Mansoura Engineering Journal

Volume 14 | Issue 2 Article 30

5-26-2021

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Recommended Citation
Abou- Taleb, Hemdan (2021) "Improvement of Servicability Properties of Egyptian Military Fabrics.," *Mansoura Engineering Journal*: Vol. 14 : Iss. 2 , Article 30.
Available at: https://doi.org/10.21608/bfemu.2021.172509

IMPROVEMENT OF SERVICABILITY PROPERTIES OF EGYPTIAN MILITARY FABRICS

تحسين خواص الخدمه للأقمشة العسكرية المصرية

By

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خلاصه – فى هذا البحث أجريت محاوله للتعديل فى التركيب الأنشائى للاقشمة التى تصنع منها الملابس الخارجيه للجنود بغرض زيادة عمر خدمتها . هذا التعديل أمكن تحقيقه عن طريق معرفة العوامل الانشائيه المثاليه للقماش مثل الماده الخام المستعمله فى خيوط اللحمه، نمرة خيط اللحمه، كثافة الحدفات والتصميم النسجى . الخواص الميكانيكيه التى تم دراستها والمتعلقه بالاستعمال النهائى للملابس الخارجيه للجنود هى اجهاد القماش نتيجة للاستطالة المتكرره، خواص ترييح القماش بعد الاستطاله، تحمل القماش للثنى المتكرر، حمل الشد واستطالة القطع للاقمشة، مقاومة القماش للتآكل والثنى معا وصلابة القماش عند الثنى . الموديلات الرياضيه التى تصف هذه الخواص أمكن الحصول عليها – بأستخدام طريقة تصميم التجارب – للتنبوء بخواص الخدمه لنوع معين لملابس الجنود الخارجيه الصيفيه . بأستعمال الطريقه البيانيه والطريقه الرياضيه وجد أن التركيب الأنشائى الأمثل لاحد أنواع الاقمشه المستعمله لصناعة الملابس الخارجيه للجنود يوصى بأن يحتوى على خيوط لحمه نمره ٢/٥٢ انجليزى مخلوطه من القطن والبولى أستر بنسبة ٥٠٪ لكل منهما بأستعمال ٦٠ حدفه فى البوصه مع تركيب نسجى مبرد ٢/١ وذلك مع استعمال مواصفات السداء للصنف رقم ٢٥٠٩ .

ABSTRACT- In this paper an attempt has been made to modify the construction of one type of fabrics which are used to make outer wear cloths for soldiers in order to increase its service life. This modification could be achieved by means of knowing the optimum constructional factors of fabrics such as material used for weft yarns, weft yarn linear density, pick density and weave design (average float length). The investigated mechanical properties that correlated with the end-use performance of the outer wear cloths of soldiers are fabric fatigue at repeated extension, relaxation characteristics of fabrics at extension, fabric endurance to repeated flexing, tensile load and extensibility of fabrics, flexing and abrasion resistance of fabrics and stiffness at bending. Mathematical models describing these properties could be obtained, by using factorial design method, for predicting the service life behaviour of military fabrics. By using both the graphical and mathematical methods, it was found that the optimum fabric construction to make outer wear cloths for soldiers is recommended to be contained weft blended yarns (50% cotton/ 50% polyester) of 52/2 Ne (11.36 x 2 tex) at 60 picks/inch with using twill 1/2 weave design and with using warp specifications of article No. 2509.

1. INTRODUCTION

Fabrics which are used to make outer wear cloths for soldiers during training and battle fields are exposed in many cases to extra stresses-especially at the elbow, knee, collar, sleeve and sitting place-than the same fabrics used in civil services, this of course, leads to a great reduction in the actual lifetime of these garments.

Although military fabrics are widely used in the army as an outer wear cloths for soldiers, no work has yet been carried out to design or modify these military fabrics. The military fabrics must suit product specifications for the resistance to repeated extension, repeated flexing and abrasion and creep-recovery properties, absorbed energy in tensile deformation and limpness. These product properties are correlated to a large extent by the material used, pick density, yarn structure and weave design.

Any attempts to modify the construction of these fabrics to suit the inviormental conditions and nature of end-uses will lead to increase the service life of these garments, and consequently to reduce the yearly consumption of these fabrics.

The purpose of the study reported in this paper was to modify the construction of the military fabrics which are used to make outer wear cloths for soldiers to increase its service life by means of knowing the optimum constructional factors of these fabrics.

When designing a fabric to suit specific product demands, it is fairly easy to suit any one of the demands. But suiting two or more demands makes the problem difficult enough to consider a mathematical treatment.

2. FABRICS PRODUCED AND EXPERIMENTAL DESIGN

Misr Spinning & Weaving Co. in El-Mehalla El-Kubra produces three different articles of military fabrics used to make outer wear cloths for soldiers with the following specifications:

Article Fabric Characteristics	No. 2509	No. 2605	No. 2653
	Warp/weft	Warp/weft	Warp/weft
Yarn count (English)(Ne)	30/2 x 30/2	30/2 x 30/2	30/2 x 30/2
Type of fibre	50% P* /50% C** (in both)	100% cotton	50% P/50% C (in both)
No. of threads per inch	96.5 x 52	82 x 42	96.5 x 52
Weave design	twill 1/2	plain 1/1	twill 1/3

* P- polyester fibres, ** C- cotton fibres.

However, it is necessary to determine the optimum constructional factors of these fabrics. For studying the wear problem of these fabriics the first article No. 2509 was basicly selected with changing its specifications only in weft direction according to the next experimental plan. The experimental plan that was used was fractional factorical design [1] of four variables at two levels, namely, -1 and +1.

