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MEASUREMENT OF FABRIC HANDLE BY USING A CYLINDRICAL HOLE OF SPONGE

قياس ملمس القماش باستخدام ثقب اسطوانى من الاسفنج

By

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خلاصه — فى هذا البحث أمكن استخدام طريقة جديدة لقياس ملمس القماش تقوم على اساس تغير قطر ثقب اسطوانى من الاسفنج طبقا لوزن المتر المربع من القماش. ايضا أمكن تطوير طريقة لتقييم ملمس الأقمشه المنسوجه مستعينا بخواص الأقمشه المتعلقه بالملمس وهذه الطريقه هى مساحة الشكل المتعدد الأضلاع. ايضا امكن تصميم وانشاء جهاز بسيط لقياس معامل احتكاك الأقمشه مستخدما طريقة المستوى المائل. لذا فقد تم اختيار أربع عشرة قماشة مختلفة الوزن من اقمشة ملابس السيدات وامكن تقييم خاصية الملمس لها بواسطة طرق عديده منها طريقة سحب القماش خلال ثقب اسطوانى من الصلب، وخلال فوهه من الصلب، وخلال ثقب اسطوانى من الاسفنج واخيرا طريقة مساحة الشكل المتعدد الأضلاع. النتائج المعمليه أوضحت أن هناك ارتباط قوى بين نتائج الطرق المقترحه ونتائج الطرق الاخرى المعروفه. بواسطة تحليل الانحدار المتعدد امكن التوصل الى عدة معادلات معمليه تربط خواص القماش مع قوة سحب القماش المقاسه بالطرق المختلفه. باستخدام هذه المعادلات امكن التنبوء بقوة سحب القماش (ملمس القماش) بدقه.

ABSTRACT — In this work, a quantitative method for measuring fabric handle based on changing the diameter of a cylindrical hole of sponge according to fabric weight per unit area was tested. Also, a method of expressing objective test results relating to the handle of woven fabric has been developed. This method involves the area of polygon area. Also, a simple apparatus has been designed and constructed for measuring coefficient of friction of fabrics using the inclined plane method. Therefore, fabric handle was assessed for fourteen dressing fabrics by several methods such as fabric withdrawal force (by the cylindrical ring method), (by the nozzle method), (by the spongy hole method) and polygon area method. The experimental results show the high correlation between the measurement by the suggested methods and the other known methods. Several empirical equations are fitted to the measured withdrawal force values by the different methods using multiple regression analysis. These empirical relationships are shown to predict the withdrawal force (fabric handle) accurately.

1- INTRODUCTION

In considering textile products, the handle property is the one most widely used by both industry and the consumer in determining the acceptability of goods for their end use. However, when attempts are made to define the term (handle), the complexity of this term becomes apparent and its components does not yet exit.

In previous studies on fabric handle [1-12] several definitions for fabric handle have been given from which it is clear that it is difficult to define fabric handle in words. Trying to generalize all the parameters which are gathered to express the fabric handle in one definition the following definition has been proposed: "The fabric handle is the translation of the reaction of the fabric properties on human hand, by means of the nervous system and assessed by the brain, when the fingers make the action on the fabric by compressing, bending and rubbing it or handle it".

Subjectivity of fabric handle leads to a variety of assessments depending on the perceiver. Many people still consider qualitative analysis as the final judge of fabric handle. Several approaches to subjectively measure fabric handle are used at present. Evaluations performed by an expert finisher require a carefully selected format and are time consuming [13].

Quantitative analysis of fabric hand is desirable to allow more accurate comparisons between all types of fabrics. Among the objective methods, the most sophisticated is the Kawabata Evaluation System for Fabrics or KESF [10-12]. However, the KESF procedures are time-consuming and the instruments are expensive. The KESF measures up to seventeen fabric mechanical properties such as tensile, bending, shear, surface friction, compressional, weight and thickness. The disadvantages of cost, complexity and effort remain with any KESF evaluations. Therefore, simple and quick objective techniques would be useful for quality control. Attempts have been made along lines similar to KESF to overcome these limitions. There still exists a need for a simple, inexpensive and reliable objective method to screen differences in fabric handle.

Sultan, Soliman and Sheta [5-9] have been developing a test method to measure fabric handle based on measuring the force generated when withdrawing a fabric specimen through a cylindrical ring. This work found good agreement between the withdrawal forces and their subjective handle ranking for fabrics in the same end-use category. Also, in these works, the authors deduced that to make packing fraction, B, (the ratio of material volume to the hole volume) constant for all the test, it is necessary to change the radius of the disc hole for each fabric weight which is not practical or this a reasonable range of (B) was taken. Thus for each range of fabric weights a suitable hole radius has been used. Thus, it is necessary to develop the previous method to obtain a changable hole diameter suits a wide range of fabric weight per unit area. Behery [13] also investigated the relationship of withdrawal force measurement with KESF measurements and Alley [14] method using a nozzle with conical geometry. He found that his withdrawal force measurements correlated with KESF handle values and deduced that there is a fairly good agreement between the quantitative values obtained. Pan et al [15] have attempted to interpret the force-extraction curves obtained by withdrawing fabric specimens through a nozzle.

The object of this work is to introduce a new method for measuring the fabric handle and to compare the results obtained with the results obtained by the other methods and if possible, to find a means of expressing the total property of handle.

2- EXPERIMENTAL WORK

2.1- Test Samples:

A wide range of fourteen commercial dressing fabrics was obtained for handle force measurements. Fabric weights ranged from 68 to 300 g/m^2, Specifications of the fabrics are detailed in Table (1).

