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QUALITY ASSESSMENT OF 2/2 Z TWILL COTTON FABRICS WOVEN WITH VARIOUS FLOAT LENGTHS

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خلاصه ـ تشمل هذه المقالة محاولة لربط وتقييم العلاقة بين بعض الخواص الميكانيكية للاقمشة القطنية متوسطة الوزن ذات التركيب النسجي (مبرد ٢/٢) وامتداداته وهي استطالة القطع ، الشغل المبذول للقطع ، الصلابه ، رجوعية الثني مع بعض العوامل الانشائية للقماش وهي الوزن للمتر المربع ، المتوسط الهندسي لطول التشييف ، السمك ، عدد الخيوط في وحدة الطول . وبالمقارنة بين القيم النظرية والعملية لهذه الخواص وجد أن بينهما ارتباطا وثيقا بحيث يمكن التنبوء بهذه الخواص بعد ايجاد قيم هذه العوامل الانشائية . وقد وجد أن متوسط طول التشييف في القماش من أهم هذه العوامل المؤثرة على الخواص السابقة الذكر وأن التركيب النسجي (مبرد ٢/٢) بدون أى متدادات هو أحسن التركيبات النسجيه بالنسبة لهذه الخواص. وباستخدام طريقة حساب مساحة مضلع الخواص المقاسة امكن تقييم جودة الاقمشة المختبرة بدرجة عالية .

ABSTRACT- In this paper an attempt has been made to relate some mechanical properties of medium weight twill cotton fabric, specifically, extensibility, specific work of rupture, bending modulus (stiffness) and crease recovery, to some fabric constructional factors which are fabric weight, average warp and weft floats (number of threads), thickness and density of threads. It is found that average float length as an aspect of weave is the most important factor contributing to the investigated properties and that 2/2 ordinary twill-weave fabric has the superior serviceability compared with the other structures. By using the polygon area method, it is possible to assess the end use performance of outerwear twill cotton fabric from a knowledge of its initial specific work of rupture, extensibility, bending modulus and crease recovery.

1. INTRODUCTION

The angle formed in the cloth by a twill weave depends upon: (a) the relative ratio of ends and picks per unit space and (b) the rate of advance of one interlacing in respect of the following one.

If the ends and the picks per unit space are equal a regular twill advancing in steps of one runs at an angle of 45 . If however, there are more ends than picks per inch in the cloth, the line of an ordinary twill more nearly approaches the vertical; while if the picks exceed the ends the line becomes flatter.

Extended or elongated twills, running at various angles, can also be constructed by advancing the points of intersection two or more threads in one direction to one thread in the other direction.

The relationship between the angle formed by a twill on weft direction and the two sets of factors which determine it may be expressed by the following simple formula [1].

$$\tan\theta = \frac{\text{Rate of advancement of twill upwards X ends per inch}}{\text{Rate of advancement of twill outwards X picks per inch}} \quad (1)$$

Each thread must make at least two intersections in a complete repeat of a weave, one in passing from the face to the back, and another in passing from the back to the face; otherwise the thread will float continuously on one side of the cloth. The intersecting of the threads gives the cloth firmness, and the more frequent the intersections are the firmer the cloth.

The effect of twill angle i.e. average float length and picks per unit length on 2/2 twill fabric properties in both warp and weft directions seperately has been investigated by Barghash [2], which did not include any mathematical models to predict fabric properties or to obtain the optimum value for different twill angles. The twill angle as a main variable, has been studied as a major factor and this has led to extensive studies to understand the influence of average float length and fabric construction on tensile strength, extensibility, bending modulus and crease recovery.

The effect of the weave on fabric properties has been studied by Ping [3], Taylor [4] and several others. The experimental results indicated that the weave has a very marked effect on both tearing strength and stiffness. It was found that the float length in the weft direction has a strong direct correlation with the tearing strength across the warp. The main difficulty of these reported works was to choose an aspect of the weave that was suitable to the mechanical properties in question. The same may well be true of other properties, such as air permeability, ballistic protection, abrasion resistance, etc.

Practically when changing the fabric weight and thickness by means of changing the number of picks per unit length and the average float length (i.e. fabric structure), consequently, fabric properties will not stay constant.

Unfortunately, fabric weight and thickness are not the only criteria by which twill-weave fabric is judged and mechanical properties are assessed. For this reason it is proper that the effect of average float length, sum of the warp and weft threads per unit length, fabric weight and thickness should be also investigated.

