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Objective evaluation of multidirectional fabric creasing

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Objective evaluation of multidirectional fabric creasing

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Creasing is one of the most important properties of textiles for apparel application. Most fabrics are regularly evaluated by means of etalons, that is, visual standards. Nevertheless, due to the disadvantages of visual evaluation, which is unreliable and time consuming, several objective methods were developed. In this article, a new objective method of multidirectional evaluation of creasing is described. We have proposed the test method of angle recovery using image processing. The specimen of the fabric was of a circular shape and it was measured by the method of angle recovery in various directions. We compared the results obtained from our method with the method described by Sommer and by the hollow cylinder method also. We found good conformity between the results obtained from our method and the method described by Sommer.

Keywords: clothing; fabric creasing; crease recovery; recovery angle

Introduction

For some consumers the appearance of a garment is very important. They require clothing without creasing and wrinkling during wearing. The most important factors that influence wrinkling of fabrics during wearing are the type of fibres, structure of the fabric, fold direction, and temperature as well as humidity developed by body activity during wearing.

Wrinkle Recovery Method AATCC 128 (Standard ISO 9867) and Crease Recovery Method AATCC 66-2008 (Standard ISO 2313) are among the most used methods for evaluating creasing of textiles. However, the method of wearing is still used as well, which is obvious from the work of Salter, Roczniok, and Stephens (1998).

It is possible to simulate the real creasing of fabrics by using the method AATCC 128. It is "the method of a hollow cylinder". A set of photographs of the textile surfaces is often used for the evaluation of the wrinkling of textiles, which is a subjective evaluation. Nevertheless, we can find objective methods of evaluation of wrinkling in many research works.

The AATCC 66-2008 is a traditional method of evaluating textiles. Nevertheless, creasing is not sufficiently realistically described, because the specimen of the fabric is creased only in two directions (warp and weft) and that does not correspond with the real creasing of the worn fabric. However, there are studies in which the authors try to remove the deficiencies of this method (Fan, 2001; Kang, Cho, & Whang, 1999; Kim, 1999; Mihailovic, Nikolic, & Simovic 1995; Nikolic, Simovic, & Mihailovic, 1999; Yu, Yao, & Xu, 2009).

This article aims to inform about the innovative method of measuring fabric wrinkling using the principle of measuring the angle of recovery.

Experimental part

Principle of measurement and innovation of the method

The innovative method of evaluation of the creasing of textiles by means of the angle of recovery is based on the standardised method CSN 800919 (EN 31092).

As shown in Figure 1(a), the semicircle sample, diameter (d) = 4.5 cm (2), is fixed in the clamping system (1). Then the sample is loaded, as shown in Figure 1(b), with the mass of 1 kg. The time of loading is 5 min, and then the sample is unloaded (Figure 1(c)).

The manual measurement of the angle, as shown in Figure 2, is subjective and imprecise, and therefore this part of the test has been changed. The angle of recovery was scanned with a web camera, as shown in Figure 3.

It is not an optimal way to measure samples only in the directions of warp and weft. Such a measurement does not correspond with the real behaviour of fabrics during wearing. Therefore, the samples should be measured in many directions, which means getting closer to the real behaviour of fabrics when worn. As

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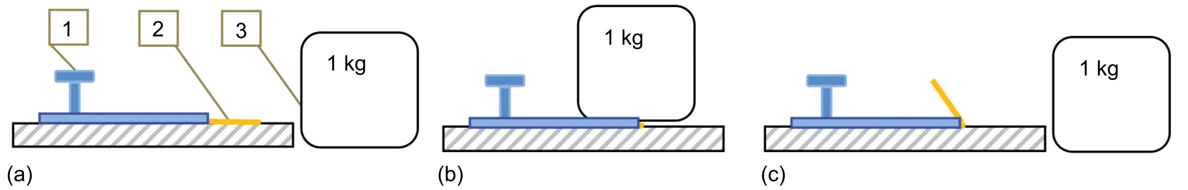


Figure 1. The principle of measuring recovery angle: (a) clamping system, (b) sample, and (c) mass (1 kg).

