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Drape analysis of fabrics used for outerwear

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This study has been aimed at analyzing the fabrics of different characteristics drapes, considering the specimen–shape which is similar to the garment part construction. Three wool and wool blended fabrics suitable for outerwear have been chosen for the study. The bending rigidity of tested fabrics is determined using the bending meter which works on the cantilever principle. In order to examine the influence of clothes construction on the fabrics drape, the cape is chosen for this work. The specimen has the shape corresponding to the shape of a side part of a cape which can be flared during design until desirable degree has been reached. For prediction of fabric behaviour in a garment, the traces of horizontal projections of specimen's bottom view as well as specimen's front view are analyzed. The results show that geometrical fold characteristics depend not only on the structural and mechanical properties of fabrics but also on the clothes construction.

Keywords: Bending rigidity, Blended fabric, Cotton fabric, Drape, Elastane, Polyester fabric, Wool fabric, Worsted fabric

1 Introduction

One of the most important properties of fabrics is their ability to drape into complex three-dimensional shapes and to provide a graceful aesthetic effect for apparel and other industrial design and uses. This fabric property is based on the deformation under its own weight and on the ability of producing a free flowing form. Drape in a garment depends upon the draping quality of material used and on the garment construction[1]. The fabric parameters, such as structure, yarn type and fibre content, as well as its finishing treatment have an influence on its drape[2]. The textile and clothing industry has traditionally used Cusic drape meter for the assessment of fabric drape. Based on measurements from the drape meter, most researchers reported the relationship between fabric drape and other mechanical properties, such as bending, shearing and extension. The material properties important to the fabric draping are often measured using the Kawabata evaluation system (KES)[3] or the fabric assurance by simple testing system (FAST)[1]. Drape coefficient is the main parameter for fabrics drape evaluation. A low drape coefficient indicates easy deformation of a fabric and a high drape coefficient indicates less deformation. It has been established[4] that drape coefficient of 30-40% is most suitable for worsted fabrics with respect to garment appearance. The drape coefficient is relevant to the drape of fabrics but is not sufficient, and hence other parameters such as number of folds and their dimensions are also used to describe the drape quality[3,5]. Fabric drape is time-dependant problem and the drape coefficient of a fabric changes significantly over a longer time period[6]. Some studies have focused not only on the static but also on the dynamic drape, because it shows the actual dynamic real-life performance. For this purpose, the dynamic drape tester and the regression equations were derived from mechanical parameters of fabrics obtained from KES system[7]. The practical mass-spring model allowing describing and simulating the dynamic draping behavior of selected woven and knitted fabrics may be also used[8]. It should be noted that imaging techniques have the potential to fully describe the drape character of fabrics. It allows receiving the detailed description of fabric drape profiles captured directly from a traditional drape tester instrument, and identifying any observed relationships between the measured drape parameters[9]. Fabric drape simulation is one of the most important technologies in virtual garment design process[10,11,12]. In a work[13], series of simulation results were generated using an implicit integration based simulation engine with various physical properties and a search algorithm was developed to find ont a property combination which

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generates the most similar result to that obtained by Cusick tester. Clothes usually consist of different components. To understand the final garment appearance, drape should be treated as a complex problem that incorporates the material properties, pattern construction, types of seam and their directions on the garment[5,14,15]. As a rule, the drape coefficient was, in most cases, greater for samples with seams than in samples without seams. On stitching with different types of seams, the drape coefficient may increase by 13-42% (ref. 16). It was determined that seam allowance, seam position, seam direction and number of seams also have the influence on the drape quality of fabric[17,18]. The behaviour of fabric drape may not be the same as the behaviour of garment drape. The examination of the difference between the behaviour of fabric drape and garment drape through drape coefficient and drape profile analysis has been reported earlier[3]. The circular fabric and a circular flared skirt hanged over the same object were used for this experiment. In order to evaluate the aesthetic performance of finished garments, sometimes those methods are used wherein shape of specimen is closer to the garment construction[14].

The drape coefficient is widely used parameter to describe fabric drape but it needs other parameters to explain the fabric behavior. Therefore the fabric drape profile and its geometrical characteristics are used simultaneously for fabrics deformability in hanging state determination. The aim of the present work is to analyze fabrics drape using specimen shape which is similar the garment part construction.