The fabric bending tests can give an important information related to fabric performance, particularly when the relation between bending properties and structure is required.

Kaswel [5] proposed that, wear-resistance should be correlated with the energy absorption of mechanically conditioned load - elongation curve. The greater the area under the mechanically conditioned load-elongation curve the higher the wear resistance.

It is recognized by Ruppenicker and et al., [6] that mobility of the yarns in the fabric is one of the necessary conditions required for increasing the durability of fabrics. Yarn mobility in the fabric is influenced by the yarn count, twist, fabric construction, weave, etc. It is known that fabric extensibility and crease recovery also depend on the yarn mobility, since one mechanical property of a fabric can not satisfactorily characterize fabric performance. By considering specific work of rupture, extensibility, bending modulus and crease recovery together, it could be possible to assess the wear performance of a fabric.

2. EXPERIMENTAL WORK

2.1 Fabric Used

A 100% cotton 2/2 z twill fabric of (240 - 260) gm/m2 with different average floats investigated previously by Barghash [2] was used. The fabrics were designed and woven from 20s/2 and 20s/1 as warp and weft threads of Ashmouni cotton fibres, with 66 ends/inch and (56 - 71) picks/inch varies from one structure to another, to obtain different twill angles. The base weave of the tested fabrics was 2/2 z twill. The fabrics of the 2/2 twill weave and the stepping (extensions) were woven on a dobby loom at average floats ranging from 2 to 6 in both warp and weft directions and tested in grey state according to the following designations:

a- 2/2 twill, ordinary;
b- 2/2 twill, 2 ends as one;
c- 2/2 twill, 2 picks as one;
d- 2/2 twill, 3 ends as one;
e- 2/2 twill, 3 picks as one;
f- 2/2 twill, 2 ends as one and 2 picks as one;
g- 2/2 twill, 3 ends as one end 2 picks as one;
h- 2/2 twill, 2 ends as one and 3 picks as one;
i- 2/2 twill, 3 ends as one and 3 picks as one.

Diagrams of the weaves are shown in Figure 1(a-i) .

2.2 Tensile Test

For each fabric tensile strength and elongation were carried out on ravelled specimens (30 x 5 cm) cut in both warp and weft directions. The specific strength (sp. work of rupture in g/tex) was calculated by dividing the energy to break fabric specimen by the product of the specimen length, width and fabric linear density. A mean value of 10 samples for both specific work of rupture and extensibility was obtained for each fabric.

2.3 Stiffness and Creasing Tests

The bending length was determined by the Shirley Standard Stiffness Tester using a specimen of 6 x 1 inch. For comparison between the stiffness of fabrics with different thickness, the bending modulus was calculated [7].

Crease recovery was measured on the Shirely Crease Recovery Tester using a specimen of 1 x 2 inch.

2.4 Thickness and Mass

The average value of thickness was obtained from 10 specimens for each fabric by using a dial gauge with 10cm2 foot and a pressure of 70 g/cm2. The mass per unit area was calculated as the mean value of ten samples each of 10 cm x 10 cm.

All tests were carried out in a standard atmosphere of 20 °C and 65% r.h. after a conditioning period of 24 hours.


Fig. 1(a)


Fig. 1(b)

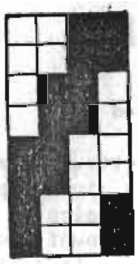


Fig. 1(c)

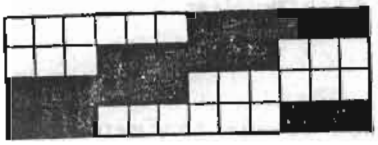


Fig. 1(d)

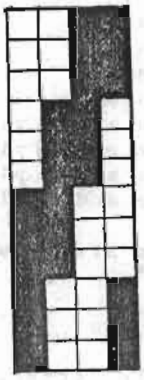
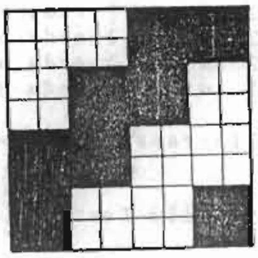


Fig. 1(e)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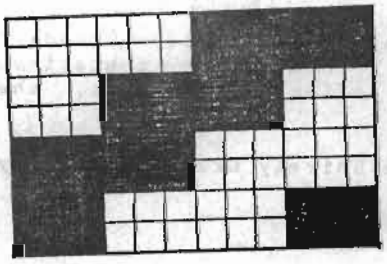
Fig. 1(g)

