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Representation of the Wrinkle Profile in Garments.

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REPRESENTATION OF THE WRINKLE PROFILE IN GARMENTS

التعبير عن شكل التجعدات فى الملابس

BY

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خلاصه : امكن انشاء، جهاز لقياس مقاومة الاقشة للتجعد وايضا لدراسه شكل التجعد الخارجى لاسطوانه من القماش شبيه بكم البدله الرجالى وذلك فى الحاله الشائعه حيث النسبه بين قطر زراع الانسان الى قطر كم البدله حوالى ٠،٨ امكن افتراض ثلاث اشكال منتظمه لشكل الكم اثناء اللبس وهى الموجه الجيبيه والموجه ذو الخط المنكسر المنتظم والموجه ذو الشكل الشبه منحرف. وقد امكن التوصل الى ان شكل الكم الخارجى للبدله يمكن التعبير عنه رياضيا وتمثيله جيدا خاصة باستخدام معادله الموجه ذو الشكل الشبه منحرف المنتظم وذلك عن طريق حساب سعه الموجه وطول الموجه ومقاومه الاقشة للتجعد . سعه الموجه للاقشه المختلفه امكن حسابها باستخدام طريقه الاسقاط.

ABSTRACT:

An apparatus made to measure fabric crease resistance and to study the form (profile) of suit sleeve under different conditions is described. Three regular shapes were assumed for representing the sleeve profile of suit such as sine, zig-zag and trapezoid profiles. It is deduced that the form (profile) of suit sleeve during wear can be expressed mathematically by the equation of a trapezoid profile when the diameter ratio between the arm and the sleeve is within a certain range (0.8). The experimental profile is found to be reasonably close to the theoretical regular profile of trapezoid. The theoretical profile (form) can be predicited if the fabric crease resistance, the amplitude of wave and the wave length are known. A projection method is used to calculate the wave amplitude of the different fabrics.

1.INTRODUCTION

The form of the crushed (buckled) cylinderical cloth is one of the main reasons for estimating the quality of wool/terylene fabrics. The form of cloth profile as wool fibre crimp can be expressed by three fundamental parameters such as the amplitude of wave, the wave length and the effective wave number [1-3].

Although cloth form (profile) seems to be one of the important properties characterizing the quality of wool/terylene fabrics, no work has been done in this field and no method for measuring this property has been established.

The present paper is concerned with the development of predictive relations for the form (profile) taken be buckling a vertical cylinderical cloth.

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2. EXPERIMENTAL PROCEDURE

2.1 Apparatus:

The apparatus used for this investigation consisted of a clamping unit and a projection system.

The clamping unit of the specimen consists of the base (1) with a guiding rod (2). A disc (3) is fixed on the upper end of the rod. The tested specimen (4) in a cylinderical shape 50 mm dia. and 50 mm height is fitted on the rod and fixed at the bottom with a clamp 10 mm height. A force of 2 kg created by weight (5) is applied to the specimen. When the lever (6) is free from handle (7), the disc (3) is in the bottom position and the load is transmitted through a lever (6) to specimen, causing its wrinkling. Lever (6) which is swung around the pivot (8) and is smoothly descended by the help of a damping spring (9).

But the projection system shown in Fig. I contains a lamp (10) which illuminates the crushed cylinderical specimen (4) in its outside edges and a lens (11) arranged so as to give an enlargement of the crushed specimen. The image of the crushed specimen at three planes of projection is formed on a millimetric square scale (12) of 20x30 cm on a vertical wood plate.

2.2 Test Method

A cylinderical specimen of cloth of 50 mm dia. and 45 mm height is fixed vertically. A compression force of 2 kg is applied to the specimen, causing its wrinkling. After 15 min, the load is removed and the specimen is allowed to recover from the crease or wrinkling. At the end of the time allowed for recovery, 5 min, the average height of the cylinderical specimen after crushing is measured. Then, wrinkle resistance (kn) can be determined [4]. In this case, the image of the crushed cylinderical cloth profile is formed and is drawn on a millimetric square scale. Measurements of the profile radius along the two outer outside edges of the cylinder were determined at constant intervals of about 5 mm. Several measurements of the wave amplitude, wave length and number of waves of the same length of cylinderical cloth were performed accurately.

