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The Correlation Between Certain Parameters Used to Characterise Fabric Wrinkling Properties

by

I. W. Kelly

SOUTH AFRICAN
WOOL AND TEXTILE RESEARCH
INSTITUTE OF THE CSIR

P.O. BOX 1124
PORT ELIZABETH
REPUBLIC OF SOUTH AFRICA

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THE CORRELATION BETWEEN CERTAIN PARAMETERS USED TO CHARACTERISE FABRIC WRINKLING PROPERTIES

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ABSTRACT

Good correlation was found between the AATCC Wrinkle Recovery Rating and the mean wrinkle height for a series of cotton/polyester blend fabrics. Where an ordered arrangement of creases is inserted in a fabric, the fabric wrinkling can be adequately described by the mean wrinkle height. The recovery from AKU or FRL wrinkling after 1 hour and 24 hours is highly correlated. In general, better correlation was found between the Shirley and Monsanto results than between the Monsanto or Shirley results with either the AKU or FRL results.

INTRODUCTION

The measurement of the propensity of a fabric to wrinkle during wear has long eluded laboratory evaluation. Many test methods have been proposed which encompass a wide range of loading conditions, loading times, atmospheric conditions and periods of recovery, and almost as many methods have been abandoned.

Of the popular test methods in current use there are two AATCC methods, commonly known as the Monsanto[1] and AKU[2] tests, one of which (the Monsanto test) is also an ASTM method[3]. Three other methods appear in the 1974 edition of the British Standards Institution handbook on textiles, of these the first is a standard method[4], based on the ISO vertical strip recovery test and replaces the Shirley test. The second[5], sponsored by WIRA for wool and wool blend fabrics, is based on the same method of creasing as the ISO test while in the third method random creases are inserted into the fabric and the fabric is assessed visually for retained creases[6]. In an interlaboratory trial[6], this third method was compared with the AKU test, which is also subjective, and the recovery angle method when used to test a wide range of woven and knitted outerwear fabrics. The conclusions of the investigation were that there was poor agreement between observers, but that there appeared to be better agreement between operators when using the random creasing test than when using the AKU test, and that these subjective methods of assessing crease recovery showed poor agreement with the crease recovery angle method.

There are another three test methods which have their adherents: the Katz multiple pleat test[7] used by the CSIRO, the FRL[8] test and the TEFO Conic Wrinkle Test[9].

The test methods used at SAWTRI are the Monsanto, the AKU, and the FRL

tests at either standard atmospheric conditions or at a higher humidity (75% RH) and temperature (27° C). When proposed, the AKU and the FRL test methods made use of photographic standards for assessing the fabrics. Because of the subjective nature of the assessment, which is influenced by the patterning of the fabric, research workers at SAWTRI[10] and elsewhere[11] introduced a profile method of measuring the fabric's wrinkling propensity.

From an analysis of the parameters which can be used to characterise a random surface Shiloh[11] proposed that certain derived functions of the fabric profile can be used to assess the appearance of a wrinkled fabric. These are H, the root mean square of the deviations of the fabric surface from the regression line, T the first derivative of H, K the second derivative of H and the index H x T (also termed the wrinkle severity index). The mean wrinkle height as used by Slinger is equivalent to H if the plane of the fabric is horizontal, i.e. the slope of the regression line is zero. In practice, this holds good for apparel fabrics lying on a horizontal traversing table.

The experimental procedure adopted at SAWTRI has been to wrinkle fabrics under either high humidity and temperature (75% RH and 27° C) or under standard atmospheric conditions (65% RH and 20° C) and to measure the recovery at 65% RH and 20° C after either one hour or 24 hours in terms of H and T or sometimes H alone. The choice of two recovery times was necessitated by the wide range in the wrinkle propensity of the fabrics tested at SAWTRI, ranging from medium weight wool and polyester fabric with good recovery properties to lightweight cotton fabrics with poor recovery properties. The 24 hour recovery period (as stipulated in the AATCC test method) is suitable for untreated, resin-treated cotton and cotton/polyester blends but not for wool and wool blend fabrics, which only show slight wrinkling after a 24 hour recovery period. This makes it difficult to distinguish between the performance of different wool and wool blend fabrics, hence the use of a one hour recovery period sometimes in addition to the 24 hour period.