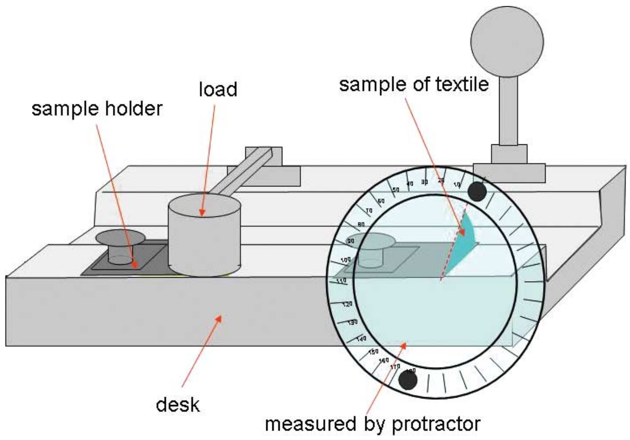


Figure 2. Manual measurement of the angle (CSN 80 0819).

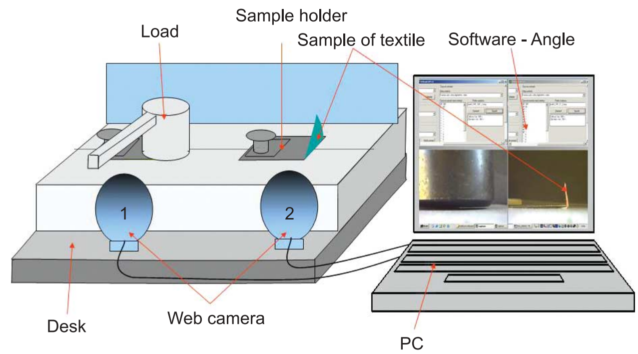


Figure 3. Innovation – recovery angle is scanned by a web camera.

shown in Figure 4(a) and 4(b), we used 12 positions for cutting samples where the edge of the sample was turned by 30° owing to the warp yarns in the interval from 0° to 330°. If there is a big set of samples, it is sufficient to cut the samples in the interval from 0° to 180° degrees.

We have investigated which shape of sample is optimal for testing the anisotropy of creasing. We have found out that rectangular samples are not suitable for the measurement for two reasons. First, if the rectangular shape of the sample is used, we need a larger area of the fabric for our experiments, as shown in Figure 4(a) and 4(b). Second, rectangular shape of the sample has a tendency to twist during measurement, as shown in Figure 4(c) and 4(d). If semicircular shape of the sample is measured, the described effect is smaller.

The next innovative step was obtaining the value of the measured angle. The manual method was replaced by the image processing method – NIS-Elements. We unloaded the 1 kg mass off the sample and took a picture of the sample with a web camera. We used our own software for processing pictures. By means of this