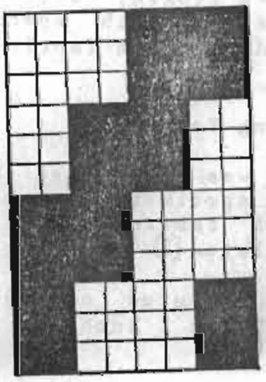
Fig. 1(h)

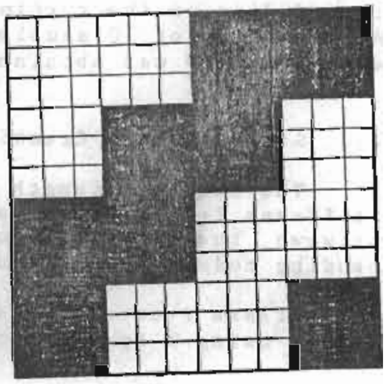
Fig. 1(i)

Fig. 1

Diagrams of the twill weave designs

3. RESULTS AND DISCUSSION

Table I shows the experimental results along with the fabric average float length in an increase order.

The fabric average float could be represented by the geometric mean of both warp and weft floats which can show the significance of individual readings and magnify the higher value and minimize the lower value to a wide range to be suitable for comparing the different samples.

3.1 Tensile Strength

Fig. 2 shows the decrease of specific work of rupture by the increase of fabric average float for the 2/2 twill fabric where the decrease of number of intersection points / unit area and the more laking in firmness by the increase of fabric average float could be the main reasons.

3.2 Breaking Extension

Fig. 3 shows the breaking extension for twill cotton fabrics with different float lengths.

Short float twill fabrics, as expected, show higher breaking extension than long float twill fabrics because the yarns crimp being much higher in the short float fabrics compared with the crimp in the long float fabrics, which are more straight than the yarns in the short float fabric.

It can also be noticed from the two previous figures that a 2/2 twill ordinary - fabric woven with shorter float length would give a better strength and consequently a better durability during use than a fabric woven with longer float length.

3.3 Stiffness

From Fig. 4 it could be seen that the increase of float length decreases the fabric stiffness. This can be related to the lower internal friction between yarns of long floats and the higher possibility of their mobility.

It can be deduced that weaving 2/2 twill fabrics with 6 average float length decreases the fabric stiffness by about 75%, which means that the fabric smoothness and handle are greatly affected.

3.4 Crease Recovery

Fig.5 shows the effect of fabric average float length on crease recovery, where a maximum value of crease recovery angle (117°) is obtained at fabric average floot of 3.5.

Table I
Experimental Results of Tested Fabrics

Fabric Symble	Float Length, F (number of threads) W	F	$\sqrt{F_w.F_f}$	Twill Angle, θ (degrees)	Threads/inch N: N1	N2	Crimp (%) C_1	C_2	Fabric Weight (g/m^2)	Fabric Thickness (mm)	Sp. Work of Rupture, S (g/tex) W	F	$\sqrt{S_w.S_f}$	Extensibility, E (%) W	F	$\sqrt{E_w.E_f}$	Bending Modulus, Q (Kg/Cm^2) W	F	$\sqrt{Q_w.Q_f}$	Crease Recovery, C (degrees) $(C_w+C_f)/2$
a	2	2	2.00	49.5	66	56	5.0	4.2	241	0.69	1.867	0.477	0.944	22.0	13.5	17.23	24.5	17.35	20.62	100.2
b	2	4	2.83	29.2	66	59	3.6	3.8	248	0.75	1.108	0.688	0.873	15.0	18.0	16.43	17.9	9.64	13.14	92.6
c	4	2	2.83	63.4	66	66	4.6	2.4	245	0.75	1.929	0.300	0.761	22.0	9.5	14.96	17.0	8.83	12.25	111.5
d	2	6	3.46	20.2	66	60	3.6	4.4	245	0.81	0.867	0.675	0.765	12.5	19.5	15.61	11.9	8.44	10.02	95.8
e	6	2	3.46	70.5	66	70	7.0	2.2	262	1.04	1.831	0.355	0.806	22.5	10.5	15.37	6.7	5.04	5.81	117.5
f	4	4	4.00	45.1	66	66	4.8	3.4	248	0.82	1.181	0.453	0.731	15.0	13.5	14.23	10.3	5.60	7.59	105.6
g	4	6	4.90	35.4	66	62	3.4	3.6	243	0.83	1.093	0.294	0.567	14.5	14.5	14.5	9.1	6.90	7.94	109.4
h	6	4	4.90	54.3	66	71	3.8	3.4	249	0.89	1.200	0.427	0.716	15.5	12.5	13.92	6.4	3.82	4.95	99.0
i	6	6	6.00	43.7	66	69	3.0	2.8	257	0.89	1.049	0.408	0.654	14.5	12.5	13.46	3.8	7.01	5.18	99.9