Table (1): Details of the Fabric Samples.

Sample No.	Type of Material	Yarn Count (N_m)		Threads/cm		Weave Design
		w	f	w	f	
1	100% Nylon	110	110	33	33	Plain 1/1
2	100% Cotton	107	79	34	29	Plain 1/1
3	100% Cotton	55	48	23	18	Plain 1/1
4	65% P/35%C*	70	60	35	22	Plain 1/1
5	65% P/35%C	64	53	33	20	Plain 1/1
6	50% P/50% C	59	45	27	24	Plain 1/1
7	100% Cotton	56	46	28	24	Plain 1/1
8	100% Wool	29	23	24	19	Twill 2/2
9	100% Cotton	25	11	18	14	Plain 1/1
10	100% Acrylic	26	26	26	19	Twill 2/1
11	100% Polyester	26	23	25	19	Twill 2/1
12	100% Wool	10	8	9	8	Plain 1/1
13	100% Cotton	28	14	20	16	Plain 1/1
14	100% Wool	9	7	11	10	Twill 5/5

*P means polyester fibres, C means cotton fibres.

2.2- Objective Test Methods:

Some mechanical and surface tests considered relevant to fabric handle were performed on the fabrics including fabric weight, fabric thickness, fullness (specific volume), smoothness (coefficient of friction), extensibility, compressibility, crease recovery, flexural rigidity, tensile modulus and drap coefficient.

2.2.1- Weight per unit area (g/m^2)

By using a template measuring 250 mm X250 mm, specimens were cut from each fabric. The specimens were then weighed and their weights per unit area were calculated.

2.2.2- Fabric thickness (mm)

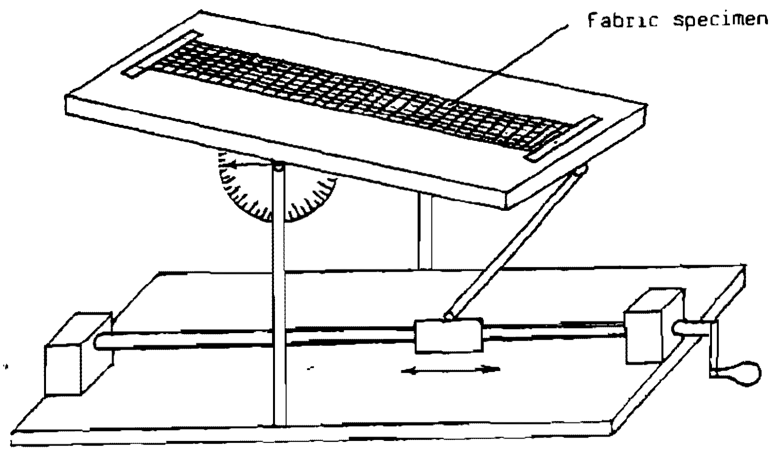
The fabric thickness was measured by Shirley Thickness Meter. The thickness of the fabric specimens in millimetres when a load of 700 gf (representing a pressure of 70 gf/cm^2) was applied.

2.2.3- Fabric bulk (cm^3/g)

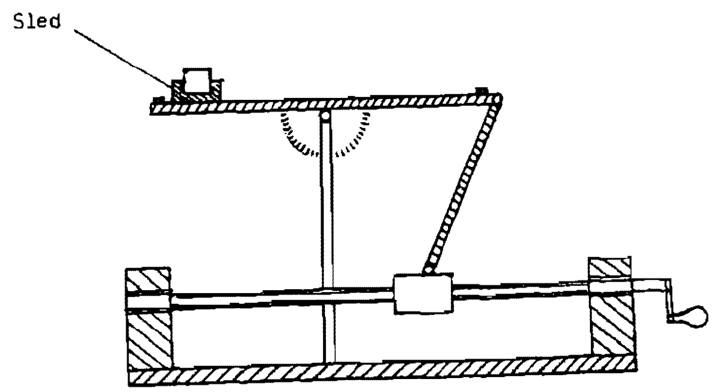
This was determined in terms of specific volume using the reciprocal of fabric density.

2.2.4- Fabric friction measurement:

For measuring the coefficient of friction between the samples and the hole wall, an apparatus was designed and constructed using the inclined plane method as shown in fig.(1). For tests, three specimens in both warp and weft directions 50 mm X 150 mm in size are cut out from the fabric to be tested and also one specimen in warp direction 160 mm wide and 600 mm long. The specimen (160 mm X 600 mm) was fixed to the plane surface. A steel sled (63 mm X 63 mm) of mass 200 g was placed on the fabric surface to determine fabric-to-steel friction. Also the sled was covered with the same tested specimen 50 mm X 150 mm (in warp or weft) to determine fabric-to-fabric friction. Also the



Isometric of the apparatus



Section elevation of the apparatus

Fig. (1): Schematic diagram of fabric friction apparatus.

led was covered with the same material as hole material (sponge) to determine abric-to-sponge friction. The plane was slowly inclined until the sled began o slide, at which the angle (θ) was measured. The coefficient of friction was alculated as $\mu = \tan \theta$. The test is repeated 15 times for each specimen (in oth warp and weft direction). The first ten results for each specimen are not aken into consideration and the mean value of the plane inclination angle is etermined by the results of the last five tests. Also five measurements were arried out for both face and back of each specimen. Thus the mean values of he results were recorded for both fabric-to-fabric friction, fabric-to-sponge riction and fabric-to-steel friction.