The response Y is given by a second-order polynomial, i.e.:

$$Y = bo + \sum_{i=1}^{k} bi\ Xi + \sum_{i,j=1}^{k} bij\ \ Xi\ yi,$$

where Xi = i th variable.
k = number of variables, and
bo, bi and bij = regression coefficients associated with the variable.

In order to determine the regression coefficients, the response Y had to be found by using different experimental combinations of the variables under consideration. For the case of four variables, the actual levels of the variables are given in Table I and the experimental plan is given in Table II.

Table I: Levels of Studied Variables.

Level Variable	Minimum -1	Centre point 0	Maximum +1
X_1 = yarn count (English) (Ne)	20/2	40/2	60/2
X_2 = cotton percent in the blend (%)	100	75	50
X_3 = pick density (picks/inch)	40	50	60
X_4 = average float length (weave design)	1 (plain 1/1)	1.5 (twill 1/2)	2 (twill 1/3)

Table II: Experimental Plan for Four Variables.

No.	Levels of Variables			
	X_1	X_2	X_3	X_4
1	-	-	-	-
2	+	-	-	+
3	-	+	-	+
4	+	+	-	-
5	-	-	+	+
6	+	-	+	-
7	-	+	+	-
8	+	+	+	+

3. METHODS OF FABRIC TESTING

The fabrics produced in El-Mehalla Co. were tested in the laboratories of Science of Textile Materials Dept. (Moscow Textile Institute) in order to determine the most important properties such as fabric fatigue at repeated extension, relaxation characteristics of fabrics at extension, fabric endurance to repeated flexing, tensile load and extenibility to breakage of fabrics, flexing and abrasion resistance of fabrics and fabric stiffness at bending.

3.1 Fabric Fatigue at Repeated Extension:

Fabric fatigue at repeated extension was tested by the pulsator PD-5M shown in Fig. 1 designed by Prof. A. Koblyakov in Moscow Textile Institute, Dept. of science of textile materials. This instrument allows testing for repeated extension of five fabric specimens 0.1 - 5 mm thick simultaneously. The instrument has a high sensitivity and the maximum error in deformation, 0.02 mm. The tests were carried out with the following conditions:

- Diameter of changeable semispherical punches for deformation of specimens, mm	50
- Frequency of repeated deformation, cycles per minute	50
- Number of deformation cycles, cycles	5000
- Static load on the specimen, grams	10
- Cyclic amplitude, mm	4

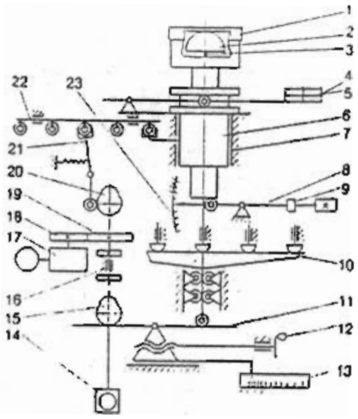

Fig. 1: Diagram of pulsator PD - 5M

The instrument (Fig. 1) has clamping units for specimen 1, locks 6 in guides 7, the loading arrangement 5 with change weights 4, the balancing arrangement 8 with weights 9, pushers 2 of semispherical shape mounted on rods 3 which rest on cross-piece 10 which interacts with the amplitude adjuster 11. The latter is kinematically connected with cam 15 of the distributing shaft 16 which carries also the cam 20 and ensures the control of lock 6 by means of the lever 21 and rod 22.

The instrument is also provided with a worm drive 17 kinematically connected through a couple of gears 18 and 19 with the distributing shaft 16, the scale of cyclic amplitude 13, the scale of residual deformation 23, the counter unit 14 and the counters of deformation cycles (not shown in the drawing).

The specimens are deformed by the pusher 2 with rod 3 which is moved in action by the displacement of cross-piece 10 with the closed ball lock. When the pusher reaches the maximum amplitude unloading and rest of specimens start. Then, the ball lock disengages the bush, which ensures the take-up of residual cyclic deformation. In the ball lock there is a skew bushing which in rotating makes the balls out of engagement with the power bushing. The rotation is effected by rod 22 displaced by lever 21 which is moved by cam 20.

When operating, the amplitude is adjusted by means of mechanism 11. The value of amplitude is registered on scale 13. At the same time, on the loading arrangement 5 a maximum load is set by means of change weights 4.

Prior to starting the tests adjust the amplitude by turning the knob 12 (See Fig. 1) up to the required division on scale 13, the deformation freauency by changing the gears 18 and 19, and the required number of deformation cycles.

This later process is automatic and performed as follows. Press the knob of the cycle counters (not shown in the drawing) and turn it counterclockwise. Holding the knob on the general counter 14, set the number of deformation cycles by pushing the button of this counter.

Mounting of specimens in the clamp is made as follows. A 100 - mm diameter specimen is placed between clamping rings, inserted into a sleeve and fixed with a nut. The clamp with the specimen is placed in a special seat, the clamping nut is tightened with a wrench, placed on the power bushing and fixed with a union nut. A static tension load is placed on the clamps, the instrument is switched on and the readings of the residual cyclic deformation are taken on the scale 23. The results obtained of residual cyclic deformation are shown in Table III.

3.2 Relaxation Characteristics of Fabrics at Extension

For evaluating the shape retention of fabrics it is important to study their relaxation characteristics at extension. For testing the fabrics for single-cycle extension (creep-creep recovery properties), A. Koblyakov and V. Osipov have designed a new unified tester PRTP.

