(REFEREED RESEARCH)

EFFECT OF FABRIC STRUCTURE VARIATION ON GARMENT AESTHETIC PROPERTIES

GİYSİNİN ESTETİK ÖZELLİKLERİ ÜZERİNDE KUMAŞTAKİ YAPISAL VARYASYONLARIN ETKİSİ

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ABSTRACT

The paper investigates the effect of slight variation in fabric structure and finishing on bending and drapes properties of woven fabrics for tailored garments. There are five pairs of fabrics investigated. One structural parameter or type of finishing treatment is varied within fabrics in each pair. The results obtained have shown that variation in weft density and weft yarn count can influence fabric bending stiffness and drape. The effects vary with the scale of variation and testing direction. The greatest effect on rising bending stiffness and fabric drape was achieved with the introduction of higher count double ply weft thread. Compared to bending stiffness, the variations investigated have lesser effect on fabric drape.

Key Words: Aesthetic properties, Bending stiffness, Drapeability, Oilproof and waterproof finishing, Woven fabric.

ÖZET

Bu çalışmada, özel dikim giysilerde kullanılan dokuma kumaşların eğilme ve döküm özellikleri üzerinde kumaş yapısı ve bitim işlemlerindeki küçük varyasyonların etkisi incelenmektedir. Beş çift kumaş ile çalışılmıştır. Bir yapısal parametre veya bitim işlemi tipi, her çiftteki kumaş arasında değişmektedir. Elde edilen sonuçlar, atkı yoğunluğu ve atkı iplik numarasının kumaşın eğilme sertliği ve dökümünü etkileyebileceğini göstermiştir. Etkiler varyasyon derecesi ve test yönüne göre değişmektedir. Eğilme sertliğinde artış ve kumaş dökümü üzerindeki en büyük etki, daha yüksek numaralı çift katlı atkı ipliğinde görülmüştür. Eğilme sertliği ile karşılaştırıldığında, varyasyonların kumaş dökümü üzerinde daha az etkili olduğu görülmüştür.

Anahtar Kelimeler: Estetik özellikler, Eğilme sertliği, Dökümlülük, Yağ ve su geçirmez bitim işlemi, Dokuma kumaş.

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1. INTRODUCTION

Bending stiffness is a property of fabrics that can influence fabric drape and therefore the aesthetic characteristics of garments, and clothing comfort as well.

The behavior of textile flexible structures in a response to bending deformation depends to a great extent on inherent fiber properties and fabric construction features. The fabric stiffness is a feature having important effect on converting flat fabric into 3-D garment, influencing aesthetic appearance of the garment. Additionally, fabric stiffness affects fabric hand.

The most detailed analyses of the bending behavior of weave fabrics were given by Abbott *at al.* (1), de Jong and Postle (2), Ghosh *at al*. (3-5), Lloyd (6) and Hu *at al.* (7, 8). Modeling the bending of a woven fabric requires knowledge of the relationship between fabric bending stiffness, the structural features of the fabric, and the tensile/bending properties of the constituent yarns, measured empirically or determined through the properties of its constituent fibres and yarn structure. It requires inclusion of large number of parameters and is very difficult to express in a closed form (9).

Drape, one of the most important properties of fabric, has played significant role in providing graceful aesthetic effects in garment. Drapability of a fabric is combined effect of several factors such as: stiffness, flexural rigidity, weight, thickness etc. Stiffness, an attribute of fabric hand is one of the most important factors determining draping quality of fabric in a way that soft fabric drapes closer to the body forming ripples, whereas stiff fabric drapes away from the body. Stiffness of fabric itself depends upon geometrical parameters of the fabric.

Cusick (10) investigated the method of testing fabric drape using a parallel light source that reflects the drape shadow of a circular specimen from a hanging disk into a piece of ring paper. He confirmed the study of the effect of bending and shear stiffness on fabric drape by statistical analysis, and found high correlation between drape coefficient and bending length and shear stiffness of the fabric (11). Sudnik (12) studied factors which are related to drape such as bending length, fabric weight and shear properties.

Mooreka analyzed the relation between drape coefficient and fabric mechanical properties. He found that bending rigidity and weight are the most determinative parameters of drape. The actual draping at any point in a garment depends upon the total weight suspended from that point (13). Chen and Govindraj (14) found that young's modulus, shear modulus, and fabric thickness have varying effect on extent of fabric drape while poisson's ratio did not prove to have appreciable effect. Jevšnik *at al.* (15) investigate some mechanical properties and parameters of drapability using different methods from two different points of research area knowledge bases and numerical modeling using the finite element method.

The numerous investigations proved that the properties of bending, creasing and draping ability are all related to the factors of fabric structure. Zhang *at al*. (16) tested and analyzed some cotton, wool, silk and man-made fabrics, and they concluded that the bending, creasing and draping are correlated to fabric type.

Jing (17) has analyzed the structures of lightweight worsted fabrics. He has investigated some characteristics of worsted fabric, such as wrinkle resistance, blend resistance, drapability and air permeability. He has used the gray interrelation theory to deal with the data of structure parameters and wearing characteristics target, and analyzed the relationship between the wearing fabric characteristics and structure parameters. The results indicated that the most important factor of fabric wearing characteristics was linear density followed by fabric area weight, thickness and tightness. The results provided theoretical basis for designing high-grade worsted fabric.