2.2.5- Fabric compressional properties:

(i) Compression, C(%):

This was determined from the following formula:

$$C = \left(\frac{\text{thickness at } 0.5\ g/cm^2 - \text{thickness at } 500\ g/cm^2}{\text{thickness at } 0.5\ g/cm^2}\right) \times 100 \qquad \ldots\ldots(1)$$

(ii) Springiness ratio, SR:

This was determined from the following formula:

$$SR = \frac{\text{thickness at } 1.4\ g/cm^2}{\text{thickness at } 140\ g/cm^2} \qquad \ldots\ldots(2)$$

(iii) Normalized fabric compressibility, NC

This was determined from the following formula:

$$NC = \left(\frac{T_o - T_m}{T_m}\right) \times 100 \qquad \ldots\ldots(3)$$

where T_o = fabric thickness at 0.5 g/cm^2;
T_m = fabric thickness at 50 g/cm^2.

(iv) Fabric hardness, H ($gf/cm^2/cm$)

This was determined from the formula:

$$H = (P_2 - P_1)/(T_1 - T_2) \qquad \ldots\ldots(4)$$

where P_1 = fabric initial pressure, 70 g/cm^2.
P_2 = fabric final pressure, 500 g/cm^2.
T_1 = thickness in centimetres under pressure 70 g/cm^2.
T_2 = thickness in centimetres under pressure 500 g/cm^2.

2.2.6- Fabric crease resistance, CR

For measuring crease resistance factor (CR) on Shirley Crease Recovery Tester, a specimen is cut from the fabric with a template 2 in. long by 1 in. wide. It is carefully creased by folding in half, placing it between two plates and adding a 2 kg weight. After 1 min the weight is removed and the specimen transferred to the fabric clamp on the instrument and allowed to recover from the crease. After the time period allowed for recovery (1 min), the recovery angle in degrees (θ) is read on the engraved scale. Then crease resistance factor (CR) can be determined from the following formula:

$$CR = (\theta/180) \times 100 \qquad \ldots\ldots(5)$$

2.2.7- Fabric stiffness

The instrument used was the Shirley Stiffness Tester. Three specimens for both warp and weft directions, measuring 6 in. x 1 in., were cut from each fabric sample. Then bending length, flexural rigidity and bending modulus can be determined.

2.2.8- Fabric tensile properties

The instrument used was Lloyed Universal tester with a max load-cell capacity of 2500 N. Three fabric specimens, measuring 300 mm x 50 mm, were cut with the long side parallel to the warp yarns, and four specimens were cut with the long side parallel to the weft yarns. The gauge length between the jaws was set at 200 mm and the crosshead speed was set at 50 mm/min during both extension and recovery. From these tests, the tensile modulus, was determined. This was the force required to stretch a fabric specimen by 10% of its original length.

2.2.9- Fabric drape coefficient, DC

The apparatus used for measuring drape coefficient was the Drapeometer. Three specimens, 25 cm in diameter, were cut from each of the fabric samples. A specimen was placed on the lower horizontal disc of the apparatus. The disc had a smaller diameter (d_i = 15 cm) than the diameter of the specimen (d_s = 25 cm) so that the specimen edges draped over the disc. Then the radial axis length on polar circule was read on a rule. The mean diameter of the sixteen measurements was obtained (d). The test was carried out six times for each fabric sample, three times with the face of the fabric and three times with the back of the fabric. By using the values of d, d_i and d_s, drape coefficient (DC) were calculated from the formula:

$$DC = \frac{d^2 - d_i^2}{d_s^2 - d_i^2} = \frac{d^2 - 225}{400}, \qquad \ldots\ldots(6)$$

where d = the mean dia. of the sixteen measurements in cm.
d_i = the smaller disc diameter, 15 cm.
d_s = the specimen diameter, 25 cm.

2.3- Methods of Measuring Fabric Handle:

The fabric handle was measured by the following methods:

(i) Cylindrical ring method (M_1)

The cylindrical ring method (M_1) has been suggested by Sultan et al. [5-9]. This method can be explained as follows: A circular fabric specimen of 25-cm diameter is drawn, using a Lloyed Universal tensile tester (digital apparatus), through a cylindrical ring of steel, 2 cm in diameter and 2 cm in height. The force needed to withdraw the fabric through the ring increases as more and more if the specimen is introduced into the ring. The maximum value of the force occurs when the entire specimen has nearly passed through the ring. In order to compare different fabrics, it is necessary to calculate the specific handle force. For getting the specific handle force, S.F., the handle force, F, (N) should be devided by the hole area A (cm^2) and the packing fraction B, as follows

$$S.F = F/(A.B), \quad N/cm^2 \qquad \ldots\ldots(7)$$

where

$$B = \frac{(2R_s - H)}{10^4 \rho} \cdot \frac{W}{R_h^2} \qquad \ldots\ldots(8)$$

where: R_s is the specimen radius, cm; R_h is the hole radius, cm; H is the hole height, cm; W is the fabric weight per unit area, g/m^2 and ρ is fibre material density, g/cm^3.