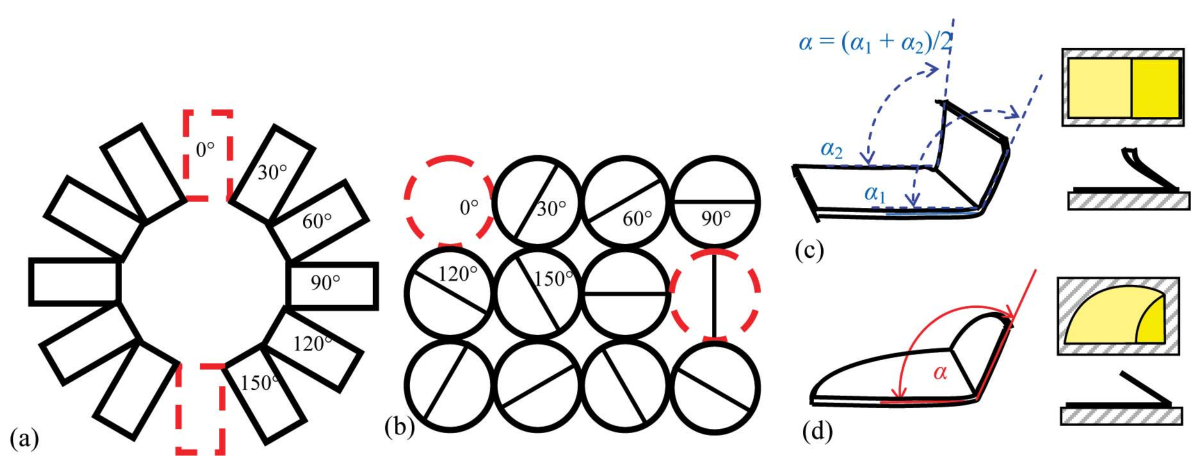


Figure 4. (a) Scheme of cutting – rectangular samples of dimension 2 × 4.5 cm. (b) Scheme of cutting circular samples diameter, d = 4.5 cm. (c) Shapes of the bent sample – rectangular. (d) Shapes of the bent sample – semicircle.

software we were able to measure the changes of the recovery angle at time lag of 1 s, which is important for investigating the viscoelastic properties of the fabric specimen.

We suggest a more accurate formula for the calculation of the creasing coefficient. Coefficient of creasing at time 5 min (C_{300}) can be defined as:

$$C_{300} = \frac{\alpha_{300}}{180°}[1] \quad (1)$$

where α_{300} is average of the angle recovery at time 5 min for multiaxial direction. In our case it was average of the six values for the one direction (i.e. φ = 30° – sample was turning by 30° owing to the warp yarns) and 12 values for direction (φ = 30°,60°, …, 330°). Thus, the coefficient of creasing (C_{300}) for one fabric was calculated as average from 72 values. The coefficient of creasing (C_{300}) ranges from 0 to 1 – for crease-resistant textiles C_{300} approaches the value 1, while textiles that crease easily C_{300} is close to value 0.

However, there are cases where identical average values of recovery angle can be obtained. We analysed the measured values and found out that one set contained close values of recovery angle (60°, 60°, 60°, 60°) and the second set contained very different values (80°, 40°, 80°, 40°), although the mean of both was 60°. We suggest a more accurate formula for calculation, i.e. harmonic mean. When we carried out a new calculation from two datasets, we obtained for the first set the result of 60° and for second set of values the result of 53°.

From the statistical analysis we found out that comparing of values (identical average) of measurement of creasing is an appropriate solution as we use weighted average when the weight is $W = (180 - \alpha_{i300})/180$. The value α_{i300} is recovery angle when i = 1–12. Coefficient of creasing for this specific case C_{w300} is:

$$C_{w300} = \frac{\sum_{i=1}^{12} W_i \alpha_{i300} / \sum_{i=1}^{12} W_i}{180°}[1]. \quad (2)$$

Harmonic average or weighted average should be used only when identical values of creasing coefficient are obtained. In other cases we used only average, and compared our results with the results of Sommer's "Güterziffer" K:

$$K = \frac{\alpha_0 \alpha_5}{324} \times 100[\%] \quad (3)$$

where α_0 is the immediate recovery angle and α_5 is the recovery angle at time 5 min.

As shown in Tables 2 and 3, we compared order of values, C_{300}, K and order values by cylinder method. We also found good conformity between the average of α_{300} values and the method by Sommer's "Güterziffer" K.

The innovative steps can be summarised in the following way:

- We replaced manual reading of angle by image scanning with web camera.
- We suggest using the SOPS software.
- We simulated real behaviour of the fabrics by measuring creasing in different directions with regard to warp yarns.
- We infer that samples of circular shape had lesser tendencies to twisting edges.
- We are able to measure the relaxation of fabric samples per second.
- We suggest a more accurate calculation of the coefficient of creasing.