Determining H and T after one and 24 hours involves much labour, and it was the purpose of this investigation to determine the correlation between the two recovery periods and the two parameters H and T in an attempt to reduce the number of parameters and, consequently, the work involved in characterising fabric wrinkling.

This investigation set out to determine the agreement between:

(a) the subjective method of measuring wrinkling using AATCC Wrinkle Recovery replicas and the surface profile methods for the AKU test,
(b) the parameters H and T after recovery for one and 24 hours for the AKU and FRL tests,
(c) the various wrinkle recovery test methods employed at SAWTRI.

To investigate the above correlations further analyses were carried out, wherever possible, on wrinkle recovery results given in various SAWTRI technical publications as well as on results of unpublished work.

EXPERIMENTAL

(a) Methods:

Two crease recovery tests were considered in the first two parts of this investigation, namely the AKU and FRL tests, with the AKU test being used to measure the recovery from creasing of cotton blend fabrics and the FRL that of wool blend fabrics. Evaluation of the fabrics took place after either a 24 hour or one hour recovery period by either visual assessment (AKU replicas) or in terms of H and T (profile method).

The appearance after wrinkling was determined using the three dimensional replicas according to the AATCC test method. The parameters H and T were determined either on the Wrinklemeter Model SW-2 made by Elma Electronics Instrumentation Control Ltd, or from the profile of the fabric surface using the method developed by Slinger[10]. These two methods gave essentially the same results.

The fabrics were creased at either 27° C and 75% RH or 20° C and 65% RH, in either an FRL tester or an AKU tester for 20 minutes, and allowed to recover for either one or 24 hours prior to evaluation by one of the previously mentioned methods. The fabrics were conditioned in the relevant atmosphere for one day prior to creasing.

The Monsanto test was carried out either at standard conditions in accordance with the AATCC method[1] or at a higher temperature and humidity. In the modified method a higher humidity, 75% RH, and temperature, 27° C, were used before and during creasing with the creased samples always being allowed to recover in standard conditions (20° C, 65% RH). A similar technique was used with the Shirley crease recovery tester where the same two conditioning and testing atmospheres were employed. Samples were conditioned overnight and creased for two minutes before being allowed to recover for one minute at 20° C and 65% RH[12].

(b) Materials:

1. Cotton/polyester fabrics

A series of plain weave fabrics (approximately 140 g/m^2) was produced in all cotton and all polyester as well as in blends of cotton with three types of staple polyester, namely Trevira type 120 (normal), Trevira type 340 (low pilling) and Trevira type 140 (high bulk) at the following blend levels: 80, 60, 40 *per cent* cotton content[13].

2. Wool/polyester blend fabrics

Blends were prepared from a 64's quality merino wool and two types of polyester fibres, namely Trevira types 220 and 330. In addition to the 100 *per cent* wool and 100 *per cent* polyester fabrics, blend fabrics were woven containing 80, 60, 40 and 20 *per cent* wool. Each blend was woven into a square, plain weave fabric with approximately 22 ends and picks per cm and finished to a fabric mass

per unit area of about 200 g/m^2. For finishing the fabrics were divided into two lots, one lot was decatised and the other was autoclave decatised[14]. The autoclave decatised fabrics were later given an easy-care treatment with silicone and polyurethane resins[15].

3. **Mohair/cotton/polyester fabrics**

Lightweight suiting fabrics, a blend of 56 *per cent* mohair (as weft) and 22 *per cent* cotton/22 *per cent* polyester (as warp) were either finished conventionally or treated with a silicone polymer.

4. **Cotton/polyester Raschel outerwear fabrics**

The fabric, a Raschel warp knitted ladies' dress fabric of about 250 g/m^2 from blends in 70 *per cent* cotton/30 *per cent* polyester was easy-care finished with an aminoplast polymer and a softener at two levels of treatment, namely 2,5 and 5 *per cent*[17].

5. **Wool-rich/synthetic blends**

The fabrics, 200 g/m^2, were woven from five yarns, 100 *per cent* wool, an intimate blend of 80 *per cent* wool/20 *per cent* polyester and three core-spun yarns, viz. 88 *per cent* wool/12 *per cent* untextured nylon core, 88 *per cent* wool/12 *per cent* textured nylon core and 88 *per cent* wool/12 *per cent* textured nylon core with Alon, an aluminium oxide finish which increases fibre cohesion in the yarn[18]. Each of the fabrics was split into two lots which were either autoclave decatised or decatised.