Figure 2 shows the general view of this the instrument. The fabrics could be tested on this instrument with the following conditions:

- Gauge length, mm	100
- Width of the tested specimen, mm	50
- Constant load, % age of breaking load	5
- Loading time, min	60
- Relaxation time after unloading, min	60
- Time from unloading to first reading, sec.	2-5
- Number of the tested specimens	10

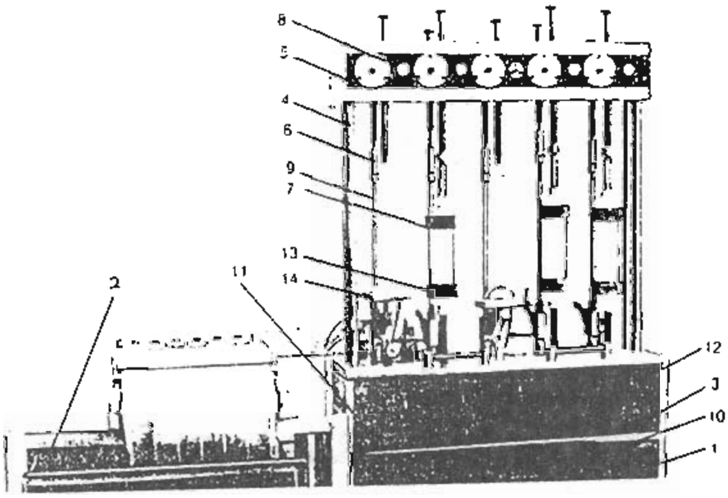

Fig. 2: Tester PRTP.

1- Power unit; 2- control unit; 3- housing; 4- stands; 5- cross-piece;
6- multiplier; 7- working clamp; 8- control handle; 9- rods;
10- scale; 11- control switch; 12- scale; 13- non-working clamp (at uniaxial extension); 14- clamp at double-axial extension.

The equations for calculating the component parts of deformation are given below:

total deformation (ε), %

$$\varepsilon = (L_1 - L_0)/L_0 \times 100$$

instantinuous (quickly recoverable deformation ε_1, %)

$$\varepsilon_1 = (L_1 - L_2)/L_0 \times 100$$

elastic (slowly recoverable deformation ε_2, %)

$$\varepsilon_2 = (L_2 - L_3)/L_0 \times 100$$

permenant (non-recoverable deformation ε_3, %)

$$\varepsilon_3 = (L_3 - L_0)/L_0 \times 100$$

Where L_0 is the initial (gauge) length of the tested specimen; L_1 is th length of the specimen in the last measurement under load; L_2 is the length of specimen immediately (from 1 to 2 sec.) after removal of load L_3 is the length of specimen in the last measurement of deformation afte removal of load (at rest).

However, the recoverable deformation ($\varepsilon_1 + \varepsilon_2$) are determined at a constant load (5% of breaking load). The results obtained of the rec overable deformation are shown in Table III.

3.3 Fabric Endurance to Repeated Flexing

The resistance of military fabrics to destruction during use depends on many factors, among which the repeated flexing. It causes the fatigne of the material resulting in the local change of fabric structure and progressive deterioration of its properties. For assessing the fabric resistance to repeated flexing the term of endurance was used. The number of bending cycles which the material withstands up to its destruction is known as endurance.

Resistance of fabrics to repeated flexing is determined in flex testers. The automatic flex tester for fabrics is used for transversal destruction of fabric specimens at the fold. The tester can be used for testing three specimens simultaneously. The tester operates on the principle of transformation of the motor shaft rotation through a crank gear into oscillatory motion of the lop jaws. The specimen 3 (Fig. 3), as a strip 10 mm wide is fixed in the jaws 2 and 4. The screw 1 reliably fixes the specimen in the top jaws which, effecting oscillatory motion with a speed of 100 cycles per minute, can bend the specimen bel the line of its clamping. A static load is suspended from the lower ja 4 by means of weights 5. The used static load was 25% of breaking loac Each couple of jaws is equipped with electrical pulse counters for recc rding the number of bends. The counters are switched by means of electric magnet control contacts.

After the readings are taken, the counters are set to zero.

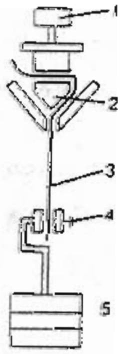

Fig. 3: Schematic diagram of flex tester.

When the specimen is mounted in the jaws, the instrument front panel is closed with a cover and the switch is turned on. The signal lamp goes up, thus indicating that the instrument is ready for work. The The instrument is stopped at the breakage of the last specimen and also when the cover is opened.

The endurance of the specimen greatly depends upon such testing parameters as the angle and radius of bending, static stretching load and width of the specimen.

The tests were carried out with the following conditions:

- Angle of bending, degrees	180
- Radius of bending, mm	0.05
- Width of the tested specimen, mm	10
- Static load on the specimen, % age of the average breaking load	25

The results of enducrance are shown in Table III.

3.4 Specific work of Rupture in Tensile Deformation

Fabric specific work of rupture is given by [2] , as:

Fabric sp. work of rupture in g(f)/tex =

$$= \frac{\text{energy to break specimen in g(f).Cm}}{\text{area density of fabric in g/m}^2\text{ X specimen width in mm X specimen length in cm}}$$

The specific work of rupture (absorbed energy) in the fabric gives a useful comparative value of the fabric resistance to breakage as a result of repeating loading cycles. The absorbed energy in each fabric specimen could be obtained from the above expression. The results obtained are shown in Table III.

3.5 Flexing and Abrasion Resistance of Fabrics

Wear is a process occurring in time under the action of some factors causing its destruction. The ability of the material to resist destruction is called wear resistance. Abrasion is one of the most largely encountered kind of wear, as a result of which a considerable part of the material is lost under the action of friction. The capacity of the material to resist destruction due to abrasion is called the abrasion resistance [3] .

