frictional behavior of fabrics. Though fabric friction has gained much significance, there is no suitable instrument in the textile industry to measure fabric smoothness. Hence, an indigenous cost effective instrument is developed to determine smoothness behaviour of fabric. The instrument is capable to give indication on change in surface characteristics after the various pre-treatment and finishing processes. By this instrument finisher can change finishing recipe or process to meet the required smoothness characteristics of the fabric.

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