6. **Wool/acrylic blends**

The wool/acrylic intimate blend fabrics ranged from all-wool to all-acrylic with four intermediate blends and were prepared from 64's quality merino wool and regular acrylic[19]. Plain and 2/2 twill fabrics of fabric mass/unit area of 190 g/m^2 were made from each blend.

RESULTS AND DISCUSSION

1. Correlation between either H or the H x T index of the AKU Replica Profile and the AATCC Wrinkle Recovery (WR) Rating

The AKU replica profile was measured on the Elma Wrinklemeter in terms of H, T and H x T and the values obtained are given in Figure 1. It can be seen that there is an inverse relationship between the WR rating and the parameters H and T. The value of H corresponding to WR 4 (45 x 10^{-2} mm) lay well away from the others (it lay off the graph in Figure 1) but this was due to a buckle in the replica, as a trace of the surface profile confirmed. The value of H for this particular replica was therefore discarded when comparing the WR rating with the mean wrinkle height.

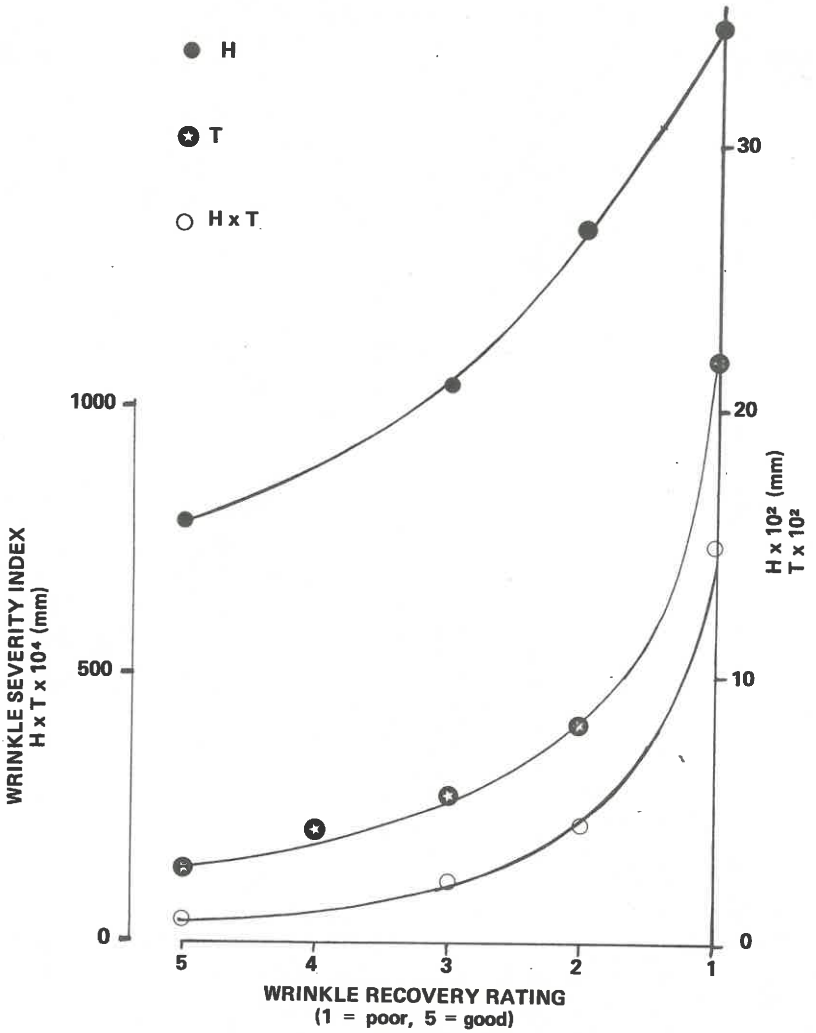

FIGURE 1

Graph of H, T and H x T against Wrinkle Recovery Rating of the AATCC plastic replicas