The fabrics were tested by means of Flexing and Abrasion Tester shown in Fig. 4 following ASTM standard methods [4] . For testing the abrasion, the following conditions were used: tested specimen 8 in. long and 1 in. wide after ravelling; number of specimens from each sample, 10; pressure on abradant plate, 2 lb; fabric strip under a tension of 5 lb using unidirectional abrasion to automatic end point.

When the specimen is completely abraded the instrument is automatically stopped and the number of cycles is recorded on the counter. The results obtained are shown in Table III.

3.6 Fabric Stiffness at Bending

Stiffness is the ability of fabrics to resist changes in their shape at bending deformation and it affects their draping capacity, i.e. the ability to form soft rounded folds with a small radius of curvature[3].

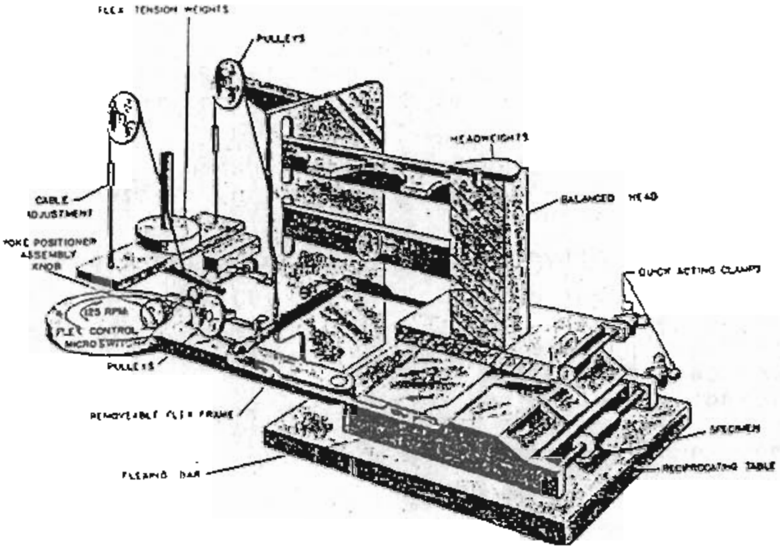

Fig. 4: Schematic diagram of flexing and abrasion tester.

The fabric stiffness is determined on a flexibility tester by the cantilever method. The tested specimen 1 (Fig. 5) is symmetrically placed with the face upwards on a horizontal supporting platform 3 and fixed in place by a weight 2. When the switch 8 is cut in the mechanism 7 smoothly and uniformly lowers the movable side shelves of the platform, thus imparting a flexural deformation to the test specimen. From the moment of its seperation from the platform the specimen flexes under the action of its own weight. When the side shelves are completely lowered, the deflection indicator 5 is displaced upwards by screw 6, noting on scale 4 the deflection f of both sides of the specimen with a precision up to 1 mm. Ten specimens of 160 x 30 mm in size are cut in weft direction for each sample according to the standard method.

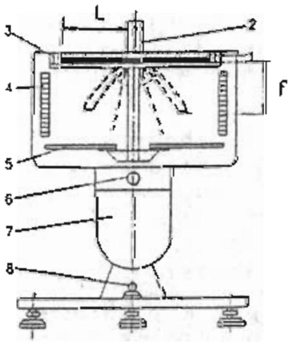

Fig. 5: Diagram of a flexometer for determining stiffness of fabrics at bending.

The relative deflection is calculated by the formula;

$$f_o = \frac{\bar{f}}{L} \times 100$$

Where $\bar{f}$ is the average deflection of tested specimens, cm;
L is the length of the hanging-down ends of the tested specimen, equal to 7 Cm (see Fig. 5). The results of relative deflection are listed in Table III.

Table III: Experimental Data.

No.	RCD*	Recoverable deformation (%)	Endurance (cycles)	Sp. work of rupture (g(f)/tex)	Flex & Abrasion resistance (cycles)	Relative deflection (%)
1	7.33	1.19	607	0.8462	2239	22.857
2	8.65	1.86	623	0.2329	312	93.214
3	9.51	2.28	1653	0.8842	1915	69.214
4	9.05	1.07	731	0.4171	866	86.107
5	8.46	2.47	415	1.0860	2942	37.465
6	8.00	0.80	863	0.3180	1713	59.463
7	7.50	1.13	2921	0.9742	2121	29.823
8	7.64	2.80	782	0.7015	1779	84.570

* RCD = residual cyclic deformation at repeated extension, mm.

4. RESULTS AND DISCUSSION

4.1 Experimental Analysis

The results obtained for residual cyclic deformation; recoverable deformation; endurance; specific work of rupture; flexing and abrasion resistance and relative deflection in Table III were fed to an U.K. 101 computer, and regression coefficients were determined. The coefficients were tested for significance at the 95% significance level. Only significant terms were taken into consideration for a further analysis of the results. The response-surface equations for the various fabric characteristics are given in Table IV with the correlation coefficients between the experimental values and the calculated values obtained from the response-surface equation. The response surface agrees fairly with the experimental data, as can be seen from the high correlation coefficients. Contour maps were constructed by using the response-surface equations as shown in Figures 6 - 17.

4.2 Graphical Method

Figures 6, 8, 10, 12, 14 and 16 are contour plots of each property on two or three dimensions represent two or three variables in a two-dimensional space when X2 = +1 (material used 50% P/50% C). But Figures 7, 9, 11, 13, 15 and 17 are contour plots of each property when X2 = -1 (material used 100% cotton). The plots show how the studied properties behave within the limitation of the tested materials.