2 Materials and Methods

Three wool and wool blended fabrics were chosen for this study (Table 1). Fabrics M1 and M2 were knitted and fabric M3 was woven. Fabric M1 was given special treatment of washing and hence is named ‘boiled wool’.

Fabric thickness was determined under a pressure of 1.0 kPa using Textil – Dickenmesser DPT 60 digital instrument; density in accordance with LST EN 1049-2:1998 and mass per square meter in accordance with LST EN 12127. The bending meter, according to FAST system, was used to measure the fabric stiffness. The instrument works on the Cantilever principle, which involves pushing of fabric specimen over inclined plane until it has bent to a specified angle (41.5^0). The received length ($2c$) of the fabric was measured with the ruler. Then a basic parameter as bending rigidity *(B)* was determined using the following equation:

$$B = W \times c^3 \times 9.81 \times 10^{-6}\ \mu\text{Nm} \qquad \ldots (1)$$

where W is the mass per unit area (g/m^2); and c, the half of fabric bending length.

The characteristic B was measured both in length-wise and cross-wise directions. In order to examine the influence of clothes construction on the fabric drape, the cape was chosen in this work. The specimen has shape corresponding to the shape of a side part of a cape which can be flared during design until desirable degree [Fig. 1(a)]. In spite of spreading degree, the side parts of cape would have the ability to hang in graceful folds. The specimen had two

Table 1—Main characteristics of tested fabrics

Symbol	Composition	Stitch density, cm^{-1}		Mass per unit area, g/m^2	Thickness, mm	Structure
		Wale	Course			
M1	100 % wool	10	6.5	366	2.79	Plain weft knitted
M2	51% wool+ 49% cotton	6	12	410	1.29	Double 1×1 rib
M3	30% wool+ 68%polyester+ 2% elastane	20 Ends	29 Picks	208	0.4	Plain woven

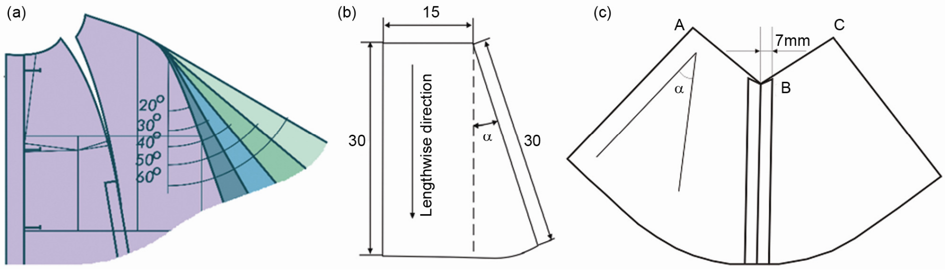

Fig. 1—Part of cape with its possible flare out degree (a), shape and measurements of specimen element (b), and ultimate shape of specimen with seam (c)