N.B.: W and F denote warp and weft directions respectively.

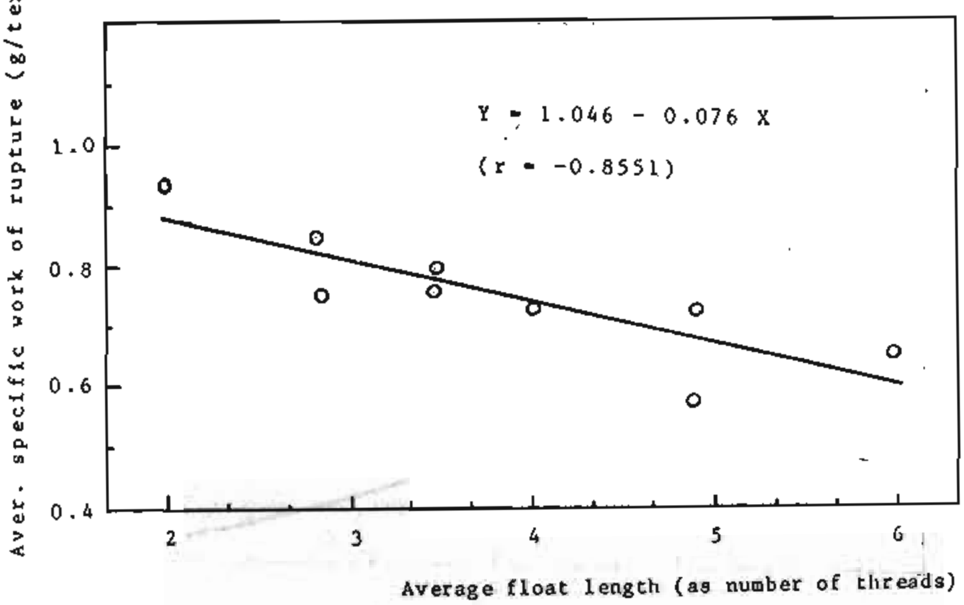

Fig. 2

Effect of the average float length on specific work of rupture

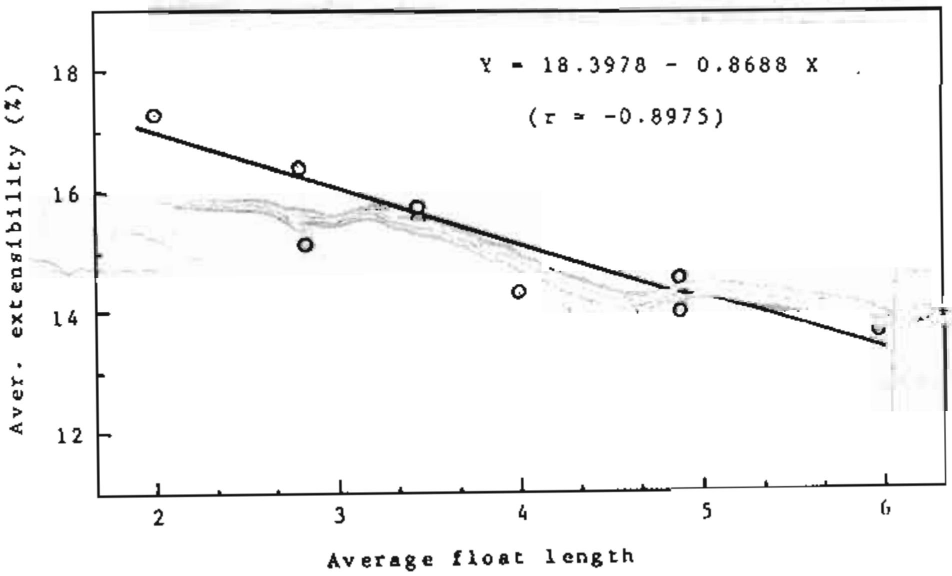

Fig. 3

Effect of the average float length on extensibility

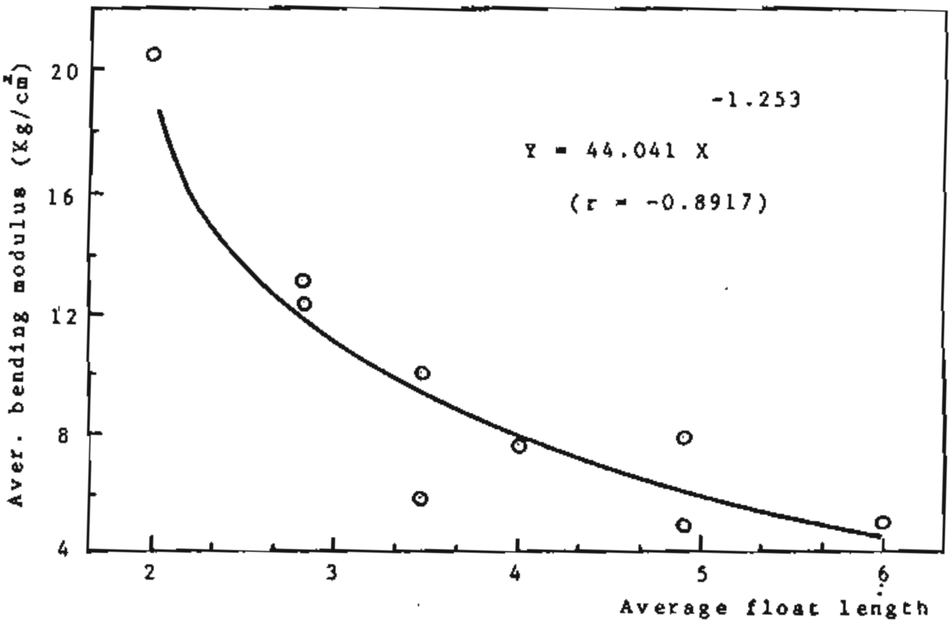

Fig. 4