The problem of improving the servicability properties of military fabrics could be solved by overlaying the graphs (Figures 6, 8, 10, 12, 14 and 16) of the response - surfaces together as shown in Fig. 18. Overlaying the graphs (6, 8, 10, 12, 14 and 16) when X2 = +1 (50 P/50 C) is prefered to overlaying the graphs (7, 9, 11, 13, 15 and 17) when X2 = -1 (100% cotton) because when X2 = +1, the best servicability properties can be achieved. In Fig. 18 if the value of residual cyclic deformation was equal to 7.6 mm and downward and % age recoverable

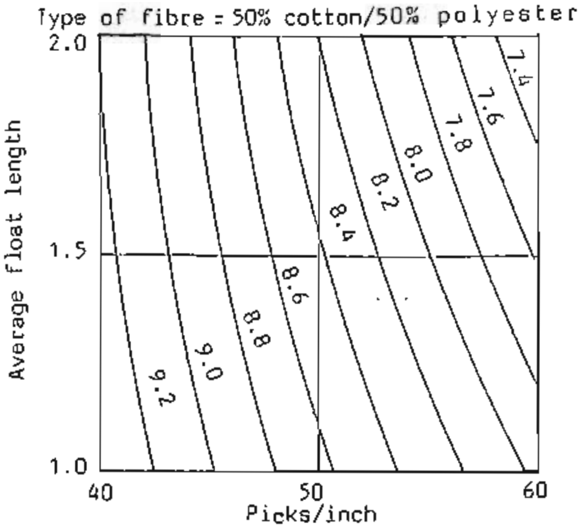

Fig. 6: Contours for residual cyclic deformation(mm).

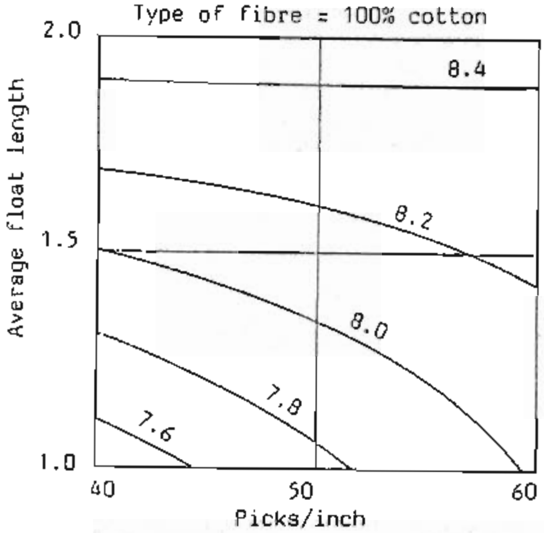

Fig. 7: Contours for residual cyclic deformation(mm).

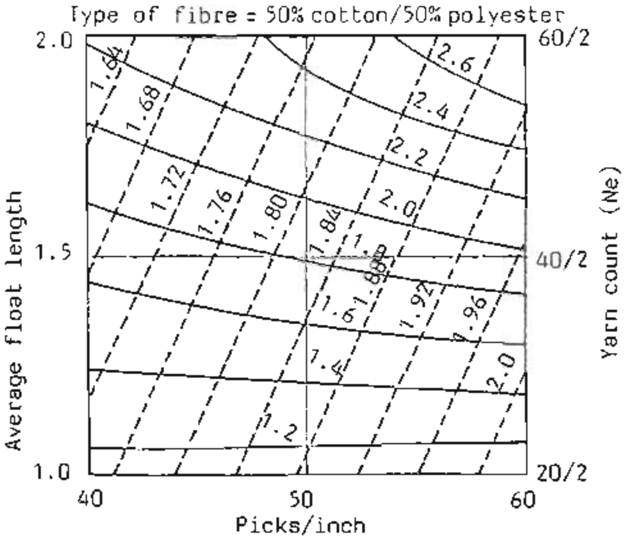

Fig. 8: Contours for recoverable deformation (%)

Float length ——— Cross section of (X_3-X_4) at $X_2=+1$, $X_1=0$
Yarn count ------- Cross section of (X_3-X_1) at $X_2=+1$, $X_4=0$

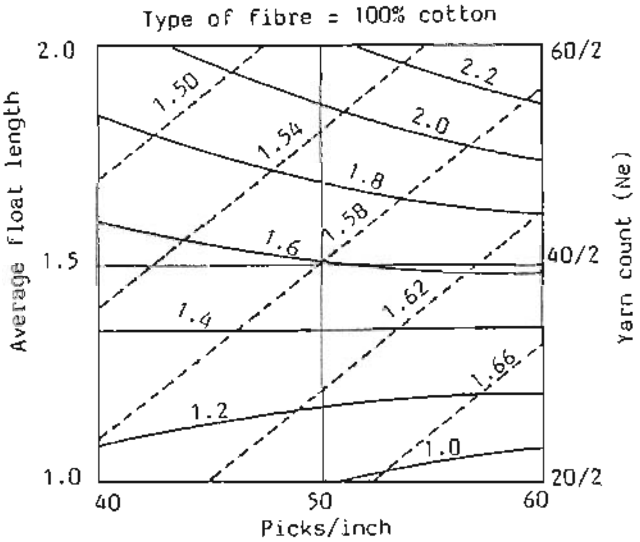

Fig. 9: Contours for recoverable deformation (%).