R_s, H and R_h were taken constants and equal 12.5 cm, 2 cm and 1 cm respectively; giving

$$S.F. = \frac{F(N) \times \rho\,(g/cm^3)}{0.007226\, W\,(g/m^2)}, \quad N/cm^2 \qquad \ldots\ldots(9)$$

(ii) **Nozzle method (M_2)**

The nozzle method (M_2) has been suggested by Behery [13]. This method can be explained as follows: Circular fabric specimens of 10 cm in diameter were drawn through the nozzle using a tensile tester with cross-head and chart speeds of 50 mm/min; the nozzle had a minimum radius of 5 mm, height of 24.5 mm and one-have cone included an angle of 50^o. R_s, H and R_h were taken constants and equal 5 cm, 1 cm and 0.5 cm respectively; giving

$$S.F. = \frac{F(N) \times \rho(g/cm^3)}{0.0028274 \; W\,(gm^2)}, \quad N/cm^2 \qquad .....(10)$$

(iii) **Spongy hole method (M_3)**

The spongy hole method (M_3) for measuring fabric handle has been suggested to measure the withdrawal force by using a cylindrical hole of sponge. An attachment was designed and constructed as shown in Fig. (2). This method can be explained as follows: A circular fabric sample (25 cm in diameter) held in the centre is extracted through a spongy hole. The hole had a diameter of 10 mm and a height of 40 mm, which is connected to a tensile tester (Lloyed Universal with a maximum load-cell capacity of 2500 N) so that a load-displacement curve can be obtained with cross head speed of 50 mm/min. For each fabric, a circular sample 25 cm in diameter was tested, a total of ten times alternating between pulling the back and face of the fabric through the spongy hole.

(iv) **Polygon area method (M_4)**

This method (M_4) involves the use of polar diagram, which offers a pictorial representation of the handle of the fabric. It was felt that such a polar diagram might form the basis of a simple method for expressing handle completely in a numerical form.

The inclusive assessment of fabric handle could be estimated by using the relative characteristics method of the quality [16]. The relative characteristics of fabric handle could be calculated from the following equations:

$$K_j = \frac{X_i}{X_{max}}, \quad \text{(for positive characteristics which have positive correlations)} \qquad .....(11)$$

$$K_j = \frac{X_{min}}{X_i}, \quad \text{(for negative characteristics which have negative correlations)} \qquad .....(12)$$

where K_j – relative characteristics of handle;
X_i – individual readings of each property;
X_{max} – max. value of the same property; and
X_{min} – min. value of the same property.

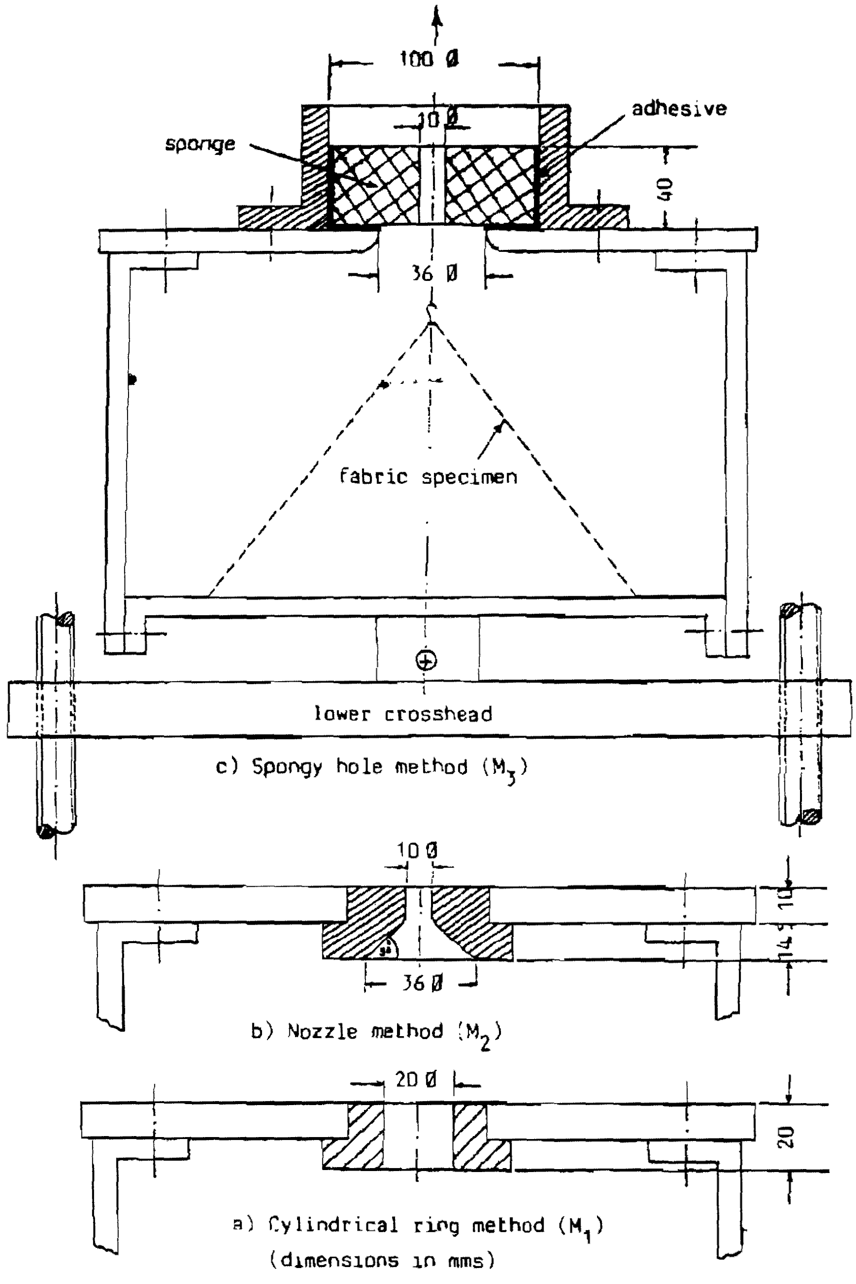


Fig. (2): An attachment for measuring the fabric handle force.