Effect of the average float length on bending modulus

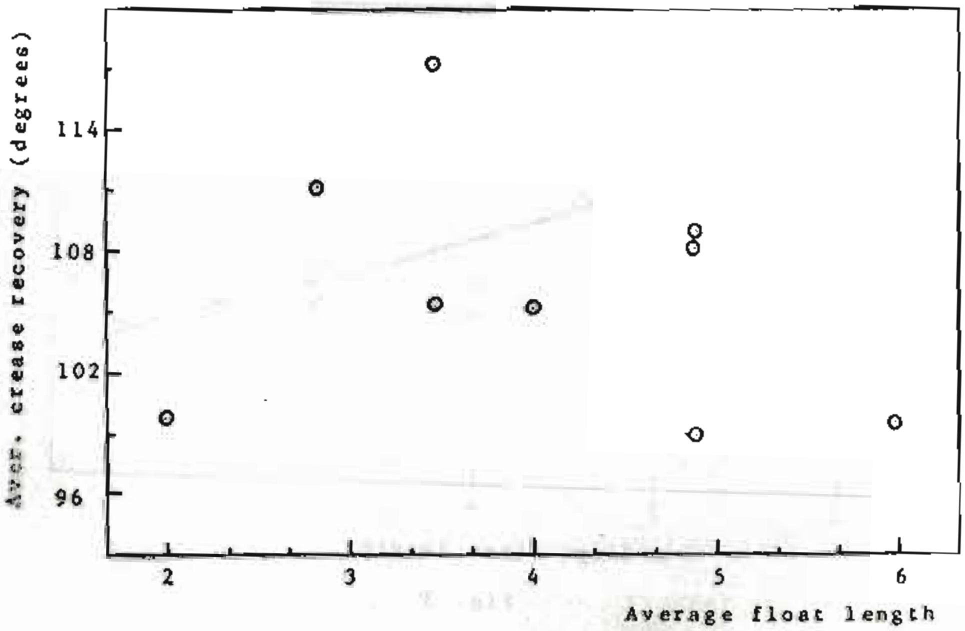

Fig. 5

Effect of the average float length on crease recovery

The larger radius of curvature of thicker fabric during bending and consequently lower strains to which the fibres are subjected may lead to an increase of crease recovery.