Float length ——— Cross section of (X_3-X_4) at $X_2=-1$, $X_1=0$
Yarn count ------- Cross section of (X_3-X_1) at $X_2=-1$, $X_4=0$

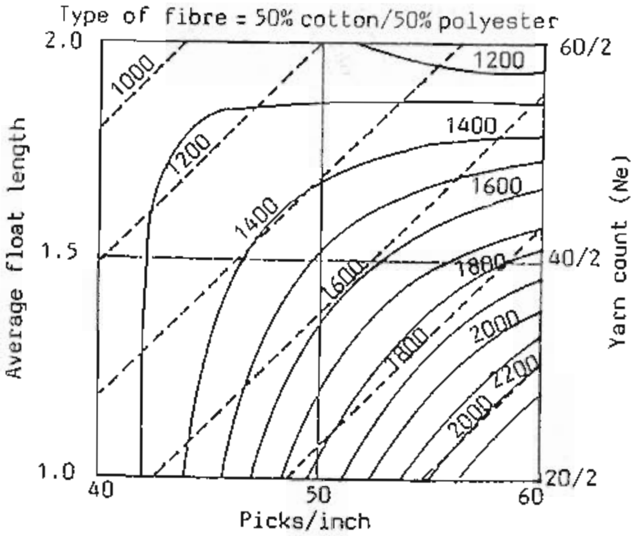

Fig. 10: Contours for endurance (Cycle)

Float length ——— Cross section of (X_3-X_4) at $X_2=+1$, $X_1=0$

Yarn count - - - - - - - - Cross section of (X_3-X_1) at $X_2=+1$, $X_4=0$

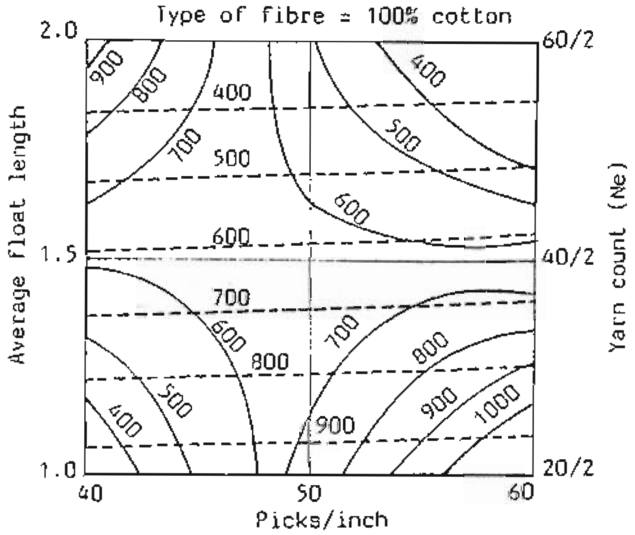

Fig. 11: Contours for endurance (Cycle).

Float length ——— Cross section of (X_3-X_4) at $X_2=-1$, $X_1=0$

Yarn count - - - - - - - Cross section of (X_3-X_1) at $X_2=-1$, $X_4=0$

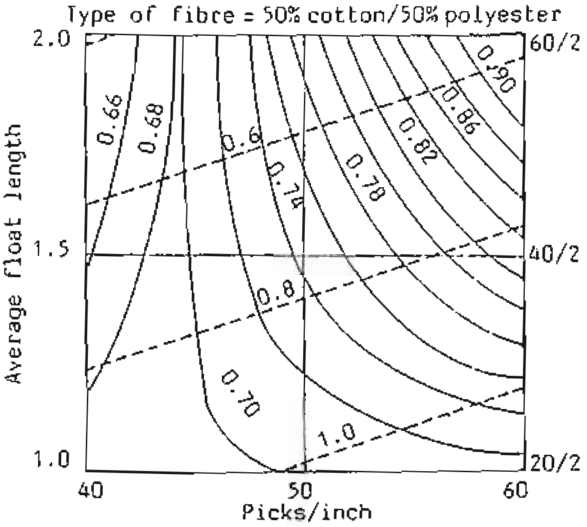

Fig. 12: Contours for specific work of rupture (gf/tex).

Float length———— Cross section of (X_3-X_4) at $X_2=+1$, $X_1=0$

Yarn count -------- Cross section of (X_3-X_1) at $X_2=+1$, $X_4=0$

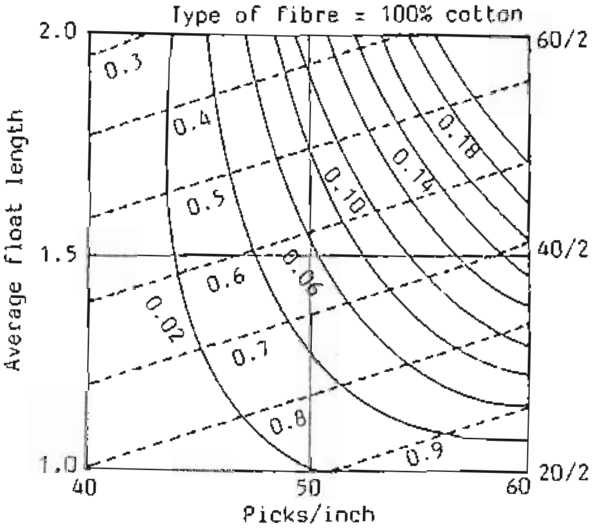

Fig. 13: Contours for specific work of rupture (gf/tex)

Float length———— Cross section of (X_3-X_4) at $X_2=-1$, $X_1=0$

Yarn count -------- Cross section of (X_3-X_1) at $X_2=-1$, $X_4=0$

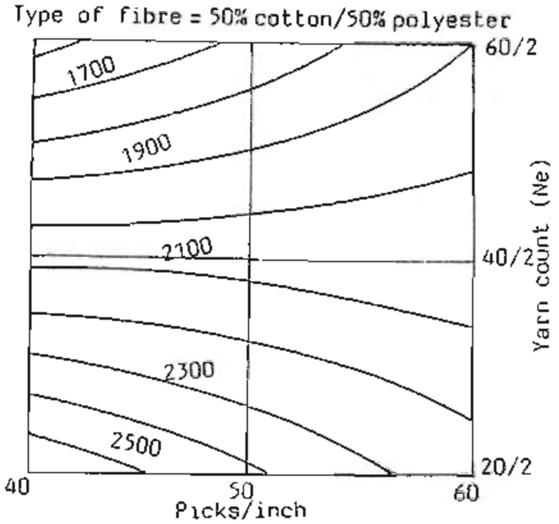

Fig. 14: Contours for flex & abrasion resistance (Cycle).