Characteristics of the materials

For the experiment 100% cotton fabrics, without chemical finishing, i.e. raw materials, were used. While in the first set of samples, M1–M6, the weft and the warp yarns were of different types, in the second set, S1–S5, both the weft and the warp yarns were woven from the same type of yarns. The first set of fabrics contained different weaves (plain, twill, satin), while the other set contained only plain weaves. The characteristics of the fabrics are shown in Table 1.

Measuring of recovery angle

The web camera was scanning the recovery angle in the following intervals: every second from first to 10th second, every 5 s from 11th to 60th second, every minute from 61st second to 5 min. Within the time of relaxation (5 min), 24 digital photographs of recovery angle were obtained. Then the recovery angle was measured with the help of the program of NIS-Elements.

For the recovery of textiles, the first few seconds of relaxation of the sample are important. Within this period, elastic properties of the textiles, which affect the final aesthetic appearance of the fabric, become evident. Figure 5 shows the values of the angle recovery during 1-hr relaxation of the sample fabric (at time: 1 s, 1 min, 5 min and 1 hr). As it is obvious from Figure 6, the largest value of the angle recovery of the textile takes place within the first second of the recovery of fabric.

The manual measuring did not enable the measuring of the recovery angle at very short intervals, for

Table 1. Characteristics of materials.

Code of fabrics	Weave	$\text{Sett}_{\text{warp}}$ (yarns/cm)	$\text{Sett}_{\text{weft}}$ (yarns/cm)	T_{warp} (tex)	T_{weft} (tex)	Surface density (g/m^2)
M1	Plain	24.4	16.0	40	33	158
M2	Plain	24.4	22.0	40	33	182
M3	Twill	24.4	16.0	40	33	153
M4	Twill	24.4	22.0	40	33	176
M5	Satin	24.4	22.0	40	33	179
M6	Satin	24.4	16.0	40	33	153
S1	Plain	23.0	10.0	29	29	104
S2	Plain	23.0	15.0	29	29	120
S3	Plain	23.0	19.0	29	29	140
S4	Plain	23.0	24.0	29	29	160
S5	Plain	23.0	26.0	29	29	170

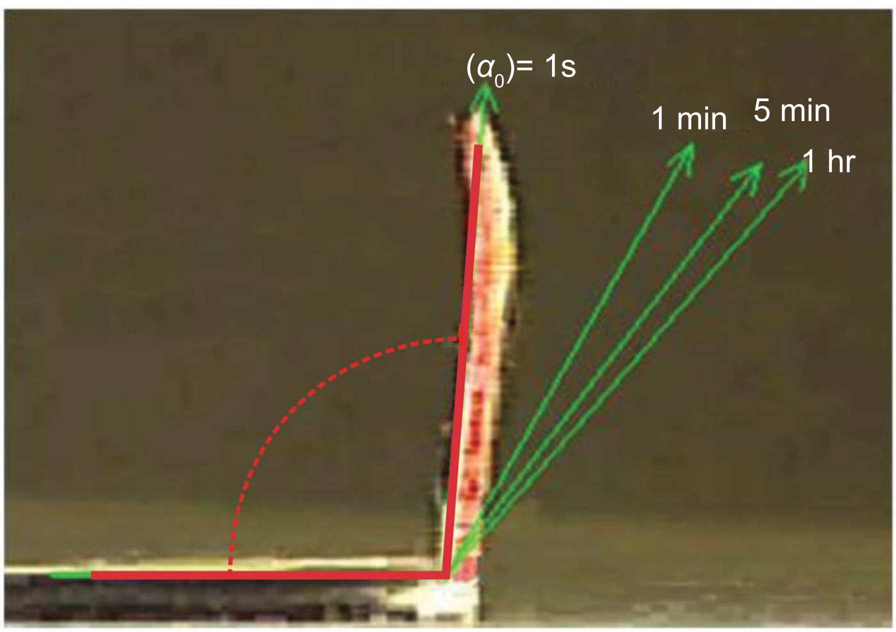


Figure 5. One-hour relaxation of the sample fabric.