The relation between the previous properties and the measured fabric constructional factors could be evaluated by using linear multiple regression in the form of the following equation:

$$Y = a + b\,X1 + c\,X2 + d\,X3 + e\,X4, \qquad \ldots(2)$$

where X1 - the geometric mean of float length in both warp and weft directions;
X2 - Sum of the warp and weft threads/inch;
X3 - Weight per unit area. g/m2;
X4 - Fabric thickness, mm;
Y - Mean value of fabric property in both warp and weft directions.
a,b,c,d, and e - Constants.

Mathematical analysis of the results was done on an Apple I microcomputer.

Table II shows the computed constants in Equation (2). However the values of the regression coefficients in Table II show particular trend in mangitude with respect to fabric specific work of rupture, extensibility, bending modulus and crease recovery respectively. With respect to all mechanical properties investigated, it was found that the regression coefficients associated with fabric thickness had very high values. Also values of the partial correlation coefficient obtained for all the investigated properties are given in Table III. Therefore, the calculated values from Equation (2) could be compared with the measured ones as in Figures 6 to 9.

Table II
Values of Regression Coefficients in Equation(2)

Property	a	b	c	d	e
Sp. work of rupture	-1.3101	-0.0782	-0.0049	0.0139	-0.5542
Extensibility	27.383	-0.5957	-0.2173	0.0634	2.9302
Bending modulus	33.459	-1.7595	-0.3663	0.2149	-27.5162
Crease recovery	120.343	-2.1198	0.4951	-0.4953	59.7832

Table III
Values of Partial Correlation Coefficient in Equation (2)

Property	X1	X2	X3	X4
Sp. work of rupture(Y1)	-0.9283	-0.4431	0.8278	-0.6238
Extensibiliy (Y2)	-0.9313	-0.9464	0.6703	0.4933
Bending modulus (Y3)	-0.7608	-0.6085	0.4291	-0.6371
Crease recovery (Y4)	-0.3102	0.2329	-0.2453	0.3833