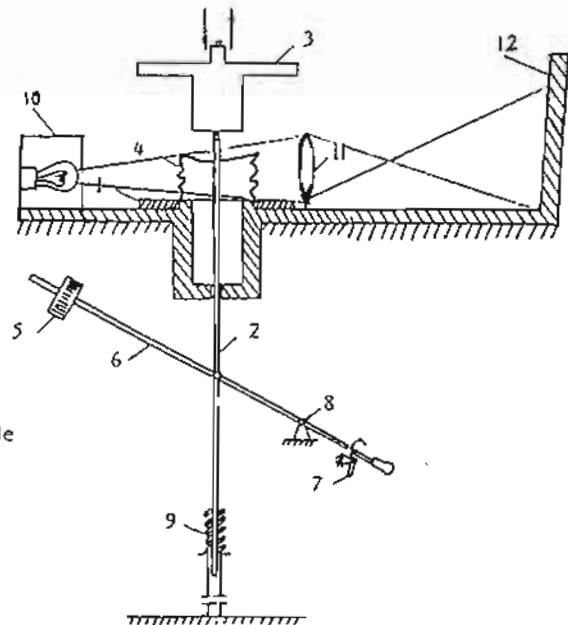|	
1	base
2	guiding rod
3	disc
4	test specimen
5	weight
6	lever
7	handle
8	pivot
9	damping spring
10	lamp
11	lens
12	millimetric square scale

Fig.1
Schematic diagram of the apparatus

2. 3 Fabrics Used

Eleven wool/terylene fabrics were tested on the previous apparatus used for measuring crease resistance and wave amplitude.

3. THEORETICAL WORK

The geometrical shape of a cloth profile can be characterized by wave amplitude, wave length and number of waves per unit length.

The wave amplitude (A) of the corresponding problem is proposed to calculate [3] by the following equation.

$$A = [(\sum_{i=1}^{n} r_i^2)/n]^{1/2} \qquad \qquad ...(1)$$

where r_i is the profile radius or the distance between each point of the profile and the original outside edges of the cylinder before crushing and n is the number of points.

It is generally impossible to measure directly the wave length of the cloth profile. However, wave length or number of waves can be calculated.

The wave amplitude of cloth profile represents only one feature of the geometrical shape influencing the physical behaviour of the clothes. But the different shaped profiles may yield the same wave amplitude. This is due to different number of waves and/or wave length.

Thus, the wave amplitude can characterize only one aspect of the geometrical shape of a cloth profile and an additional geometrical independent term is necessary for describing this shape. However, the wave length can be used as the second term. But it is impossible to measure directly the wave length of a cloth profile.

Although it would be possible to use these two measures (wave amplitude and wave length) for characterizing the shape of the cloth profile, it is possible to deduce from these two measures the number of waves per unit length.

In order to find the equation of the geometrical shape of the cylinderical cloth after crushing, it is necessary to assume any regular profile shape. The regular shapes assumed in the present paper are:
(1) sine profile, (2) zig-zag profile and (3) trapezoid profile.

3.1. The sine profile :

Nomenclature :
A - wave amplitude
h - wave length (pitch)
L - curve length of one wave of a sine profile

The equation of sine profile (Fig.2) can be written as follows :

$Y = A \sin (\theta)$

$Y = A \sin (2 \pi X / h)$

$(dy/dx)^2 = (2 \pi A/h)^2 . \cos^2 (2 \pi X / h)$

$L = 4 \int_0^{h/4} [1+(dy/dx)^2]^{1/2} . dx$

$L = 4 \int_0^{h/4} [1+ (2 \pi A/h)^2 . \cos^2 (2 \pi x/h)]^{1/2} dx$

put $(2 \pi X / h) = \phi$; hence $(2 \pi/h) dx = d\phi$

i.e. $dx = (h/2 \pi) . d\phi$

$L = (4h/2 \pi) \int_0^{h/4} [1+(2\pi A/h)^2 . \cos^2 \phi]^{1/2} . d\phi$

$\cos^2 \phi = 1-\sin^2 \phi$

FIG.2. SINE PROFILE

$L = (2h/\pi) \int_0^{h/4} [1+(2 \pi A/h)^2 - (2 \pi A/h)^2 . \sin^2 \phi]^{1/2} . d\phi$