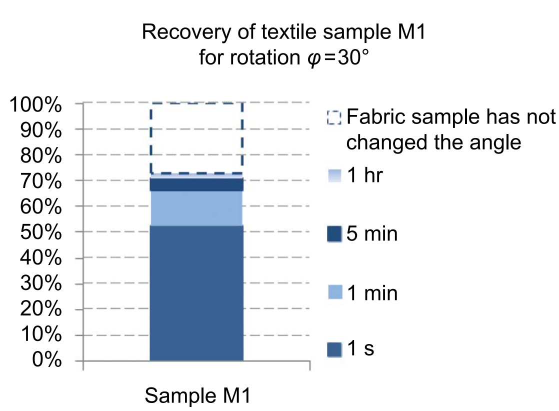


Figure 6. Recovery of the sample M1.

example, at the first second. The experimenter could not manage to unload the sample and at the same time to set the protractor for measuring it. That was one of the reasons why the immediate recovery angle was only calculated by the Sommer formula (Sommer & Winkler, 1960):

$$\log\alpha_0 = \log\alpha_{60} - 3.5\times\log\frac{\alpha_{60}}{\alpha_5} \tag{4}$$

where α_0 is the immediate recovery angle, α_5 recovery angle at time 5 min and α_{60} recovery angle at 60 min.

As we used a web camera, we were able to scan the picture of relaxation angle of the fabric at the first second after unloading. The achieved values were

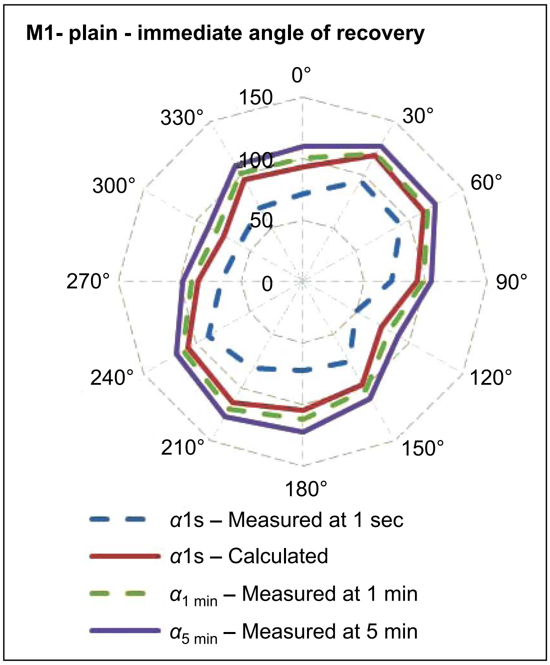


Figure 7. Comparison of the measured and calculated (first second) immediate angle of recovery. Values are given for all directions of rotation which were measured.

compared with the calculation of the immediate recovery angle by the Sommer's equation. The result of the comparison is shown in Figure 7. The computed values obtained by Sommer formula (Equation (4)) differ from the measured values by about 20% approximately.

Results and discussion

Coefficient of creasing

We compared order of values: C_{300}, K and order values by cylinder method for different materials, as is shown in Tables 2 and 3. We also found good conformity between C_{300} values and the method by Sommer's "Güterziffer" K. The order of values are identical for fabrics M2, M3, M5 and M6 and for S1, S2 and S3. We have not found consensus in orders of fabrics M1 and M4 and S4 and S5 but results were very near.

Anisotropy of creasing and the parameters influencing creasing

As is shown in Figure 8, the creasing is also influenced by the changing number of yarns in the sett (in this case we change the sett of weft yarns) and the type of weave of the fabric, as is shown in Figure 9. The influence of the sett on the creasing was observed in the samples of plain weave. The recovery angle increased with the growing number of yarns in the weft sett (see fabrics S1 and S2 in Figure 8a); however, if the weft sett approximately equals to the warp sett (see fabric S3 in Figure 8b), the recovery angle does not increase any more.