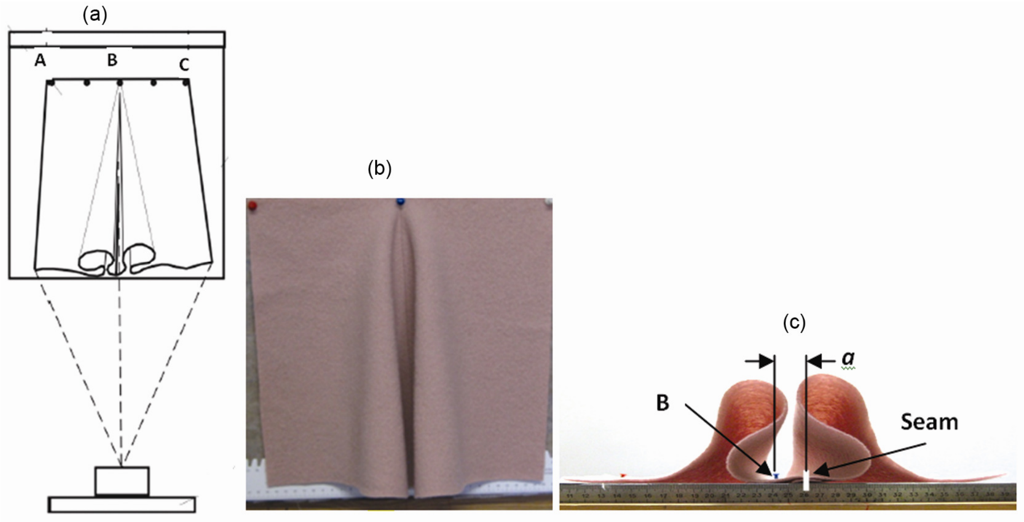

Fig. 2—Schematic view of specimen supporting (a), front (b), and bottom (c), images of specimen M1, when α=40^0

identical parts joined with seam. The shape of one part is shown in Fig. 1 (b) and sewn specimen is shown in Fig. 1 (c). The angle of seam position α was changed from 10^0 to 60° with step of 10^0 for every measurement. The seam was made using sewing machine Juki DLU 490. The stitch density was 4 stitches/cm, the needle size was No 70, and the thread was a polyester spun 50S/2 5000Y. Machine loading and thread tension were always kept constant. The seam allowance was pressed open and equal to 7 mm.

The test of fabric drape was performing agreeably to following conditions. The upper selvages A-B and B-C of specimen were supported in a straight line to plate as it is shown in Fig. 2 (a). The bottom and front views of folds were captured with a digital photo camera Toshiba PDRM70 [Fig. 2 (b) (c)].

The specimen bottom traces as waves (nodes) were processed by graphical program AutoCAD 2000. Since the fabrics are anisotropic and exhibit different mechanical properties, their bottom may exhibit different traces shape. Therefore, each trace of specimens bottom view was characterized by such geometrical measurements, as wave high (h), wave base length (b), maximum wave's width (p) and minimum wave's width (n) [Fig. 3 (a)]. The fold of perfect shape must be straight, symmetrical and characteristic p wave ought to be equal to p_1+p_2. More often the fold may lean on one side, therefore the additional characteristic of lean angle δ was determined [Fig. 3 (b)]. The degree of fold lean δ_n was calculated using the following formula:

$$\delta_n=90-\delta, \text{ deg} \qquad \dots (2)$$

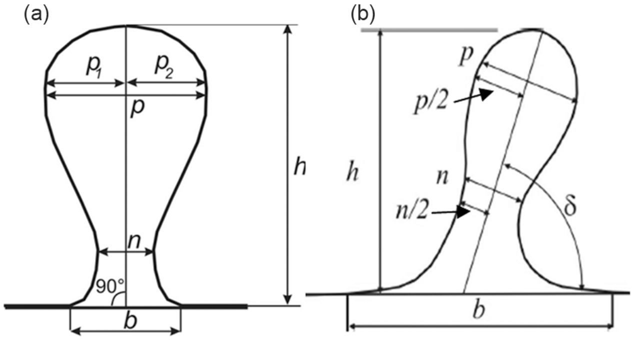

Fig. 3—Traces of horizontal projections of specimen bottom view and measurements of symmetrical (a), and leaned (b) wave

It should be noted that during the test all specimens bottom traces were formed into two folds. In this case not only left (A) and right (B) folds characteristics were determined, but also their average values were calculated. After folds formation the seam must remain vertical. The degree of seam shift from the vertical position a was measured in millimetre [Fig. 2 (c)].

In each case, 3-5 separate measurements were taken. The coefficient of variation (CV) exceeded 3.2 % for the bending rigidity but did not exceed 10% for folds geometrical characteristics. All measurements were taken after the specimens had been conditioned in standard atmospheric conditions for 24 h at 20 ± 2 °C temp. and 65± 2% RH.