The correlation between the replica rating and H or H x T was also determined by correlating the values of H or H x T obtained on the fabric with their WR rating for a range of cotton/polyester blend fabrics. Since the fabrics were white, the same colour as the replicas, they were easy to rank using the replicas. In this instance a linear relationship appeared to exist between either $\log_{10}H$ or

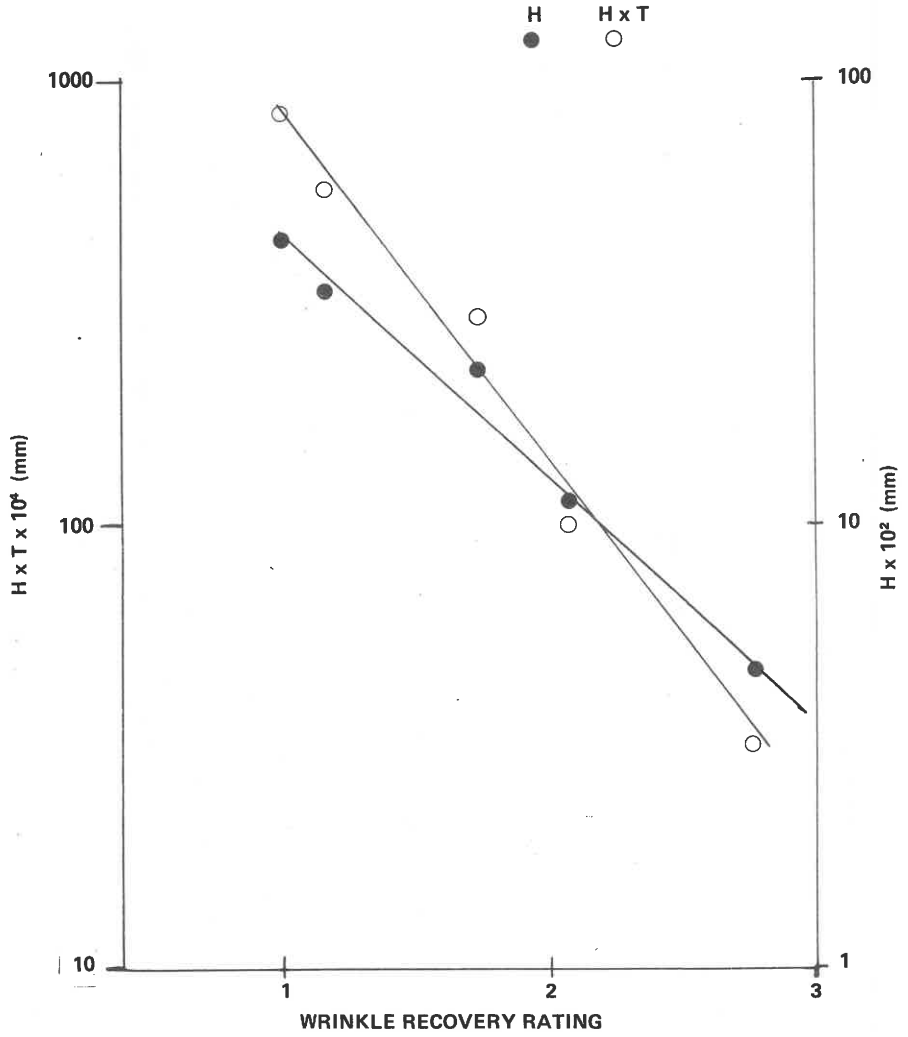

FIGURE 2

Graph of H and H x T against Wrinkle Recovery Rating for a range of cotton/polyester plain weave fabrics after 24 hours recovery period

$\log_{10}$(H x T) and the WR rating, with good fit of the experimental points (see Figure 2). A correlation coefficient of 0,99 was obtained which is highly significant (almost 99,9 *per cent*), (see Table I). These findings agree with work by Hanekom, Shiloh and Slinger who found that the correlations between the subjective Durable Press rating and the H x T index usually exceeded the 99,9 *per cent* confidence level[20].