This method can be represented from a knowledge of number of properties (n) in the inclusive assessment, which starts from the same point at the centre and make an angle $2\pi/n$ between them. And the coordinates can be joined and a polygon can be obtained.

For the inclusive assessment of fabric handle the area of this polygon could be calculated from the following equation:

$$A = 1/2 \sin(2\pi/n)(K_1K_2 + K_2K_3 + K_3K_4 + K_4K_5 + K_5K_6 + K_6K_1) \quad .....(13)$$

where A = polygon area of each fabric;
n = 6-number of the measured properties.

Also, an inclusive coefficient of fabric handle (I) can be calculated as follows:

$$I = (A/A_{max}) \times 100, \quad (\%) \quad .....(14)$$

where A_{max} — maximum polygon area when $K_1 = K_2 = K_3 = K_4 = K_5 = K_6 = 1$ and equal to 2.598.

3. RESULTS AND DISCUSSION

The test results for the different samples are listed in Table (2).

Table (2): Values of Test Results.

Sample No.		Fabric weight, g/m^2	Fabric thickness, mm	Fabric bulk, cm^3/g	Coeff. of friction: Fabric-to-steel μ_{fs}	Fabric-to-fabric μ_{ff}	Fabric-to-sponge μ_{fs}	Compression, %	Springiness ratio
1	Light weight	68.3	0.100	1.464	0.335	0.612	0.794	96.3	2.64
2		88.1	0.100	1.135	0.254	0.574	0.859	59.8	1.50
3		89.7	0.155	1.728	0.316	0.635	0.898	48.0	1.44
4		100.4	0.109	1.086	0.256	0.615	0.819	63.9	1.39
5		106.9	0.115	1.076	0.241	0.629	0.804	63.6	1.50
6		114.6	0.189	1.649	0.286	0.773	0.882	59.7	1.62
7		117.1	0.153	1.307	0.296	0.762	0.869	61.3	1.51
8	Heavy weight	178.5	0.496	2.779	0.250	0.754	0.884	71.8	2.25
9		187.3	0.441	2.355	0.254	0.750	0.902	47.3	1.37
10		189.3	0.423	2.235	0.244	0.736	0.894	50.0	1.33
11		194.4	0.300	1.543	0.240	0.695	0.878	50.2	1.38
12		196.5	0.700	3.562	0.311	0.819	1.700	53.6	1.31
13		198.4	0.459	2.314	0.265	0.799	0.925	53.7	1.43
14		299.8	1.062	3.542	0.310	0.791	0.838	46.7	1.37

•Table (2): Values of Test Results (Continued)

Sample No.		Fabric compressibility, %	Fabric hardness gf/cm²/cm	Crease resistance, %	Flexural rigidity, mg·cm	Bending modulus, Kg/cm²	Tensile modulus, (N)	Sp.w.r., g/tex	Drape Coeff.
				$\sqrt{w.f}$	$\sqrt{w.f}$	$\sqrt{w.f}$	$\sqrt{w.f}$	$\sqrt{w.f}$	
1	Light weight	147.3	47778	90.0	63.0	755.4	34.1	4.210	0.569
2		65.8	215000	49.3	81.6	978.8	119.7	1.352	0.660
3		26.3	172000	59.4	90.4	291.3	61.5	1.249	0.623
4		108.3	477778	86.3	76.4	708.1	73.0	1.341	0.517
5		69.2	122857	76.9	205.1	1618.1	117.3	0.950	0.791
6		41.9	62319	87.0	126.0	223.9	97.7	1.316	0.655
7		72.2	130303	45.4	170.5	571.4	137.2	1.313	0.757
8	Heavy weight	87.0	19907	91.1	429.9	42.3	179.2	3.037	0.731
9		40.0	39450	57.8	253.1	35.4	106.1	0.482	0.780
10		33.3	34959	91.1	493.8	78.3	159.3	3.782	0.796
11		45.2	56579	84.3	161.0	71.6	145.1	5.929	0.500
12		54.5	22632	90.6	203.1	7.1	51.0	0.975	0.622
13		40.4	33333	65.1	248.2	30.8	91.5	0.750	0.779
14		37.1	16412	88.8	467.5	4.7	58.3	1.020	0.704

3.1– Comparison between the different methods of measuring fabric handle:

The fabric handle was measured by the above mentioned methods in order to compare the reliability of the results obtained by the suggested methods. The results are given in Table (3).

Table (3): Values of Fabric Handle Measured by the Different Methods.

Sample No.		Fabric Handle						
		Cylindrical ring method (M_1)		Nozzle method (M_2)		Spongy hole method (M_3)	Polygon area method (M_4)	
		N	N/cm²	N	N/cm²	N	A	I, (%)
1	Light weight	0.78	1.802	0.84	4.959	2.38	2.322	89.376.
2		1.54	3.169	1.26	6.626	3.07	1.892	72.825
3		2.12	4.285	2.24	11.570	3.61	1.205	46.382
4		1.00	2.123	1.12	6.076	3.22	1.812	69.746
5		1.88	3.565	1.64	7.949	3.62	1.446	55.658
6		2.00	3.484	2.40	10.685	3.76	0.959	36.913
7		3.35	6.097	2.86	13.303	4.23	1.070	41.186
8	Heavy weight	8.61	9.629	9.25	26.438	12.54	0.513	19.746
9		17.26	19.640	34.19	99.425	8.90	0.487	18.745
10		12.99	14.625	20.39	58.668	11.71	0.473	18.206
11		3.47	3.434	15.46	39.097	4.82	0.734	28.253
12		45.23	41.729	50.75	119.662	12.97	0.422	16.243
13		17.21	14.045	44.45	92.710	7.63	0.494	19.014
14		187.13	133.025	224.47	407.812	35.39	0.311	11.971

Statistical analyses were made by calculating the correlation coefficients to compare the various means of assessing fabric handle. Correlations were examined between fabric properties and measured withdrawal force. The results are shown in Table (4). Significant and strong correlations were noted between withdrawal force and fabric properties especially when using spongy hole method as listed in Table (4).