3 Results and Discussion

Usually woven fabrics are more rigid than knitted fabrics, however during our test the highest value of characteristic B is determined for knitted fabric M1

(Fig. 4). It is known that fabrics bending rigidity depends not only on their yarn properties and density, but also on the fabrics thickness and weight, while the weight of the fabric provides the force causing it to bend down, the larger thickness provides higher resistance. Therefore, the thin and comparably light woven fabric M3 has shown lowest values of characteristic *B* while the heavy and thick knitted fabric M1 shows the highest. Taking into account the construction of tested specimens used for drape test, the more significant influence on the folds formation has fabrics bending rigidity in cross-wise direction. As evident from Fig. 4, the characteristics *B* of fabrics M2 is higher (~76.4 %) in cross-wise than in length-wise direction. The bending rigidity of fabrics M1 and M3 in length-wise direction is similar. The results indicate that bending rigidity of tested specimens varies from 6.25 µNm to 28.72 µNm. With reference to these values, FAST 'fingerprint' recommends woven worsted fabrics to be divided into three groups, namely limp fabrics $B<5$µNm, average stiff fabrics 5µNm $\leq B \leq$14µNm and stiff fabrics $B>$14µNm. Our test has shown that according to the rigidity results in two principal directions the fabrics M2 and M3 may be characterised as average stiff fabrics while fabric M1 as stiff.

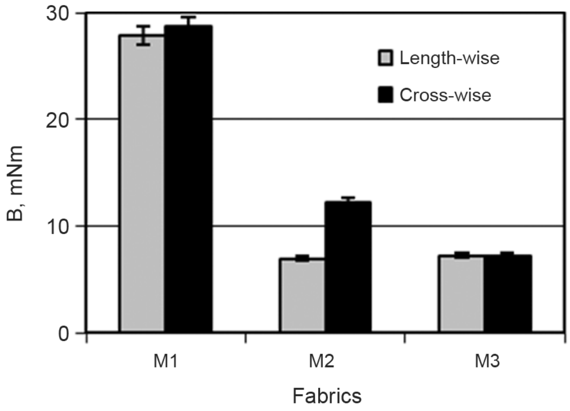

Fig. 4—Fabrics bending rigidity *B*

Results of the waves high (*h*) changes using different seam position angle (α) are shown in Fig. 5. Considering these results, it is observed that as the seam position α increases up to 50^0, the characteristic *h* for all fabrics also increases. At α=60^0 the curves trace of fabrics M1 and M2 slightly goes down, whereas the waves high *h* of woven fabric M3 decreases considerably. During fold formation the fabric bending proceeds over the cross-wise direction. Therefore, the highest wave is received for the stiffest fabric M1. As for the softest fabric M3, the test has shown that different seam position angle (α) changes waves high more considerably as compared to two other fabrics. It is also determined that differences between left and right waves high are varied from 2 mm to 9 mm.

Figure 6 shows that seam position angle α has no marked influence on the maximum wave width *p* of woven fabric M3. The wave width remains almost the same in spite of the seam position. For the rest two fabrics only using higher seam position angle, i.e. α=50^0 for fabric M1 or α=40^0 for fabric M2, the characteristic *p* have changed considerably. It should be noted that differences between right and left wave width are also largest at this stage and especially for rigid fabric M1.

The results of waves base length *b* changes are presented in Fig. 7. It can be seen that waves base length *b* decreases with increasing the seam position angle α. The linear relation between these two characteristics is found for fabrics M1 and M3. The changes of waves base length *b* of these fabrics are almost similar, though the bending rigidity of fabric M1 is considerably higher than that of

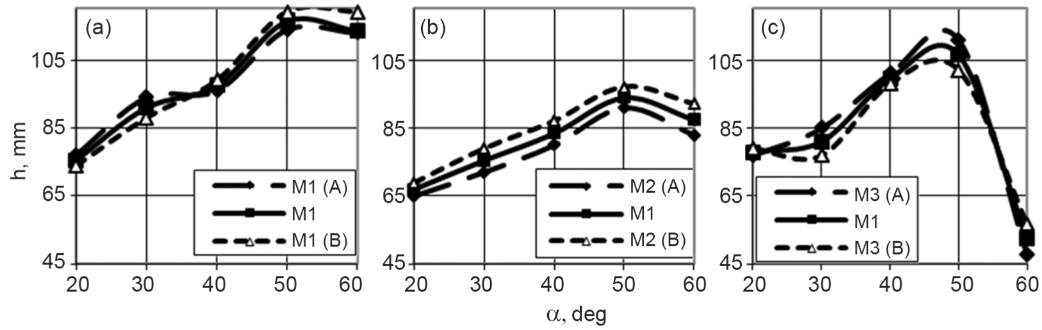

Fig. 5—Influence of seam position angles (α) on the waves high (*h*) of fabrics M1 (a), M2 (b) and M3 (c) [M1, M2, M3—average values; M1(A), M2(A), M3(A) —values of left fold; and M1(B), M2(B), M3(B) —values of right fold]