TABLE I

CORRELATION BETWEEN THE LOGARITHM OF H AND THE AATCC RANKING

Variables	Fabrics	Test Method	Conditions of Wrinkling	Recovery Time	Correlation Coefficient	Significance Level	Degrees of Freedom
(Log H) vs (AATCC) Ranking	Cotton/Polyester	AKU	20° C, 65% RH	24 hrs	0,99	Almost significant at the 99% level	3

TABLE II

CORRELATION BETWEEN THE VALUES OF H DETERMINED ON TWO INSTRUMENTS

Variables	Fabrics	Test Method	Conditions of Wrinkling	Recovery Time	Correlation Coefficient	Significance Level	Degrees of Freedom
Elma vs SAWTRI	Cotton/Polyester	AKU	20° C, 65% RH	24 hrs	0,90	99,9%	8

TABLE III

CORRELATION BETWEEN H AND T AFTER EITHER 1 HOUR OR 24 HOURS RECOVERY

Variables	Fabrics	Test Method	Conditions during Creasing*	Recovery Time	Correlation Coefficient	Significance Level	Degrees of Freedom
H, T	Cotton/Polyester blends	AKU/ SAWTRI	20° C, 65% RH	24 hrs	0,89	99,9%	11
H, T	Cotton/Polyester blends	AKU/ SAWTRI	20° C, Wet	24 hrs	0,96	99,9%	11
H, T	Wool/Polyester blends	FRL/ SAWTRI	27° C, 75% RH	1 hr	0,99	99,9%	20
H, T	Wool/Polyester blends	FRL/ SAWTRI	27° C, 75% RH	24 hrs	0,99	99,9%	20
H, T	Cotton/Polyester blends	AKU/ Elma	20° C, 65% RH	24 hrs	0,99	99,9%	3

*Recovery was always at 20° C and 65% RH.

The correlation coefficient between the values of H measured using the Elma Wrinklemeter and SAWTRI Method, is given in Table II, and it is significant at the 99,9 *per cent* confidence level.

2. **Correlation between the parameters H and T**

(a) The correlation between the values of H and T was obtained using the SAWTRI method on the cotton/polyester blend fabrics (blends ranging from 100 *per cent* cotton to 100 *per cent* polyester). The fabrics were wrinkled either at 20°C and 65% RH or wet at 20°C on the AKU tester and the surface profile measured after 24 hours recovery, the recovery period stipulated in the AATCC test. The correlation coefficient between H and T for the fabrics wrinkled at standard conditions was 0,89 and that when wrinkled wet was 0,96. Both these coefficients are significant at the 99,9 *per cent* confidence limits (see Table III).

(b) The correlation between H and T values also was calculated for a series of wool/polyester blend fabrics. The fabrics were creased according to the FRL method at 27°C and 75% RH and allowed to recover for one and 24 hours at 20°C and 65% RH before the profile was measured. The correlation coefficient between H and T after both one and 24 hour recovery was 0,99 which is significant at the 99,9 *per cent* confidence limits (see Table III).

(c) Good correlation was found between H and T values for a series of cotton/polyester blends when measured by the Elma Wrinklemeter after 24 hour recovery, the correlation coefficient being 0,99 which is significant at the 99,9 *per cent* confidence level (see Table III).

It is therefore evident from these results that little is to be gained in practice by measuring both H and T for fabrics which have been creased on AKU or FRL wrinkle testers.

3. **Correlation between values of H determined after one hour and 24 hours recovery, respectively**

(a) The correlation between the values of H after one hour and 24 hours recovery was calculated from results from the same series of fabrics referred to in paragraph (b) of the preceding section. From the results the correlation coefficient between the two recovery periods was found to be 0,97 which also is significant at the 99,9 *per cent* confidence level (see Table IV).

(b) The correlation coefficients between values of H after one hour and 24 hours were calculated for a series of mohair/cotton/polyester lightweight woven fabrics and cotton/polyester Raschel fabrics and were 0,91 and 0,97 respectively. The first was significant at the 99 *per cent* confidence level whereas the second, where there were only three data points, was not significant at the 90 *per cent* level (see Table IV).

To summarise, for the range of fabrics tested which ranged from all cotton, with poor wrinkle recovery properties, to wool and polyester, with good wrinkle recovery properties, the correlation between H and T was highly significant. There was also a good correlation between the one and 24 hour recovery values of H, except for the experiment where there was only degree of freedom.