Table (4): Correlation Coefficients for Withdrawal Force Measurements Versus Fabric Properties.

No.	Fabric Properties	Withdrawal Force				
		(M_1)		(M_2)		(M_3)
		N	N/cm^2	N	N/cm^2	N
1	Weight per unit area, g/m^2	0.7651	0.7818	0.8121	0.8444	(0.8631)*
2	Fabric thickness, mm	0.8623	0.8854	0.8797	0.9076	(0.9402)*
3	Fabric bulk, cm^3/g	0.6961	0.7342	0.7055	0.7472	(0.8127)*
4	Fabric-to-steel friction, μfs	0.3268	0.3311	0.2798	0.2626	—
5	Fabric-to-fabric friction, μff	0.4320	0.4661	0.4699	0.5137	(0.5485)*
6	Fabric-to-sponge friction, $\mu f\acute{s}$	—	—	—	—	0.1539
7	Fabric compression, %	−0.3407	−0.3623	−0.3845	−0.4240	(−0.8567)*
8	Springiness ratio	−0.2194	−0.2406	−0.2522	−0.2845	−0.1849
9	Normalized fabric compressibility, %	−0.2769	−0.2966	−0.3231	−0.4111	−0.2186
10	Fabric hardness, gf/cm^2	−0.2956	−0.3184	−0.3301	−0.3656	−0.4529
11	Crease resistance, %	0.2598	0.2580	0.2335	0.2271	0.3441
12	Flexural rigidity, mg/cm	0.5444	0.5617	0.5626	0.5879	(0.7520)*
13	Bending modulus, Kg/cm^2	−0.3411	−0.3671	−0.3908	−0.4374	−0.4757
14	Tensile modulus, N	−0.3279	−0.3258	−0.3104	−0.2981	−0.4095
15	Sp. work of rupture, g/tex	−0.2257	−0.2456	−0.2198	−0.2309	−0.1468
16	Drape coefficient	0.1140	0.1380	0.1453	0.1766	0.2420

*The highest correlation coefficients and more than 0.5

The results of this study led to a modification of the properties considered to be important components of handle and to be included in any polar diagram according to the correlation coefficient (> 0.5) between handle force and each property. Therefore, weight per unit area, fabric thickness, fabric bulk (specific volume), fabric coefficient of friction, fabric compression and flexural rigidity were retained while the other properties were eliminated.

The relative values of properties considered to be the most important were plotted to produce the polygon diagrams for each sample as shown in Fig. (3). Hence, the polygon area of each sample was determined as listed in Table (3). The larger polygon area the lower handle force (the better fabric).

Correlations between the different values of the fabric handle which are determined by the different methods are given in Table (5). All the values of fabric handle were significantly correlated at 0.05 level to the withdrawal force measured by the suggested spongy hole method (M_3). More over, determination of the fabric handle by using spongy hole method has several advantages, such as measuring withdrawal force (fabric handle) for each fabric weight without using a certain diameter of the disc hole for each fabric weight, simplisity in its evaluation and easy to use in the textile testing laboratory.

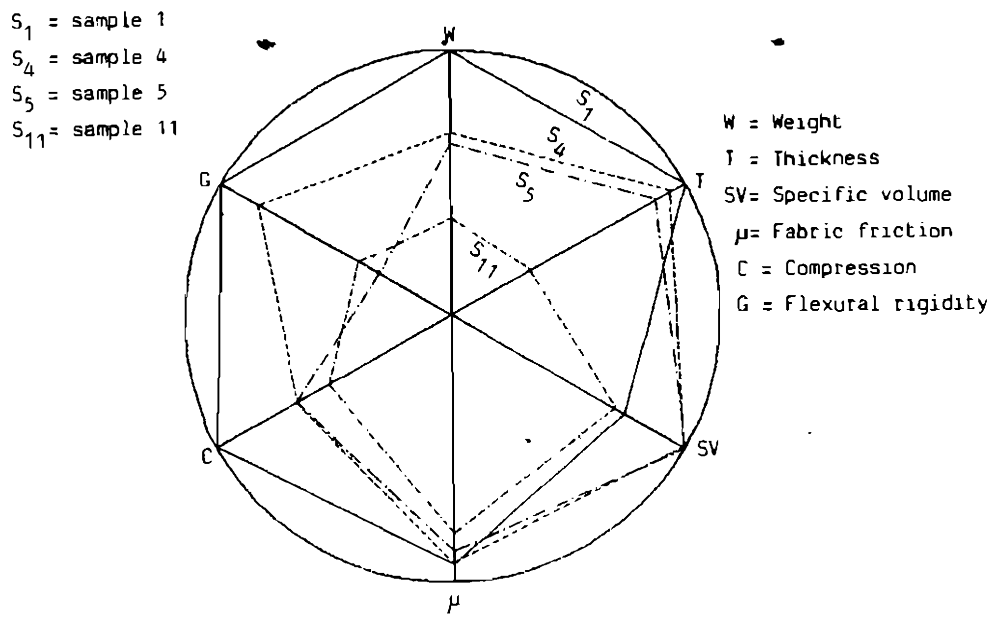


Fig.(3): Polygon diagrams for tested samples

Table (5): Correlation Coefficient Between The Fabric Handle For The Different Methods.