fabric M3 (Fig. 4). It can be seen from Fig. 7 (b) that the shape of fabric M2 curve is different. It is evident that at minimum value of seam position angle (α=20^0) characteristic *b* of M3 fabric is lower than fabrics M1 and M2. When seam position angle α exceeds 40^0, the increase in base length of M2 fabric waves has stops (Fig. 7), while folds width continues to grow (Fig. 6). The test also has shown that fabrics M2 and M3 exhibit more considerable differences between the values *b* of right and left waves.

The effect of the seam position angle α on the waves minimum width *n,* which may be characterized as fold 'neck', is shown in Fig. 8. It is obvious that at minimum seam position angle (α=20^0) the highest values of characteristic *n* is determined for rigid knitted fabric M1 and pliable woven fabric M3, while the lowest value is found for the knitted fabric M2. According to the results, the higher the seam position angle, the narrowest is the folds 'neck' until its width exceeds 0. It happens at 50^0 for fabrics M1 and M3, while at 30^0 for fabric M2.

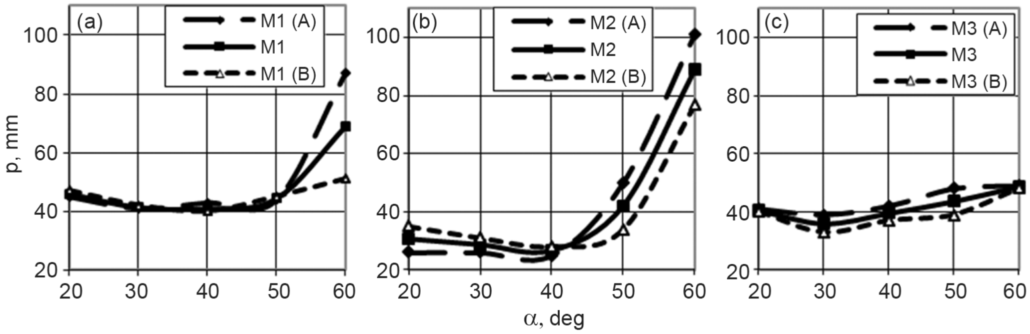

Fig. 6—Influence of the seam position angles (α) on the folds' maximum width (*p*) of fabrics M1 (a), M2 (b) and M3 (c) [M1, M2, M3—average values; M1(A), M2(A), M3(A) —values of left fold; and M1(B), M2(B), M3(B) —values of right fold]

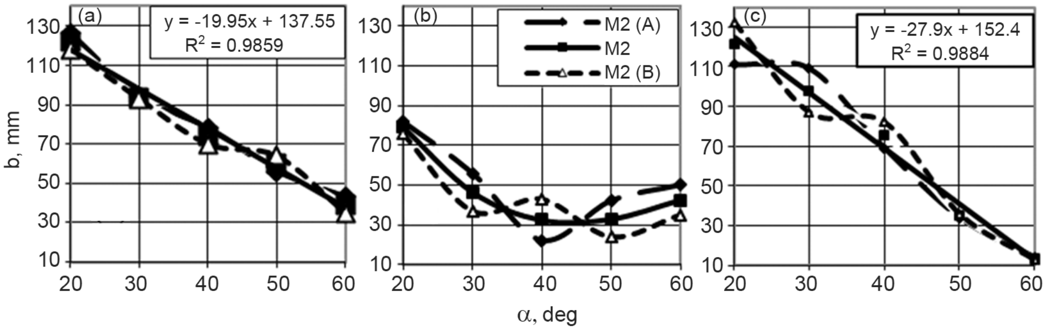

Fig.7—Influence of the seam position angles (α) on the waves base length (*b*) of fabrics M1 (a), M2 (b) and M3 (c) [M2—average values; M2(A)—values of left fold; and M2(B)—values of right fold]