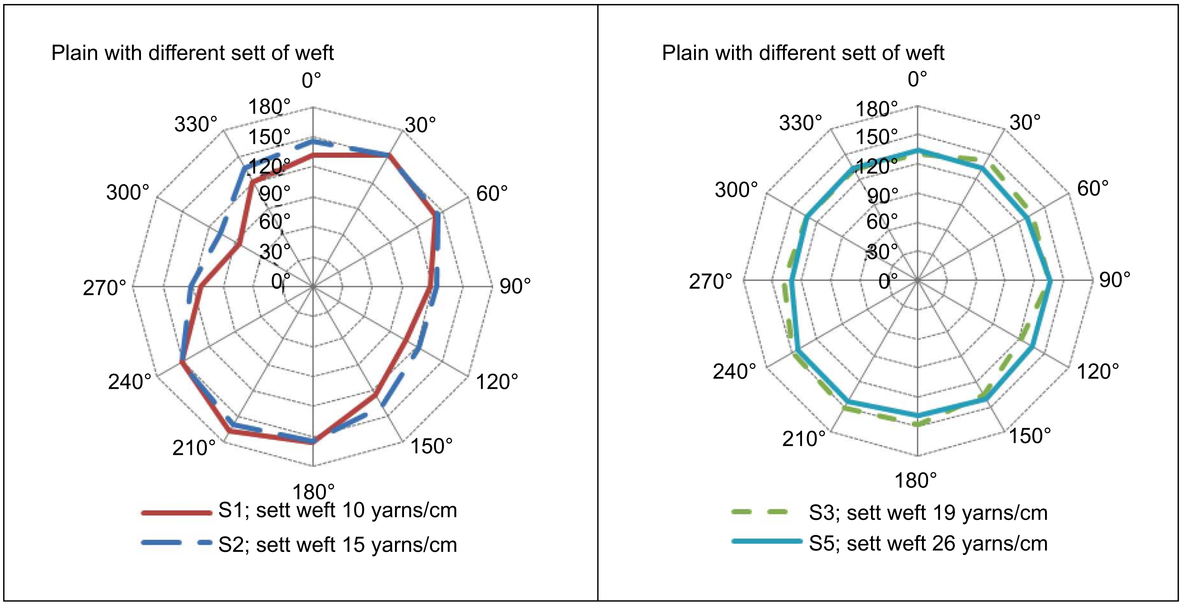
If the value of the weft sett is higher than that of the warp sett (S5; Figure 8(b)), then the value of recovery angle decreases. The low recovery angle of the fabric can be explained as follows: if there is a big space between the yarns and at the same time a low number of yarns are bent (fabrics S1 and S2; Figure 8(a)), then the yarns are permanently deformed at the

Table 2. Results of the creasing for different weave of fabric at 5 min.

Code of fabrics	C_{300} (°)	Order C_{300} (°)	K (%)	Order K (%)	Order by cylinder method
M1	0.6401	5	29.3	4	5/6
M2	0.6128	6	25.4	6	5/6
M3	0.7032	1	36.2	1	3
M4	0.6545	4	28.7	5	4
M5	0.6682	3	30.9	3	2
M6	0.6885	2	32.4	2	1

Table 3. Results of the creasing for different sett yarns of fabric at 5 min.

Code of fabrics	C_{300} (°)	Order C_{300} (°)	K (%)	Order K (%)	Order by cylinder method
S1	0.7546	5	41.8	5	5
S2	0.7550	1	47.4	1	3
S3	0.7651	2	46.3	2	2
S4	0.7684	3	45.4	4	4
S5	0.7269	4	45.9	3	1



(a) (b)

Figure 8. Influence of the sett of fabrics on anisotropy of the recovery angle – creasing of the fabric. Sett of warp $Sett_{warp}$ = 23 yarns/cm.