Method	Cylindrical ring method	Nozzle method	Spongy hole method	Polygon area method
No.	(M_1)	(M_2)	(M_3)	(M_4)
M_1	—	0.9852	0.9616	−0.4814
M_2		—	0.9551	−0.5492
M_3			—	−0.6116
M_4				—

To investigate the interaction of selected fabric properties, an equation relating the withdrawal force to the variables of weight per unit area, W(g/m^2), fabric thickness, T(mm), fabric specific volume, SV(cm^3/g), fabric coefficient of friction, μ, fabric compression, C(%) and flexural rigidity, G(mg/cm) was fitted to the experimental results using multiple linear regression analysis [17, 18] in the following form:

$$Y = Co + \sum_{i=1}^{6} C_i X_i + \sum_{i=1}^{6} C_j X_i^2 \qquad ......(15)$$

where Y = specific handle force (S.F.), N/cm^2 or handle force (F), N, X_i = measurable fabric properties and C_o, C_i and C_j = the constant and coefficient terms.

* For method (M_1):

$$S.F. = 166.7 + 0.779\ W - 10.9\ T + 8.27\ SV - 292.7\ \mu - 3.152\ C + 1.145 \times 10^{-2}\ G - 3.418\ W^2 + 288\ T^2 - 8.69\ SV^2 + 216.6\ \mu^2 + 2.192 \times 10^{-2}\ C^2 - 1.547 \times 10^{-5}\ G^2$$

$(r = 1.00)$ ......(16)

* For method (M_2):

$$S.F. = 324.46 - 1.578\ W + 1558.98\ T - 127.62\ SV + 607.56\ \mu - 10.2\ C + 8.68 \times 10^{-2} G - 2.5 \times 10^{-3}\ W^2 + 19.798\ T^2 - 27.437\ SV^2 - 372.64\ \mu^2 + 6.86 \times 10^{-2}\ C^2 - 2.764 \times 10^{-4}\ G^2 \quad (r = 1.00) \quad ......(17)$$

* For method (M_3):

$$F = -20.934 + 0.325\ W - 38.436\ T + 14.486\ SV - 2.565\ \mu - 6.03 \times 10^{-2}\ C - 4.586 \times 10^{-3}\ G - 1.06 \times 10^{-3}\ W^2 + 83.961\ T^2 - 3.638\ SV^2 - 7.466\ \mu^2 + 6.57 \times 10^{-4}\ C^2 + 2.51 \times 10^{-5}\ G^2 \quad (r = 0.9996) ......(18)$$

The fitted regression equations were used to predict the withdrawal force or fabric handle for each fabric. Table (6) and Fig. (4) show the comparison between the measured and predicted withdrawal force. As can be seen, the points fall on a straight line normally distributed with no bias, indicating that the empirical quations (16–18) give a good fit to the experimental data. The multiple correlation coefficients between the fitted equations and the experimental results as indicated in Equations (16, 17, 18) are 1.0, 1.0 and 0.9996 respectively. Thus, the empirical equations discussed above predict the withdrawal force for fourteen random samples well.

Table (6): Comparison Between Measured and Calculated Values of Withdrawal Force For The Different Methods.

Sample No.	(M_1), N/cm^2		(M_2), N/cm^2		(M_3), N	
	Meas.	Cal.	Meas.	Cal.	Meas.	Cal.
1	1.802	1.775	4.959	4.800	2.38	2.398
2	3.169	2.792	6.626	7.925	3.07	2.748
3	4.285	4.209	11.570	11.491	3.61	3.604
4	2.123	2.204	6.076	5.373	3.22	3.387
5	3.565	3.835	7.949	6.361	3.62	3.997
6	3.484	3.771	10.685	9.209	3.76	4.109
7	6.097	5.589	13.303	15.642	4.23	3.690
8	9.629	9.500	26.438	27.233	12.54	12.343
9	19.640	19.502	99.425	100.169	8.90	8.728
10	14.625	14.755	58.668	58.156	11.71	11.837
11	3.434	3.357	39.097	39.481	4.82	4.753
12	41.729	41.861	119.662	119.357	12.97	13.022
13	14.045	15.190	92.71	91.850	7.63	7.850
14	133.025	133.213	407.812	407.936	35.39	35.383

3.2– Comparison between light and heavy weight fabrics:

Table (2) compares the experimental results for both light and heavy weight fabrics. The mechanical and surface properties values show no or very little variation with fabric weight per unit area. Figures (5 & 6) show the variation of fabric handle with fabric weight per unit area for the different methods.