TABLE IV

CORRELATION BETWEEN VALUES OF H AFTER 1 HOUR OR 24 HOURS RECOVERY

Variables	Fabrics	Test Method	Conditions of Wrinkling	Correlation Coefficient	Significance Level	Degrees of Freedom
H (1 hr) vs H (24 hrs)	Wool/polyester	FRL	27° C, 75% RH	0,97	99,9%	20
H (1 hr) vs H (24 hrs)	Mohair/cotton/ polyester	AKU	27° C, 75% RH	0,92	Almost significant at the 99% level.	4
H (1 hr) vs H (24 hrs)	Cotton/polyester Raschel DP Rating	AKU	27° C, 75% RH	0,97	Not significant at the 90% level.	1

4. **Correlation between H and either the Monsanto or the Shirley Crease Recovery Angles**

Poor correlation was found between H and both the Shirley and Monsanto crease recovery angles for the series of woven resin treated and untreated cotton and wool/cotton blends for the creasing conditions given in Table V. The correlation between the Monsanto crease recovery angle and H for the AKU test on resin treated mohair/cotton polyester fabrics also was found to be significant (see Table V).

Broadly similar results were found in the correlation between the value for H in the FRL test and either the Monsanto or Shirley crease recovery angles, though there was good correlation between the FRL and Shirley crease recovery tests when the tests were carried out under similar atmospheric conditions on a series of all-wool fabrics and resin treated wool/cotton blend fabrics (see Table VI). This good correlation does not always apply, however, as the results for the other experiments in this table show.

TABLE V

CORRELATION BETWEEN AKU VALUES AND CREASE RECOVERY ANGLES

Variables	Fabric Construction	Correlation Coefficient	Significance Level	Degrees of Freedom
H x T Index, 24 hr recovery vs Monsanto CRA; (20°C, 65% RH)	Plain weave, all-cotton and wool cotton blends, untreated and resin treated	0,068	*	25
H x T Index, 24 hr recovery vs Shirley CRA; (27°C, 75% RH)	Plain weave, all-cotton and wool cotton blends, untreated and resin treated	-0,032	*	23
H, 1 hr recovery, 27°C, 75% RH vs Monsanto CRA, 20°C, 65% RH	Resin treated light-weight woven mohair/cotton/ polyester blend	-0,780	90%	4
H, 24 hr recovery, 27°C, 75% RH vs Monsanto 20°C, 65% RH	Resin treated light-weight woven mohair/cotton/ polyester blend	-0,647	*	4

* Not significant at the 90% level.

TABLE VI

CORRELATION BETWEEN FRL WRINKLING RESULTS AND CREASE RECOVERY ANGLES

Variables	Fabric Construction	Correlation Coefficient	Significance Level	Degrees of Freedom
H x T Index vs Shirley CRA; 27° C, 75% RH	Untreated plain weave wool/ polyester blends	-0,423	90%	16
H x T Index, 27° C, 75% RH vs Shirley CRA; 20° C, 65% RH	Untreated plain weave wool/ polyester blends	-0,303	*	16
H, 1 Hr recovery, vs Shirley CRA; 27° C, 75% RH	A 55/45 wool/cotton blend fabric treated with easy-care resins	-0,763	95%	7
H x T Index, 24 hr recovery vs Shirley CRA; 27° C, 75% RH	Wool/synthetic blend fibres 200 g/m^2	-0,295	*	8
H, 1 hr recovery vs Shirley CRA; 75% RH, 27° C	All wool medium-weight	-0,828	99,9%	16
H, 1 hr recovery, FRL vs Monsanto CRA; 75% RH, 27° C	Easy-care treated wool/polyester blends	0,06	*	48
H, 1 hr recovery, vs Monsanto CRA; 65% RH, 20° C	Easy-care treated wool/polyester blends	0,06	*	48
H, 1 hr recovery, 27° C, 75% RH vs Monsanto 20° C, 65% RH	Wool/acrylic plain and 2/2 twill weave blends	0,230	*	28
H, 1 hr recovery, 27° C, 75% RH vs Monsanto 27° C, 75% RH	Wool/acrylic plain and 2/2 twill weave blends	0,081	*	27

* Not significant at the 90% level.

In general it would appear that the correlation between the Monsanto or Shirley crease recovery tests and the AKU or FRL tests is poor with the best correlation being between the Shirley and FRL tests when, as one would expect, the tests were carried out under similar conditions.