$L = 2/\pi \int_0^{h/4} [h^2 + (2\pi A)^2 - (2\pi A)^2 . \sin^2 \phi]^{1/2} . d\phi$

Put $S^2 = h^2 + (2\pi A)^2$

$L = (2 S/\pi) \int_0^{h/4} [1-\frac{(2\pi A)^2}{S^2} . \sin^2 \phi]^{1/2} . d\phi$ ...(2)

put $m = \sin \psi = 2\pi A/S = 2\pi A/[h^2 + (2\pi A)^2]^{1/2}$ ...(3)

$\psi = \sin^{-1} 2\pi A/[h^2 + (2\pi A)^2]^{1/2}$ ...(4)

By substituting in Eq. (2) from Eq.(3)

$L = (2S/\pi) \int_0^{\pi/2} [1-m^2 \sin^2 \phi]^{1/2} d\phi$

$E(m) = \int_0^{\pi/2} [1-m^2 . \sin^2 \phi]^{1/2} d\phi$ ...(5)

where E (m) is the complete elliptic integral of the second kind and it can be calculated from special tables by means of the value of ψ.

Then $L = (2S/\pi) . E(m)$ ...(6)
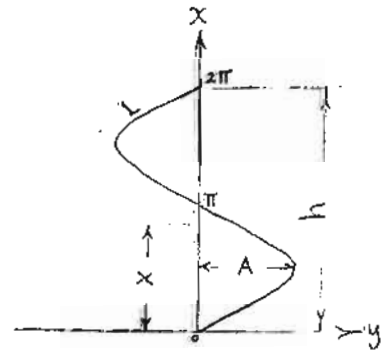
$$L = 4.A.E \ (m)/m \qquad\qquad ...(7)$$

Then, in this case the relationship between wrinkle resistance (Kn), amplitude (A) and wave length (h) can be expressed as follows :

$$Kn = h/L = (\frac{h}{A}) . \frac{m}{4.E(m)} \qquad\qquad ...(8)$$

And number of waves (N) can be calculated by the ratio of the initial height of the cylinderical cloth (45 mm) to the curve length of one wave (L) calculated from Eq.(7).

Values of m, Ψ, E (m) and Kn against (A/h) could be calculated from Equations 3, 4, 5 and 8 respectively and tabulated in Table I. Fig. 3 shows the relationship between (A/h) and Kn.

Table I and Fig.3, at a known value of wrinkle resistance Kn, the value of (A/h) can be determined. After calculating the wave amplitude (A) from Eq.1; the wave length (h) and number of waves (N) would be calculated.

Table I: Values of m,Ψ,E (m) and Kn Corresponded to(A/h) For The Sine Profile

| A/h	m	Ψ	E(m)	Kn
0	0.006	0.360	1.575	1.0
0.025	0.155	8.93	1.570	0.987
0.050	0.300	17.44	1.535	0.976
0.075	0.426	25.23	1.498	0.949
0.100	0.532	32.14	1.454	0.915
0.125	0.613	38.15	1.409	0.877
0.150	0.686	43.30	1.368	0.836
0.175	0.740	47.72	1.324	0.799
0.200	0.783	51.49	1.292	0.757
0.225	0.816	54.73	1.265	0.717
0.250	0.844	57.52	1.235	0.683
0.275	0.866	59.94	1.211	0.650
0.300	0.883	62.05	1.192	0.618
0.325	0.898	63.90	1.173	0.589
0.350	0.910	65.55	1.159	0.561
0.375	0.921	67.00	1.145	0.536
0.400	0.929	68.30	1.133	0.513
0.425	0.937	69.47	1.122	0.491
0.450	0.943	70.52	1.114	0.470
0.475	0.948	71.48	1.104	0.452
0.500	0.953	72.34	1.098	0.434
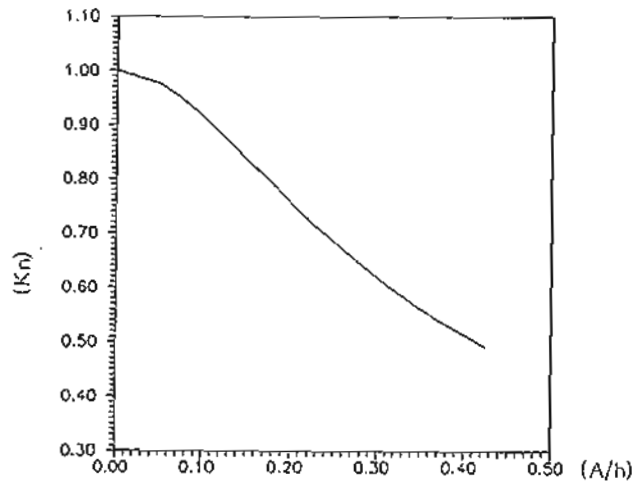
FIG.3. GRAPHICAL REPRESENTATION OF THE FUNCTION

