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A THEORETICAL STUDY OF THE RELATION BETWEEN WRINKLE RESISTANCE AND CREASE RECOVERY ANGLE OF APPAREL FABRICS

دراسة نظرية للعلاقة بين مقاومة التجعد وزاوية رجوعية الثنى لأقمشة الملبوسات

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خلاصة ـ فى هذا البحث أمكن تصميم وانشاء جهاز بسيط لقياس مقاومة التجعد فى الأقمشة • أيضا باستخدام وديل هندسى أمكن التوصل الى معادلة رياضية تربط مقاومة التجعد مع زاوية رجوعية الثنى • أمكن التأكد من صحة هذه المعادلة الرياضية وذلك عن طريق مقارنة مقاومة التجعد المحسوبة من المعادلة مع مقاومة التجعد المقاسة على لجهاز المذكور ووجد أن هناك اتفاق كبير بين النتائج المحسوبة والنتائج المعطية المقاسة •

In this work, a simple apparatus for measuring wrinkle resistance (nonorientec crease resistance) of fabrics is constructed. By using a geometrical model of a cylinderical specimen of fabric, a simple theoretical approach is attempted to relate the wrinkle resistanc to the crease recovery angle of fabrics. A wide range of apparel woven fabrics were tested on both the wrinkle resistance apparatus established by the author and the Shirley crease recovery tester. An experimental verification for the theoretical work has been made which gives a good fit.

1. INTRODUCTION

The wrinkling or buckling of fabrics in various forms has recently been given considerable attention. This is mainly because wrinkle is a very common phenomenon during the use of fabrics in garments. For example, the bending of a sleeve, the bending of a trouser leg and even the natural folding of a garment often involves wrinkle[1].

Crease resistance is the ability of material to resist wrinkling and to restore the initial state after the force causing its bending is removed. Evaluation of fabric crease-resistance is determined by the methods of oriented and nonoriented creasing (wrinkle) of the specimen.

In oriented creasing the crease resistance factor K_o is characterized by the ratio of the crease recovery angle Θ of the specimen to the angle of its full bend equal to 180.

$$K_o = \frac{\Theta}{180} \times 100 \qquad (\%) \qquad \ldots (1)$$

In case of nonoriented creasing (wrinkling) the crease resistance factor K_n characterizes the capacity of material to restore its initial dimensions after creasing (crushing) and is given by:

$$K_n = \frac{h_f}{h_o} \times 100 \qquad (\%) \qquad \ldots (2)$$

where h_f-the final height of the cylinderical specimen after its crushing and relaxation,mm;

h_o-the initial height of the specimen equal to 40 mm.

The ability of fabrics to restore the initial condition depends on the flexibility and elasticity of the material , while the ability of resisting to bending depends on their stiffness.

Not only the crease-resistance of fabrics should be taken into account at single crushing but also the crease resistance at repeated crushing is very important due to the development of fatigue especially at the points of bending where wrinkles and creases are formed[2].

The problem of oriented creasing (crease recovery angle) and nonoriented creasing (wrinkle resistance) of fabrics was early discussed and separetly investigated, but no attempts have been done to correlate these two characteristics for predicting fabric wrinkle resistance.

There are several devices[3-7] with which it is possible to assess wrinkle performance of fabrics. These devices are expensive which they utilize electronic force and recorders for the display of results.

Thus, the purpose of this work is to deduce a simple theoretical approach which correlates both wrinkle resistance and crease recovery angle. Also the present work is aimed to design a new simplified apparatus to measure wrinkle resistance of fabrics.

An apparatus designed by the auther will be described below and is based on NCTP Tester of Solovyev and Shakhbazyan[7] which measures nonoriented crease resistance.

2. EXPERIMENTAL WORK

2.1. Fabrics

A wide range of apparel fabrics commercially produced were tested. Fabrics specifications are listed in Table I. This range of fabrics was selected to cover the majority of the articles of the garments used for outer-wear clothing.