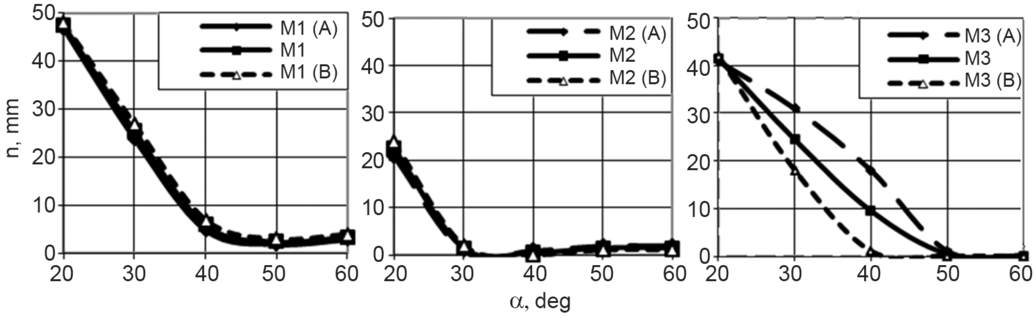

Fig. 8—Influence of the seam position angles (α) on the waves minimum fold's width (*n*) of fabrics M1 (a), M2 (b) and M3 (c) [M1, M2, M3—average values; M1(A), M2(A), M3(A) —values of left fold; and M1(B), M2(B), M3(B) —values of right fold]

The straight symmetrical shapes of waves guarantee the aesthetical view of clothes. Experimentally it has been found that no single specimen fulfilled this requirement. It should be noted that folds of most specimens are leaned to each other as shown in Fig. 2 (c). The best results of folds quality are shown in specimens of knitted fabric M1 (Table 2). The high rigidity of this fabric comparably shows correct geometrical shape which may be measured. Only at $\alpha=60^0$ the waves shape is so complicated that measurement of their lean degree is impossible. For the fabric M2, the characteristic δ_n is determined only for the specimens at two seam angles positions ($\alpha=20^0$ and $\alpha=30^0$).

To determine whether the results of waves shapes characteristics are sufficient for folds quality evaluation, the front views of specimens are also analysed. Some results are presented in Fig.9. It is observed that rigid fabric M1 at maximum seam position angle is able to form high waves with minimum 'neck', the unequal two weaves width as seen from front view of folds, reduces the specimens drape quality. The less rigid knitted fabric M2 forms the narrow waves at $\alpha=50^0$, which are comparably high and have narrow base length and zero 'neck' width. Though waves traces of horizontal projection are complicated, they are nearly symmetrical. Therefore, the specimen of this fabric may be characterized as good quality. The fabric M3 is woven and thinnest as compared to other two fabrics. In spite of the seam position angle value, the waves width remains almost the same and only their high values vary in wide range [Fig. 5 (c)]. At $\alpha=60^0$ the specimens of this fabric have shown two similar qualitatively folds (Fig.9).

According to the quality requirements, all longitudinal clothes seams ought to be vertical. The received results have shown that most of the tested specimens have some seam shift from the vertical position (*y*-axis) after folds formation (Table 3). The seam has a supportive function to the drape and therefore it remains always inside two folds.

Table 2—Influence of seam position angle (α) on the fold lean angle (δ_n)

Fabric	Lean angle, deg				
	20^0	30^0	40^0	50^0	60^0
M1	8	22	28	13	Impossible to measure
M2	19	29	Impossible to measure	Impossible to measure	Impossible to measure
M3	28	34	21	Impossible to measure	Impossible to measure

20^0-60^0 are the angles of seam position.