$$K_n = \left(\frac{h}{A}\right) . \frac{m}{4.E(m)}$$

3.2. The zig.zag profile

Nomenclature:
    A- wave amplitude
    h- wave length (pitch)
    L - zig-zag length of one wave

The equation of zig-zag profile (Fig.4) can be expressed as follows:

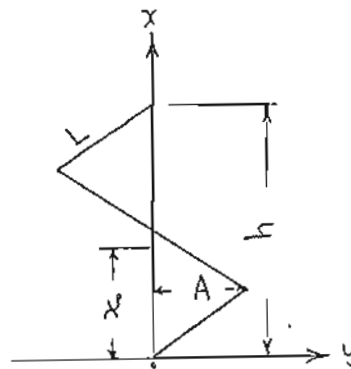|		
$Y = X.(A/X_0) = X.(4A/h)$,	at $0 \leqslant X \leqslant 0.25h$	...(9)
$Y = (h/2-X). (4A/h)$,	at $0.25h \leqslant X \leqslant 0.75h$	...(10)
$Y = -(h-X)(4A/h)$,	at $0.75h \leqslant X \leqslant h$	...(11)

FIG. 4. ZIG-ZAG PROFILE

$$L = 4 \left[(A)^2 + (h/4)^2 \right]^{1/2}$$

$$Kn = h/L = 0.25h/[(A)^2 + (h/4)^2]^{1/2} \qquad ...(12)$$

Values of (Kn) and (A/h) could be calculated from Equation (12) and listed in Table 2. Fig. 5 shows the relationship between (A/h) and Kn.

Table 2 : Values of (A/h) and (Kn) For The Zig-zag Profile.

(A/h)	Kn
0	1
0.025	0.995
0.050	0.981
0.075	0.958
0.100	0.928
0.125	0.894
0.150	0.857
0.175	0.819
0.200	0.781
0.225	0.743
0.250	0.707
0.275	0.673
0.300	0.640
0.325	0.610
0.350	0.581
0.375	0.555
0.400	0.530
0.425	0.507
0.450	0.486
0.475	0.466
0.500	0.447
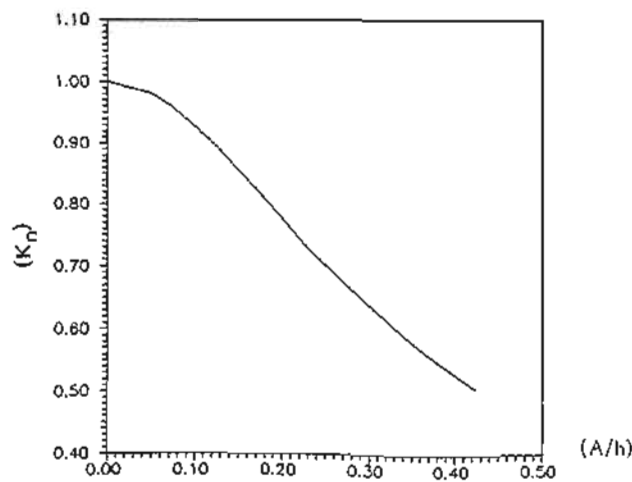
FIG.5. GRAPHICAL REPRESENTATION OF THE FUNCTION
$$K_n = 0.25h/ \left[(A)^2 + (h/4)^2 \right]^{1/2}$$

3.3. The Trapezoid Profile :

Nomenclature :

A - wave amplitude.
h - wave length (pitch).
L - curve length of one wave of trapezoid helix.