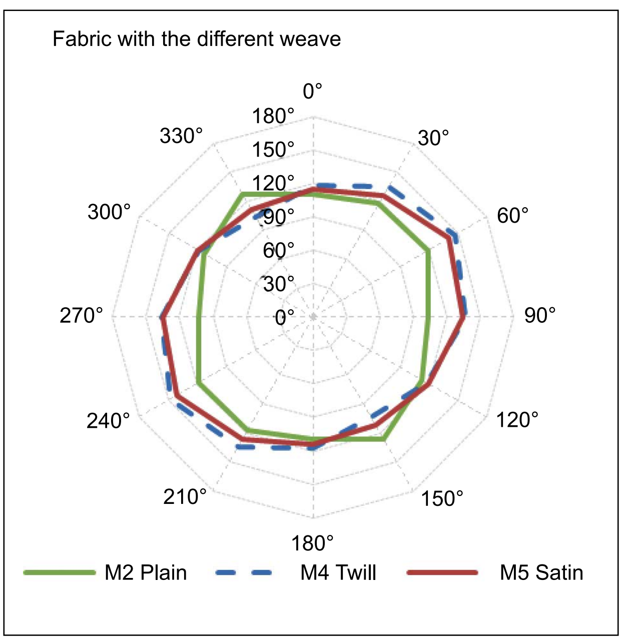


Figure 9. Influence of the weave of fabrics on anisotropy of the angle recovery.

point of folding. The yarns lack energy to recover. It is possible to see a similar effect (permanent deformation) at fabrics with too high number of yarns in the sett (fabric S5; Figure 8(b)).

Figure 8(a) and 8(b) show the results of values of measuring recovery angle for 12 directions. From the anisotropy of the fabric, usually described by a polar diagram, extreme directions of the creasing of fabric can be determined. According to the standard for measuring creasing, it is necessary to measure the angle of recovery only in two directions: in the direction of the warp and that of the weft. In the work of Mihailovic the samples are measured only in the following directions: 0°, 30°, 60° and 90°. In samples S1 and S2, as obvious from Figure 8(a), there is no symmetry; the values are not axially symmetrical, i.e. between the value of angle recovery for directions 30° and 150° or for directions 60° and 120°. The fabrics showed centrally symmetrical values for the directions 30° and 210°, 60° and 240°, etc., that is the reason why measuring in directions from 0° to 150° is suitable. The textile is not a homogenous material and that influences the values of recovery angle for different directions.

Another factor, which influences creasing, is the location of binding points in the fabric, i.e. influence of the weave of the fabric. The change of recovery angle depending on the kind of weave is evident from Figure 9. Fabrics M4 and M5 relax most, i.e. fabrics of twill and satin weave, respectively.

Conclusion

The innovative method of measuring recovery angle simulates the real creasing of textiles. Scanning samples with a camera makes possible to measure the angle of recovery at random intervals of 1 s. The semicircular shape of the sample eliminates the influence of the winding effect during the recovering of the textile. The coefficient of creasing (C_{300}) ranges in the interval from 0 to 1 – for crease-resistant textiles C_{300} approaches the value 1, while textiles that crease easily C_{300} is close to value 0. We compared order of values C_{300} and K for different materials and found good conformity between C_{300} values and the method by Sommer's "Güterziffer" K.

Resulting from the polar diagram, plain weave textiles with a low value of weft sett show direction asymmetry of creasing. There is a smaller angle of recovery in the direction of weft than in the direction of warp. The largest relaxation is in the diagonal directions 30° and 60°. The increasing number of yarns in the weft will influence the growing recovery angle. If a plain weave textile has a too high value of sett, the recovery angle will decrease. Textiles with symmetric sett and with the same fineness of weft and warp yarns show low value of creasing. Satin and twill weave textiles, in comparison with plain weave textiles, crease less.

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