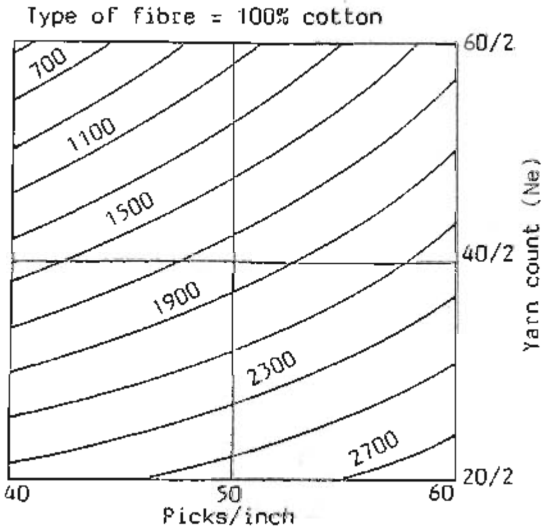

Fig. 15: Contours for flex & abrasion resistance (Cycle).

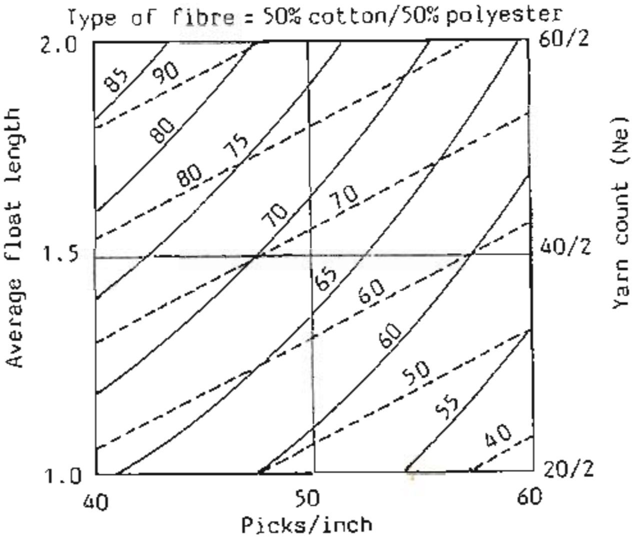

Fig. 16: Contrours for relative deflection (%).

Float length ——— Cross section of (X_3-X_4) at $X_2=+1$, $X_1=0$

Yarn count - - - - - - - - Cross section of (X_3-X_1) at $X_2=+1$, $X_4=0$

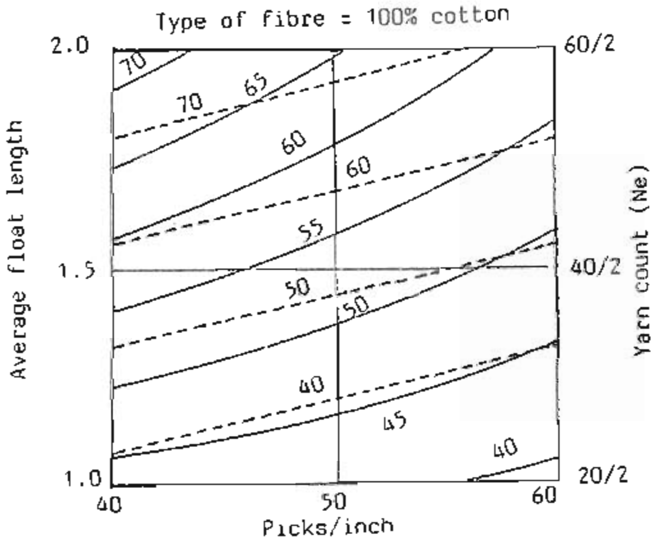

Fig. 17: Contours for relative deflection (%).

Float length ——— Cross section of (X_3-X_4) at $X_2=-1$, $X_1=0$

Yarn count - - - - - - - - - Cross section of (X_3-X_1) at $X_2=-1$, $X_4=0$

Table IV: Response-surface Equations.

Response	Response-surface Equation	Correlation coefficient
1. Residual cyclic deformation, mm	$y_1 = 8.2675 + 0.1575\, X_2 - 0.3675\, X_3 + 0.2975\, X_4 - 0.4875\, X_2X_3 - 0.0675\, X_2X_4 - 0.1475\, X_3X_4$	0.9918
2. Recoverable deformation, %	$y_2 = 1.7 - 0.0675\, X_1 + 0.12\, X_2 + 0.10\, X_3 + 0.6525\, X_4 + 0.045\, X_2X_3 + 0.0675\, X_2X_4 + 0.1825\, X_3X_4$	0.9995
3. Endurance, cycle	$y_3 = 1074.25 - 324.75\, X_1 + 447.5\, X_2 + 170.75\, X_3 - 206\, X_4 + 159\, X_2X_3 - 98.25\, X_2X_4 - 440.5\, X_3X_4$	0.9999
4. Sp. work of rupture, gf/tex	$y_4 = 0.6825 - 0.2651\, X_1 + 0.0617\, X_2 + 0.0874\, X_3 + 0.0436\, X_4 + 0.0802\, X_3X_4$	0.9997
5. Flex and abrasion resistance, cycle	$y_5 = 1735.8 - 568.525\, X_1 - 65.625\, X_2 + 403.025\, X_3 + 220.6\, X_1X_2 + 175.65\, X_1X_3 - 123.15\, X_1X_4$	0.9999
6. Relative deflection, %	$y_6 = 60.339 + 20.499\, X_1 + 7.089\, X_2 - 7.509\, X_3 + 10.777\, X_4 - 2.723\, X_2X_3 - 1.313\, X_2X_4 - 2.589\, X_3X_4$	0.9999