The equation of trapezoid profile (Fig.6) can be expressed as follows :

$$Y = A . \frac{X}{Z} \qquad \text{at} \quad 0 \leqslant x \leqslant z \qquad \qquad ...(13)$$

$$Y = A \qquad \text{at} \quad z \leqslant x \leqslant \Pi - z \qquad \qquad ...(14)$$

$$Y = -A \qquad \text{at} \quad \Pi + z \leqslant x \leqslant 2\Pi - z \qquad \qquad ...(15)$$

$$Y = \frac{A(\Pi - X)}{Z} \qquad \text{at} \quad \Pi - z \leqslant x \leqslant \Pi \qquad \qquad ...(16)$$

where · $Z = (h-2a)/4 = A \tan \theta$

or $\quad 2a = h - 4 A . \tan \theta \qquad \qquad ...(17)$

and $\quad L = 2a + 4\sqrt{A^2 + Z^2}$

$\quad\quad L = 2a + 4A\sqrt{1 + \tan^2 \theta} \qquad \qquad ...(18)$

$\therefore \quad Kn = h/L = \dfrac{h}{2a + 4A \left(1 + \tan^2 \theta\right)^{1/2}}$

From Eq. (17) Kn can be rewritten as follows :

$$Kn = \frac{h}{(h - 4 A \tan \theta) + 4 A (1 + \tan^2 \theta)^{1/2}}$$

or

$$Kn = \frac{1}{1 - 4 R \tan \theta + 4 R (1 + \tan^2 \theta)^{1/2}} \qquad \qquad ...(19)$$

where $R = A/h$

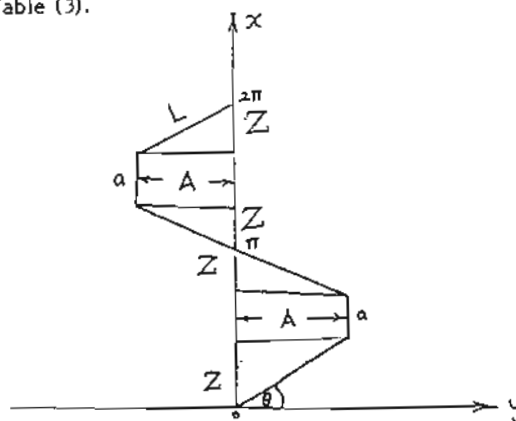At a known value of (Kn), the values of (A/h) and tan θ can be computed using the computer as listed in Table (3).

FIG.6. TRAPEZOID PROFILE

Table 3 : Values of (Kn), (A/h) and tan (θ) For The Trapezoid Profile.

Fabric	Kn	(A/h)	tan (θ)
1	0.927	0.1	2.5
2	0.943	0.1	1.7
3	0.942	0.1	1.6
4	0.946	0.1	1.8
5	0.957	0.1	2.4
6	0.968	0.1	2.5
7	0.968	0.1	2.5
8	0.964	0.1	2.5
9	0.962	0.1	2.5
10	0.973	0.1	2.5
11	0.980	0.1	2.5

4. RESULTS

The experimental results of wrinkle resistance (Kn) and wave amplitude (A) for eleven fabrics made of different wool/terylene percent are listed in Table 4.

Table 4 : Values of Wrinkle Resistance (Kn) And Wave Amplitude (A) of Wool/Terylene Fabrics.

Fabric NO.	Wrinkle Resistance (%)		Wave Amplitude (mm)	
	mean	C.V.(%)	mean	C.V. (%)
1	92.71	1.60	1.749	37.04
2	94.26	1.49	1.926	25.82
3	94.22	1.57	1.241	26.02
4	94.60	2.29	1.859	25.43
5	95.69	1.62	1.303	31.99
6	96.78	1.86	1.505	37.96
7	96.80	1.35	1.073	33.69
8	96.38	0.70	1.404	27.74
9	96.24	0.85	1.273	31.90
10	97.34	1.28	1.270	32.16
11	98.01	0.823	1.030	14.16

In view of the low variability of wave amplitude from one fabric to another, a small sample of about 5 specimens taken from the same fabric will be sufficient to estimate the average wave amplitude of a fabric.