5. **Correlation between the crease recovery angle results obtained under different atmospheric conditions**

Table VII shows a summary of the results obtained on the various fabrics. All except one of the correlation coefficients for the correlation between the two

TABLE VII

CORRELATION BETWEEN THE CREASE RECOVERY ANGLES OBTAINED AT TWO DIFFERENT ATMOSPHERIC CONDITIONS

Variables	Fabric Construction	Correlation Coefficient	Significance Level	Degrees of Freedom
20° C, 65% RH vs 27° C, 75% RH (Shirley CRA)	Light-weight wool/ polyester blends	0,625	99%	20
20° C, 65% RH vs 27° C, 75% RH (Monsanto CRA)	Light-weight wool/ polyester blends	0,528	95%	20
20° C, 65% RH vs 27° C, 75% RH (Shirley CRA)	Wool/polyester blends	0,759	99,9%	16
20° C, 65% RH vs 27° C, 75% RH (Shirley CRA)	Wool/polyester blends	0,927	99%	4
20° C, 65% RH vs 27° C, 75% RH (Monsanto CRA)	Wool/polyester blends	0,770	*	4
20° C, 65% RH vs 27° C, 75% RH (Monsanto CRA)	Cotton-rich Raschel fabrics	0,984	95%	1
20° C, 65% RH vs 27° C, 75% RH (Monsanto CRA)	Easy-care treated plain weave wool/ polyester blends	0,741	99,9%	48
20° C, 65% RH vs 27° C, 75% RH (Monsanto CRA)	Wool/acrylic plain and 2/2 twill weave blends	0,918	99,9%	27

* Not significant at the 95% level.

TABLE VIII

CORRELATION BETWEEN SHIRLEY AND MONSANTO CRA DETERMINED UNDER THE SAME ATMOSPHERIC CONDITIONS

Variables	Fabric Construction	Correlation Coefficient	Significance Level	Degrees of Freedom
Monsanto CRA 20° C, 65% RH Shirley CRA 20° C, 65% RH	Untreated plain weave wool/ polyester blends	0,805	99,9%	20
Monsanto CRA 27° C, 75% RH Shirley CRA 27° C, 75% RH	Untreated plain weave wool/ polyester blends	0,698	99,9%	20

atmospheres employed for creasing fabrics at SAWTRI were found to be significant at the 95 *per cent* level. The majority of the fabrics tested were wool or wool blends.

6. **Correlation between the results for Shirley and Monsanto tests**

All the results in Table VIII show good correlation between the Shirley and Monsanto tests for the range of fabrics tested. Whether the same test environment or a different one was used did not appear to affect the significance of the correlation.

It would appear, therefore, from the results in this and the preceding section that there was good correlation between the Monsanto and Shirley crease recovery angles with the choice of experimental conditions in general leading to a similar ranking of the fabrics.

CONCLUSIONS

For the AKU test very good correlation was found between the AATCC Wrinkle Recovery Rating and the logarithm of the mean wrinkle height (H) for a series of cotton polyester blend fabrics. For the series of fabrics chosen, which were the same colour as the replicas (white), the correlation between the visual assessment and the objective profile method is probably at its best since colour, depth of shade or patterning is known to affect the visual comparison of the test samples with the replicas.

The very good correlation between the values of H and T for both the AKU and FRL crease recovery tests, where an ordered arrangement of creases is inserted

in the fabric as distinct from the random creases which are inserted during laundering, indicate that for these tests little additional information is to be gained by using both parameters and that H would suffice, thereby reducing the labour involved in carrying out the wrinkle tests. Likewise the very good correlation between one hour and 24 hours recovery indicates that little is to be gained from measuring the surface profile after both recovery times. The most suitable recovery time should, therefore, be chosen for a particular experiment.

When comparing the results for the four test methods employed at SAWTRI good correlation was found between the Shirley and Monsanto tests, with the choice of the test environment not materially affecting the ranking of the fabrics. When comparing the Monsanto or Shirley results with the AKU or FRL results, however, the correlation was generally poor although in some cases the correlation between the Shirley and the FRL results was significant, particularly when the tests were carried out under the same atmospheric conditions.

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