It is noticed that withdrawal force values measured by the different methods are greater in value for heavy fabrics than for light fabrics. The heavy fabrics also yields greater thickness, specific volume, coefficient of friction

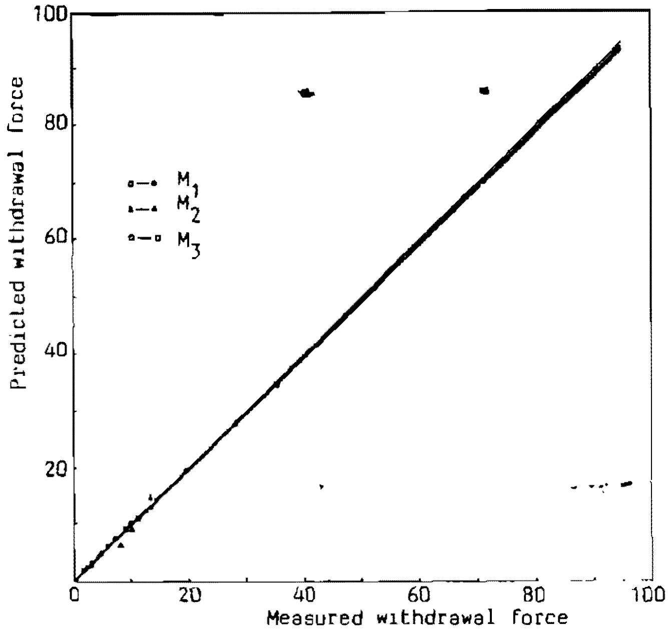


Fig. (4): Comparison between measured and predicted withdrawal forces.

and flexural rigidity than for light fabrics. These results are to be expected when one compares the handle of winter dressings with that of summer dressings.

4. CONCLUSIONS

A quantitative method for measuring fabric handle based on changing the diameter of a cylindrical hole of sponge was tested.

A method of expressing objective test results relating to the fabric handle has been developed. This method involves the area of polygon diagram which offers a representation of the handle of a fabric.

This study included the following four different methods by which the fabric handle could be assessed: withdrawal force (by the cylindrical ring method), (by the nozzle method), (by the spongy hole method), and polygon area method. We concluded that there was a fairly good agreement between the different methods used in this study and steel hole was more reliable comparing with spongy hole.

The developed apparatus for measuring coefficient of friction was found to be sensitive enough to determine the coefficient of friction between the fabric and any other material. This apparatus is very useful for assessing fabric handle.

The experimental results suggest some guidelines to maximize the handle for both light and heavy weight women's dressing materials. Fabric stiffness (flexural rigidity) should be minimized. Smoothness should be maximized i.e. the surface coefficient of friction should be minimized. The compression, compressional resilience and extensibility should be maximized. These results are physically realistic for producing soft, smooth, extensible and flexible fabrics for women's dressing materials.

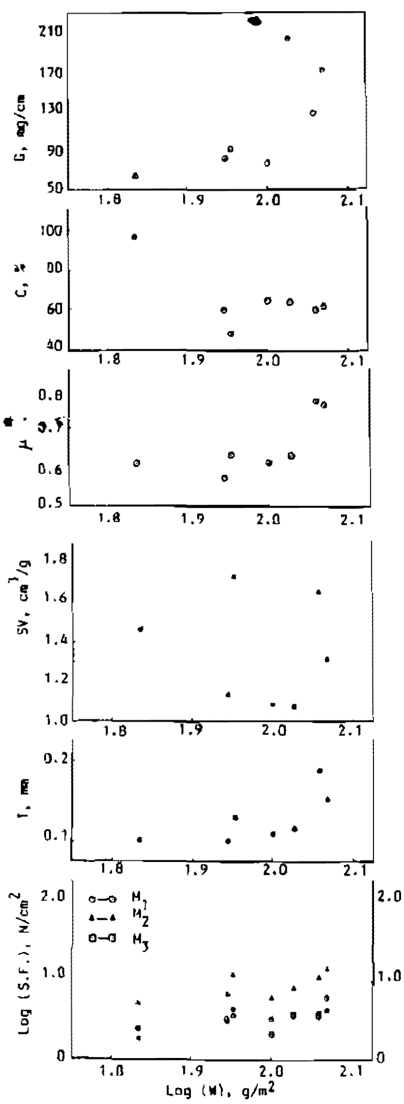


Fig.(5): The relationship between mechanical and surface properties and fabric handle, and fabric weight per unit area for light weight fabrics (68 – 117 g/m²).

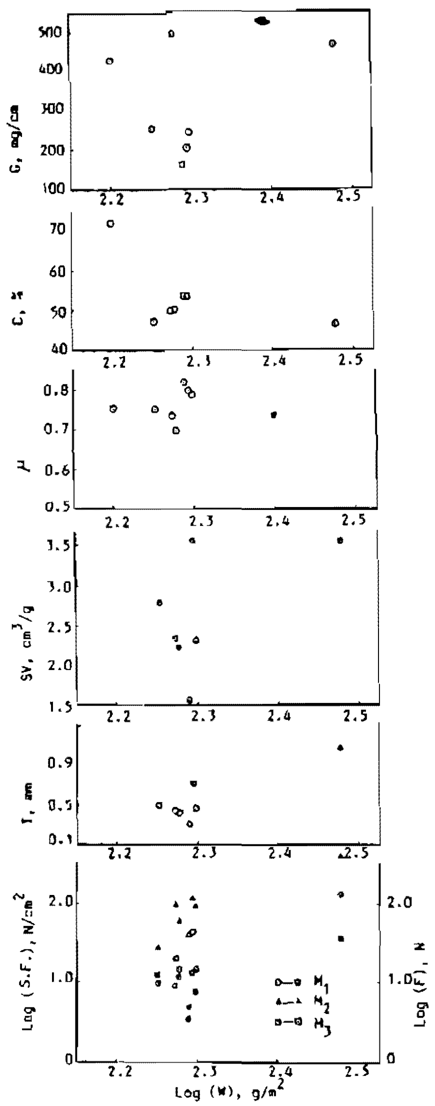


Fig.(6): The relationship between mechanical and surface properties and fabric handle, and fabric weight per unit area for heavy weight fabrics (178 – 300 g/m²).

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