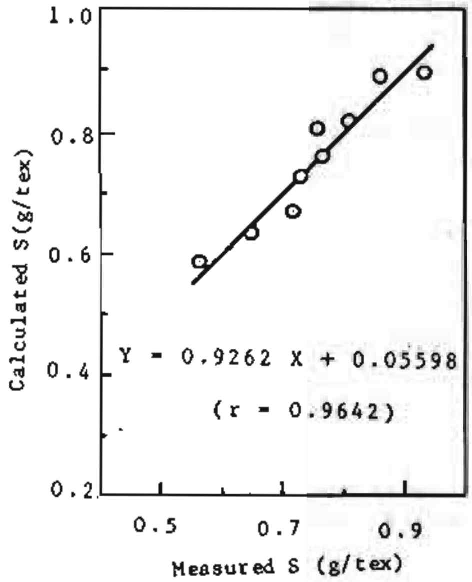

Fig. 6

Specific work of rupture of fabrics

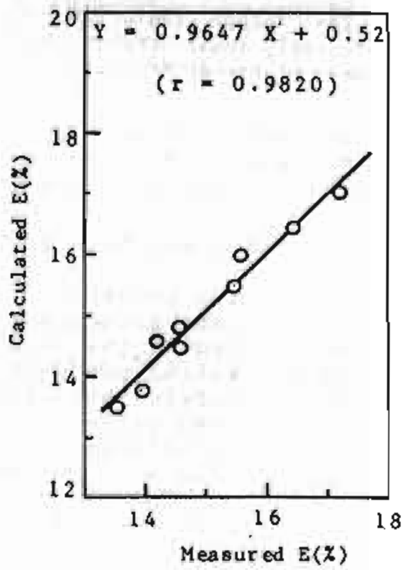

Fig. 7

Extensibility of fabrics

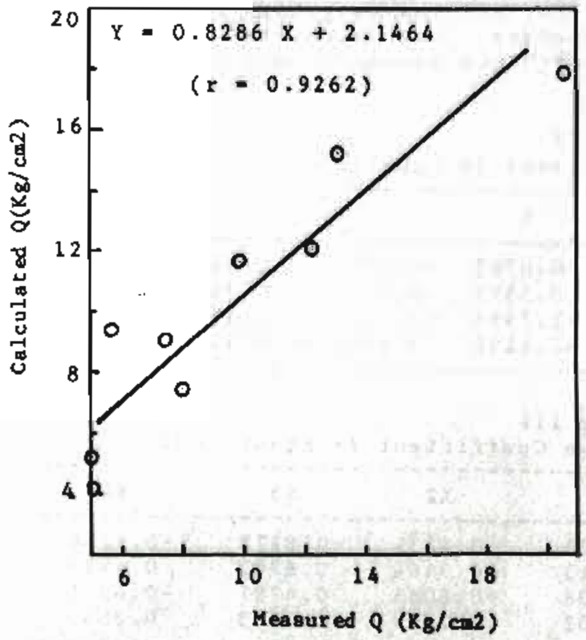

Fig. 8

Bending modulus of fabrics

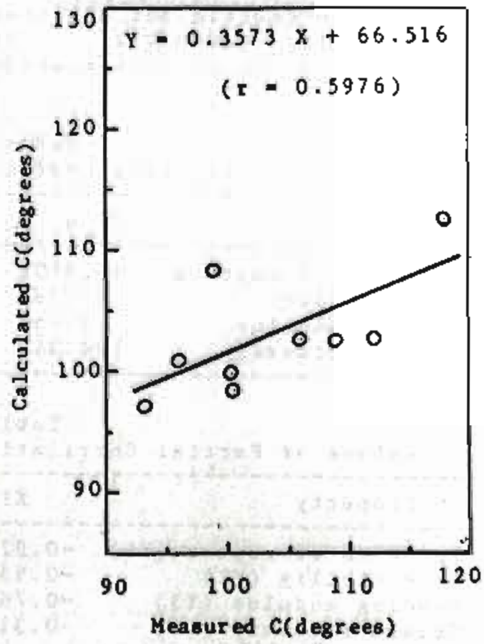

Fig. 9

Crease recovery of fabrics

This analysis shows that the end use performance of 2/2 twill cotton outerwear fabrics can be predicted from a knowledge of its fabric average float, sum of the warp and weft threads per unit length, fabric weight and thickness as shown in Figures 6 to 9.

However, serviceability of twill cotton outerwear fabrics can be assessed by taking into account specific work of rupture, extensibility, bending modulus and crease recovery.

The inclusive assessment of the end use performance of the tested fabrics could be estimated by using the relative characteristics method of the quality[8].

The relative characteristics of the quality of cotton outerwear fabrics could be calculated from Equation (3) (for positive characteristics).

$$Kj = \frac{Xi}{Xmax} , \qquad \ldots(3)$$

where Kj - relative characteristic of the quality for j-property;
Xi - individual readings of each property for i-fabric sample;
Xmax - maximum value of the same property.

This method can be represented from a knowledge of number of properties (n) in the inclusive assessment, which start from the same point and make an angle $2\pi/n$ between them. And the coordinates can be joined and a polygon can be obtained as shown in Fig. 10.

For the inclusive assessment of the quality the area of this polygon could be caculated from Equation (4) and the results are given in Table IV.

$$A = 1/2 \ \sin 2\pi/n \ (K1\ K2 + K2\ K3 + K3\ K4 + K4\ K1), \qquad \ldots(4)$$

where A - polygon area;
n = 4 - number of the measured properties.

Teble IV
The Inclusive Assessment of Serviceability for Twill Cotton Fabrics

Fabric Symble	Aver. Float length (as number of threads)	Relative Characteristics of Quality				Polygon Area
		K1	K2	K3	K4	A
a	2.00	1.0	1.0	1.0	0.899	1.899
b	2.83	0.925	0.954	0.637	0.788	1.361
c	2.83	0.806	0.839	0.594	0.949	1.252
d	3.46	0.810	0.906	0.486	0.815	1.115
e	3.46	0.854	0.892	0.282	1.0	1.075
f	4.00	0.774	0.826	0.368	0.853	0.959
g	4.90	0.601	0.842	0.385	0.931	0.874
h	4.90	0.758	0.808	0.240	0.843	0.824
i	6.00	0.693	0.781	0.251	0.850	0.770