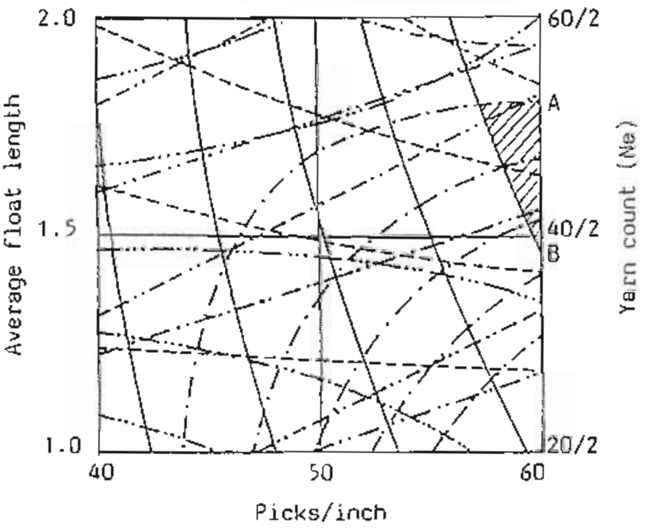
Type of fibre = 50% cotton/50% polyester

Fig. 18: Contours for servicability properties when using blended yarns(50% cotton/50% polyester).

——— residual cyclic deformation.
- - - - recoverable deformation (cross section of (X_3-X_4) at $X_1 = 0$)
—·—· endurance (Cross section of (X_3-X_4) at $X_1 = 0$)
—··—·· Sp. work of rupture (Cross section of (X_3-X_1) at $X_4 = 0$)
—···—··· flex & abrasion resistance.
—·—·—— relative deflection (Cross section of (X_3-X_1) at $X_4 = 0$)

deformation was larger than 1.8 and endurance was equal to 1400 cycles and upward and specific work of rupture in tensile deformation was greater than 0.6 gf/tex and abrasion resistance was higher than 1900 cycles and relative deflection was more than 50%, then the desired constructional factors would be found either in point A which $X_1 = +0.6$ (52/2 Ne); $X_2 = +1$ (material used 50 P/50 C); $X_3 = +1$ (60 picks/inch) and $X_4 = +0.6$ (average float length 1.8) or in point B which $X_1 = -0.06$ (38.8/2 Ne); $X_2 = +1$ (material used 50 P/50 C); $X_3 = +1$ (60 picks/inch); $X_4 = -0.06$ (average float length 1.47). Thus Fig. 18 shows two graphical solutions, which represent all the investigated properties.

4.3 Mathematical Method

Although the graphical solutions seem to be a reasonable approach, the graph is not general because other solutions may be better. Then, the solution of equations will in general solve the problem. However, some inequality constraints are made, by many iterations, to obtain one optimum solution for the equations as the following:

$y_1 < 8$ mm; $y_2 > 2.2$; $y_3 > 1300$; $y_4 > 0.70$; $y_5 > 1900$ and $y_6 > 70$.

By using the computer "Micronet" all six nonlinear equations are solved and one result could be printed as one optimum solution for the six equations. Table V shows the typical computer solution for the six equations.

Table V: Solution of Equations.

Optimum Factors			
X_1	X_2	X_3	X_4
+ 0.6 (52/2 Ne)	+1 (50 P/50 C)	+1 (60 picks/in.)	+ 0.4 (1.7 float length) ≃ twill 1/2

Corresponded parameters					
y_1	y_2	y_3	y_4	y_5	y_6
7.603	2.2855	1358.75	0.72206	1940.279	72.2454

Then the graphical solution, at point A, supports the validity of the mathematical solution. Thus, these computed optimum factors can be used to design a new military fabric for soldiers with a long service life.

5. CONCLUSION

The study reported in this paper with respect to both blend ratio, yarn linear density, pick density and weave design, led to the determination of the values of these variables that permit the longest service life to be attained for one type of military fabrics.

Thus, in this paper, it could be deduced that the optimum values of the studied variables are yarn count(English), 52/2 Ne; cotton percent in the blend, 50%; pick density, 60 picks/inch; and average float length, 1.7, (weave design is nearly twill 1/2).

These optimum factors are very important for designing a new fabric, with a longer service life, suits the outer wear cloths for soldiers in Egypt.

ACKNOWLEDGEMENTS

The author would like to express his sincere appreciation to Eng. Ahmed El-Dakhs, Eng. Abdalla Ahmed Ibrahiem, Eng. Farouk Hamouda and technical staff in spinning and weaving sections in Misr Spinning & Weaving Co. in El-Mehalla El-Kubra for production the different samples of military fabrics on a sulzer loom.

REFERENCES

1. M.C. ГеНзер. Tpukomaж gл xupypruu, MockBa, P. 181, 1981.
2. J. Hearle; P. Grosberg and S. Backer. Structural Mechanics of Fibres, Yarns and Fabrics, Wiley-interscience, Ch. 8. page 312, 1969.
3. A. Koblyakov. Laboratory Practice in the Study of Textile Materials, Mir Publishers, Moscow, 1989.
4. American Society for Testing Materials, D 1175, P. 181, 1963.