The present results indicate certain interesting relationships between the wave amplitude and characteristics of the fabric itself. Additional relationships which can be deduced from the data will form the subject of subsequent publications.

The results obtained for sine, zig-zag and trapezoid profiles are given in Table 5. These three regular shapes were used with the following experimental results. Table 5 shows the values of the wave length (h), number of waves (N) and the ratio of (A/h) for the three regular shapes.

Table 5 : Values of (A /h), (h) And (N) For The three Regular Shapes.

Fabric	Sine	Profile		Zig-zag	Profile		Trapezoid	Profile	
No.	A/h	h(mm)	N	A/h	h(mm)	N	A/h	h/(mm)	N
1	0.093	18.908	2.079	0.100	17.490	2.389	0.1	17.49	2.389
2	0.075	25.680	1.744	0.083	23.345	1.831	0.1	19.26	2.107
3	0.083	15.042	2.715	0.088	14.183	2.995	0.1	12.41	3.253
4	0.078	23.987	1.759	0.085	21.871	1.948	0.1	18.59	2.193
5	0.073	17.972	2.221	0.075	17.373	2.481	0.1	13.03	3.198
6	0.063	24.080	1.489	0.063	24.080	1.813	0.1	15.05	2.776
7	0.063	17.168	2.087	0.063	17.168	2.543	0.1	10.73	3.894
8	0.063	22.464	1.882	0.075	18.720	2.302	0.1	14.04	2.976
9	0.063	20.368	2.115	0.075	16.973	2.539	0.1	12.73	3.282
10	0.050	25.400	1.808	0.063	20.320	2.148	0.1	12.73	3.290
11	0.038	27.467	1.797	0.050	20.600	2.142	0.1	10.30	4.056

Table 6 : Values of Error Ratio (Ro) of Profile Radius For The Three Regular Shapes.

Fabric	Error Ratio (Ro) = $|(r-r_1)/r_1|$		
No.	Sine profile	Zig-zag profile	Trapezoid profile
1	4.775	7.079	7.079
2	6.147	5.741	4.397
3	2.202	1.059	2.294
4	1.930	1.515	1.769
5	3.210	1.939	2.208
6	2.351	2.020	1.625
7	7.067	5.477	8.381
8	5.191	4.175	3.785
9	1.354	0.887	1.020
10	3.854	3.408	2.443
11	3.030	6.061	2.207
mean (RO)	3.737	3.583	3.383

5. CONCLUSION

The absolute value of the error ratio (R_o) between measured and calculated values of profile radius (ri) along the profile length for the three regular shapes are calculated and listed in Table 6. However, it might be observed that the average of error ratio (R_e) for the tested fabrics was found to be smaller with respect to trapezoid profile than with respect to sine or zig-zag profile. Thus, it is deduced that the form (profile) of suit sleeve during wear can be expressed mathematically by the equation of a trapezoid profile when the diameter ratio between the arm and the sleeve is within a certain range (0.8).

Fabric elastic recovery (wrinkle resistance) depends on elasticty of fibres and the geometry to which the fabric is deformed. Keeping the elasticty constant (that is using the same type of fibre), the elastic recovery of fabric will depend on the geometry of deformation. Severe deformation causes high level of strain in the fibres and consequently low elastic recovery, while slight deformation causes low level of strain in fibres and accordingly high elastic recovery.

The severity of geometry could be represented by a mathematical model showing how sharp in the fabric is deformed. For example. by the zig-zag profile, high values for both amplitude and frequency (number of waves per unit length) show severe deformation and high level of strain and consequently low elastic recovery.

The geometry to which the fabric is deformed depends on the fabric constru- ction, e.g. yarn count, twist, picks/cm, ends/cm, type of weave, finish, etc. For a certain type of fibre the elastic recovery will then depend on the fabric construction. This fabric construction will be represented by the geometry which is taken by the fabric when it is compressed as a cylinder. In other words the amplitude and frequency of the fabric profile will indicate the elastic recovery.

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