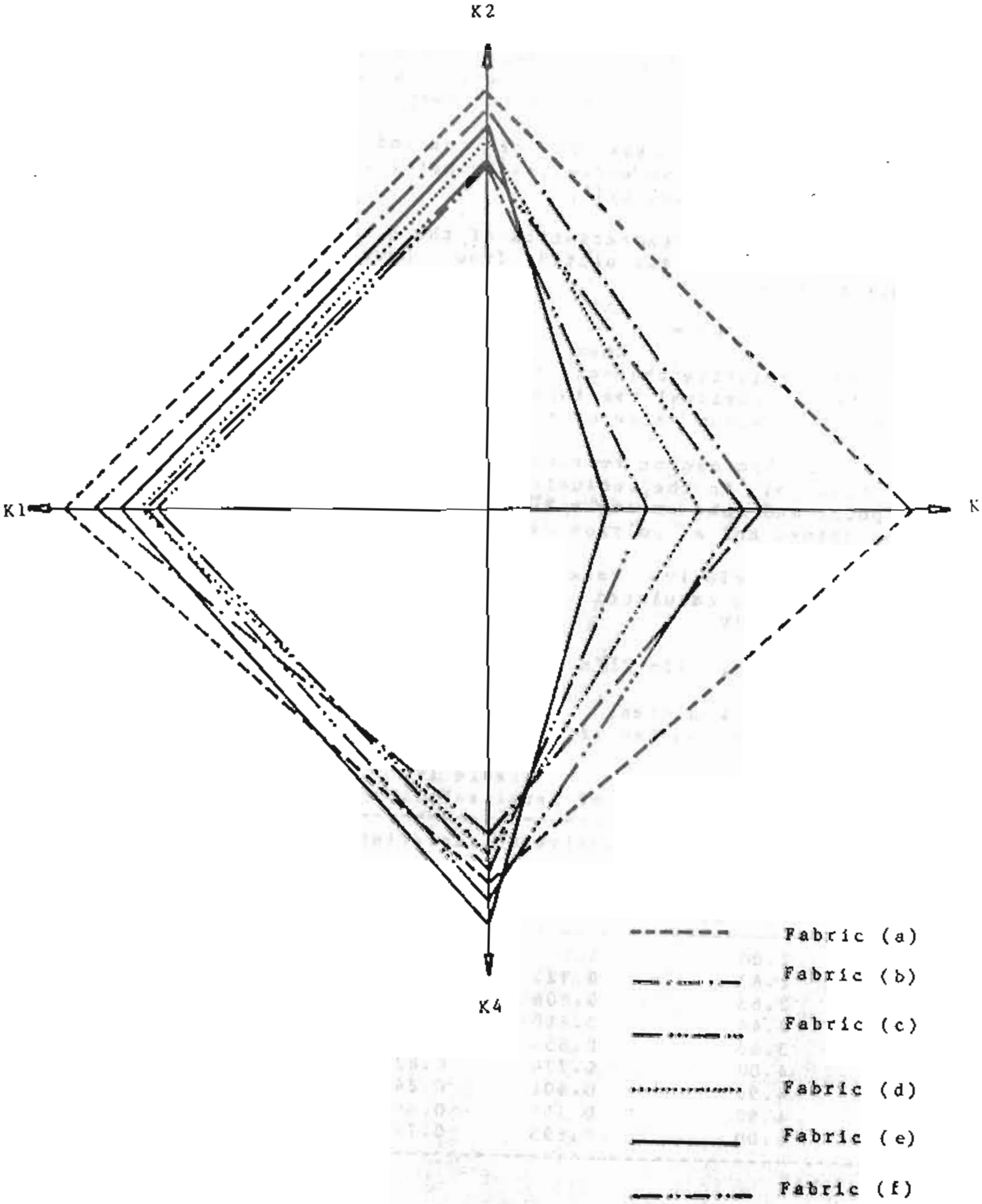

Fig. 10

" Quality polygons " for some of the investigated fabrics

From analysis the data in Table IV, it could be observed that the first fabric (a) of the lowest average float has the highest serviceability compared with the other structures. The same method could be used for predicting wear-resistance of the twill outerwear cotton fabrics.

4. CONCLUSION

From the above analysis the following conclusions can be drawn:

1- The investigated mechanical properties of the 2/2 twill cotton fabrics woven with different fabric average float lengths have been shown to be well related to the average float length, sum of the warp and weft threads per unit length, fabric weight and thickness.

2- The geometric mean of both warp and weft floats as an aspect of weave design was found to be the main factor in assessing the quality of the investigated fabrics besides its twill angle.

3- By using polygon area method, it was found that 2/2 Z twill with the smallest float length gives the best outerwear properties of medium weight cotton fabrics such as durability, stiffness and crease recovery.

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