Table I
Fabric Characteristics

Sample No.	Type of Material		Linear Density (tex)		Threads/cm		Weave Design	Weight (g/m^2)
	warp	weft	warp	weft	warp	weft		
1	100%cotton	100%cotton	36	44	22	18	plain 1/1	158
2	"	"	33	25	27	24	"	118
3	"	100%polyester	25	27	27	24	"	118
4	"	"	12	23	26	23	"	104
5	"	"	18	12	28	23	"	107
6	"	100%cotton	13	24	42	28	"	121
7	"	"	23	22	30	25	"	129
8	"	"	14	30	31	23	"	122
9	"	"	12	26	32	19	"	92
10	"	"	21	23	31	24	"	93
11		"	13	14	38	28	"	79
12	50%P*/50%C**	"	20x2	30x2	38	16	"	301
13	"	"	20x2	10x2	38	16	Twill 1/3	211
14	"	50%P/50%C	20x2	30x2	38	16	"	291
15	"	50%P/50%C	20x2	10x2	38	16	Plain 1/1	211

* P = polyester fibres ** C = cotton fibres

2.2. Apparatus Used For Testing Fabric Wrinkle Resistance

The apparatus used was established by the author as illustrated in Figures 1 & 2

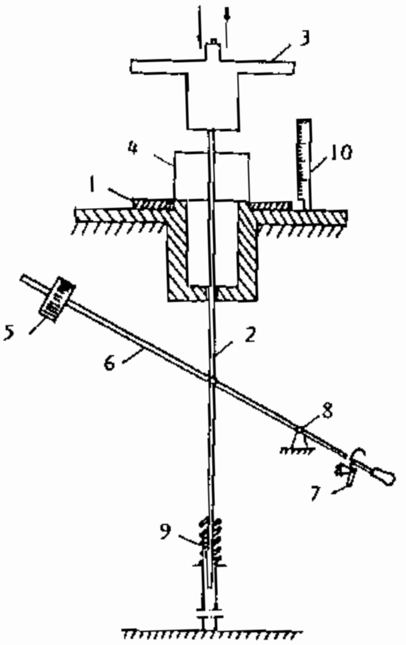

Fig.1
Schematic diagram of the apparatus

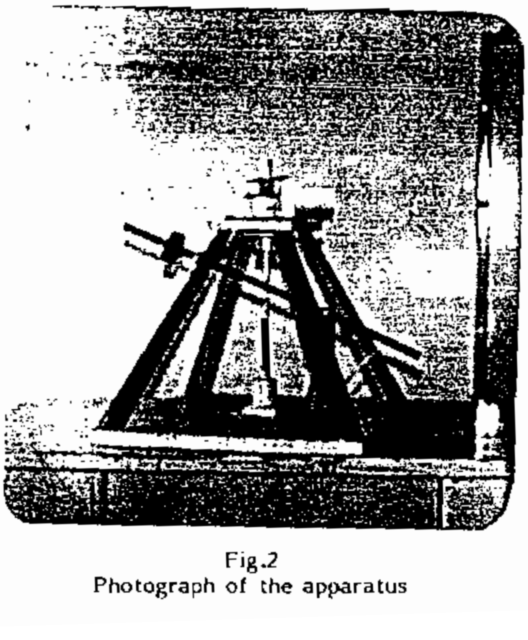

Fig.2
Photograph of the apparatus

which consists of a heavy base on which is mounted a clamping unit of the cylinderical specimen of the fabric. 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 the specimen, causing its wrinkling. Lever (6) which is rotated around the axis (8) is smoothly descended by the help of a damping spring (9). After 1 min. the load is removed and the specimen is allowed to recover from the crease or wrinkling. At the end of the time period allowed for recovery, 1 min., the average height (hmax+hmin)/2 of the cylindrical specimen after crushing is measured on the scale (10). In this case, wrinkle-resistance can be determined using Equation (2).

3. THEORETICAL WORK

The theoretical analysis is based on the apparatus used for measuring wrinkle resistance. In this case, it is considered that the generatrix of the cylinderical specimen after crushing is composed of vertical strips with equal heights h . Each strip is similar to that used on the Shirley crease recovery tester, and it is taken as an element for the study. Fig.3 shows the geometrical model of the analysis. Each element is considered as a creased specimen by folding in half and is allowed to recover from the crease. In order to correlate wrinkle resistance and crease recovery angle, it is necessary to assume any regular shape for the specimen generatix after crushing. If the projected generatrices of the specimen after crushing take a regular zig-zag helix as shown in Fig.3. Then, in this case one repeat of the zig-zag helix represents a complete wave. The helix length L of one wave of amplitude D/2 and pitch h is given by:

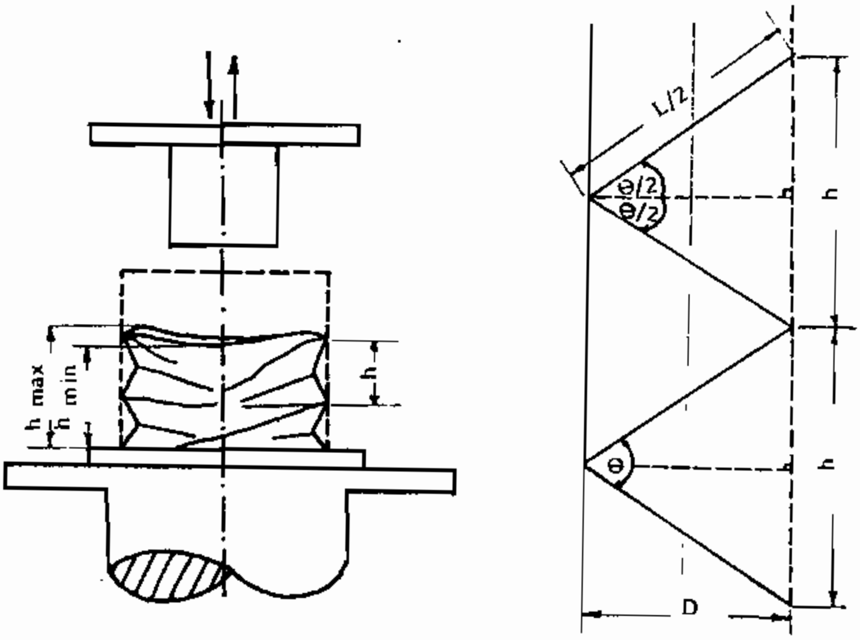

Fig. 3
Analysis of the geometrical model of the study

$$L = 2\left[\left(\frac{h}{2}\right)^2 + D^2\right]^{1/2} \qquad \ldots (3)$$

Fractional compression of each wave C can be written in the form:

$$C = 1 - \frac{h}{L} \quad \ldots (4)$$

or $$h = L\,(1 - c) \quad \ldots (5)$$

By substuting in Eq. (3) from Eq. (5)

then $$L = 2\,[\,L^2\,(1-c)^2\,/4 + D^2\,]^{1/2} \quad \ldots (6)$$

Equation (6) can be rewritten as follows

$$L = 2\,D\,/[1 - (1-c)^2]^{1/2} \quad \ldots (7)$$

By substituting in Equation (5) from Equation (7)

$$h = 2\,D\,(1-c)/[1-(1-c)^2]^{1/2} \quad \ldots (8)$$

From Fig.3, $\Theta/2 = \tan^{-1} h/2D$ ... (9)

From Equations (8&9) Θ can be written in the form:

$$\Theta = 2\,\tan^{-1}\,(1-c)\,/\,[1 - (1-c)^2]^{1/2} \quad \ldots (10)$$

If wrinkle resistance ratio K of each wave equal to h/L and fractional compression C of each wave equal to (1 - h/L), then

$$1 - c = k \quad \ldots (11)$$

From Equations (10&11), crease recovery angle (Θ)is given by:

$$\Theta - 2\,\tan^{-1}\,k/(1 - k^2)^{1/2} \quad \ldots (12)$$

From Eq.(12) it follows that

$$K = (1 + 1/\tan^2 \Theta/2)^{-1/2} \quad \ldots (13)$$

Thus fabric wrinkle resistance can be predicted by means of knowing the fabric crease recovery angle measured on Shirley Crease Recovery Tester.

4. RESULTS AND DISCUSSIONS

Table II shows the values of the calculated and measured wrinkle resistance for the different tested fabrics. Coefficient of variation of wrinkle resistance measurements ranging from 1.58% to 6.47% except sample No.9 as listed in Table II. Owing to the low variability of wrinkle resistance after one cycle only of wrinkling, a small sample of about 10 specimens taken from each fabric will often be sufficient to estimate the average of fabric wrinkle resistance. With a sample of this size the mean of K can be deviated from the calculated value by less than about 10%. Thus, the apparatus established by the author

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