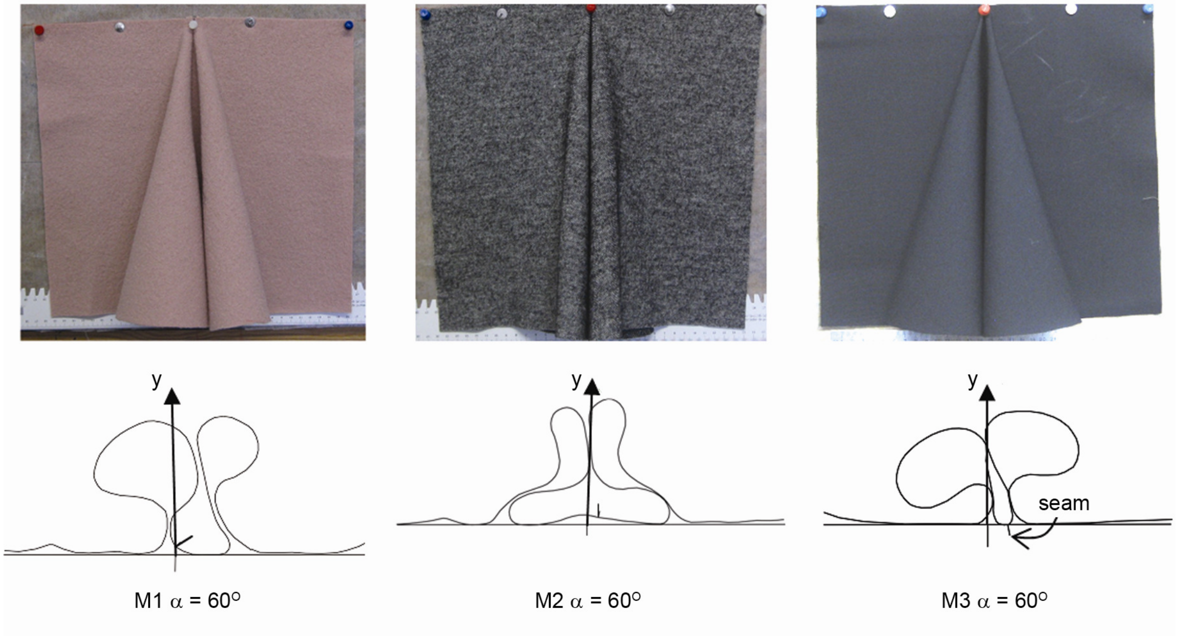

Fig. 9—Comparing the front view of some specimens with their bottom view traces

Table 3—Influence of seam position angle α on the degree of seam shift from the vertical position *a*

Fabric	Degree of seam shift				
	20^0	30^0	40^0	50^0	60^0
M1	3	0	14	13	0
M2	12	11	10	9	2
M3	7	23	19	11	10

20^0-60^0 are angle of seam position.

The non-vertical seam position may depend on the grain lines directions of left and right parts of specimen. The same effect is also determined by analyzing the asymmetrical flared skirt made from thin woven fabrics drape[15]. The largest degree of seam shift from *y*-axis is received for softest woven fabric M3 and especially when $\alpha=30^0$ and $\alpha=40^0$. By using these seam position angles, the specimens have formed mean high and width folds while the differences between left and right folds traces geometrical characteristics are noticeable. It is found that specimens of rigid knitted fabric M1 fulfil the requirements of straight vertical seam at $\alpha=30^0$ and $\alpha=60^0$. The vertical seam position is received even in case of fairly large difference in wave's width (Table 3, Fig. 6). For the less rigid knitted fabric M2, the received results have shown that seam shift from *y*-axis decreases when the seam position angle increases.

4 Conclusion

4.1 The results show that not only soft and thin but also the heavier and thicker fabrics used for outerwear can also have drape forming aesthetic folds.

4.2 It is found that folds geometrical characteristics depend not only on the structural and mechanical properties of fabrics but also on the clothes construction.

4.3 Usually the specimens that are similar to the shape of the side part of the Cape May be drape into two folds which are leaned to each other at some degree. By comparing the results of two knitted fabrics with different bending rigidity, it determined that the way of folds forming is similar, but specimens from fabric with higher rigidity afford to shape higher and wider folds, but the seam situated between two folds may shift from vertical position more significantly.

4.4 It is found that in case of softest woven fabric, the folds height is similar to that of knitted fabrics and only at maximum seam position angle it sharply decreases while the folds width increases.

4.5 The better formed waves are shown in specimens of rigid knitted fabrics while more complicated waves are shown in specimens of less rigid knitted fabric and especially at bigger seam position angle.

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