Lojen *at al.* (18) have analyzed changes in drape parameters such as the influence of time, bending rigidity, sample diameters and measurement repeatability. They concluded that in order to clarify the understanding of fabric drape phenomena one has to take into consideration the properties of the fabric, including their constructions' parameters, mechanical properties, as well as the procedure of fabric drape evaluation. Also drapeability was evaluated on the basis of drape coefficient, number of folds and maximum and minimum amplitude (19).

Jing (20) analyzes the influence of type of material and weave on fabric rigidity and the correlation between the rigidity and yarn twist, yarn count and fabric thickness for a range of light-weight worsted fabrics. The results have shown that there is a great influence of material type and yarn structure on fabric rigidity.

In this way, the aim if this paper is to further investigate the influence of slight variation of fabric structure and finishing treatment on bending stiffness and drape of woven fabrics for tailored garments.

2. MATERIALS AND METHODS

A range of worsted wool and wool blended fabrics for tailored garments were investigated for aesthetic properties, *i.e.* bending and drape. There are five distinctive pairs of fabrics in the whole range of fabrics investigated. The every second fabric in the five pairs investigated is produced whether by slight variation of fabric structure parameters, or by variation in finishing treatment. The variation of fabric structure parameters imposed is the one that can be easily achieved in everyday industrial production: variation of the weft density or variation of weft yarn count. The particulars of fabric structure parameters are shown in Table 1.

The fabrics of the first pair C21DL and C21DH have all fabric structure parameters identical, except weft density. Namely, the sample C21DH has higher weft density than its pair C21DL. All other parameters, including fibre composition, yarn count, warp density and finishing treatment are identical.

Table 1. Investigated fabric particulars

Fabric	C21DL	C21DH	C21YL	C21YH	C22DL	C22DH	MPU	MPF	MTU	MTF
Fiber composition	98% wool 2% lycra	98% wool 2% lycra	100% wool	100% wool	100% wool	100% wool	44% wool 54% PES 2% lycra	44% wool 54% PES 2% lycra	44% wool 54% PES 2% lycra	44% wool 54% PES 2% lycra
Yarn count, warp [Tex]	17x2	17x2	15x2	15x2	17x2	17x2	18x2	18x2	18x2	18x2
Yarn count, weft [Tex]	17x2	17x2	24	15x2	17x2	17x2	18x2	18x2	18x2	18x2
Warp density, cm^{-1}	32	32	31.2	31.2	30.8	30.8	29	29	35.4	35.4
Weft density, cm^{-1}	24.80	26.2	27.6	28	25.6	28.2	20	20	24.4	24.4
Fabric thickness, mm	0.36	0.41	0.29	0.34	0.39	0.41	0.39	0.39	0.45	0.45
Fabric weight, g/m^2	213	227	167	187	213	227	200	200	250	250
Finishing	standard	standard	standard	standard	milled	milled	standard	oilproof waterproof	standard	oilproof waterproof
Weave	2x1 twill	2x1 twill	2x1 twill	2x1 twill	2x2 twill	2x2 twill	plain	plain	2x2 twill	2x2 twill

The second pair of fabrics designated C21YL and C21YH, have all structure parameters identical except weft yarn count. The first fabric of the pair C21YL has single ply weft yarn of lower count, while the second fabric C21YH has double ply weft yarn of higher count.

The third pair of fabrics C22DL and C22DH have also all the fabric structural parameters identical, except weft density. The fabric C22DL has lower weft density, while C22DH has higher weft density.

The fabrics of the fourth pair designated MPU and MPF have only difference in finishing treatment. Namely, MPU has standard clear cut finishing, while MPF has additional waterproof and oilproof finishing. All other parameters of both fabrics are identical.

The fifth pair of fabrics, MTU and MTF has also all structural parameters identical except type of finishing. Here also the second fabric in the pair has standard clear cut finishing while MTF has plus waterproof and oilproof finish.

Regarding fiber composition, the first three pairs of fabric have 100% wool or 100% wool with Lycra. Regarding weave, they are similar and have twill 2/1 or twill 2/2 weave.

The fourth and fifth pair of fabrics has both an identical fibre composition: a blend of wool, PES and Lycra. These pairs have identical warp and weft counts but have different weave.

Fabrics are tested on bending stiffness according to BS 3356 (21), the samples of dimensions 2.5x20cm were tested in warp and weft direction. Bending stiffness, G was calculated the according the following equation (1):

$$G = 0.1 \cdot M \cdot C^3 \text{ (mg·cm)} \quad (1)$$

Where: M - fabric weight (g/m^2)

C - bending length mean value in warp and weft direction (cm)

The fabric drapeability was tested according AFNOR NF G 07-109 (22). According the standard, two circular fabric samples of 25 cm in diameter are tested for each measurement. Measurement is performed by positioning the fabric sample between two discs and left to rest for 15 minutes. Using the slider and the horizontal scale, the contour of the falling fabric value is obtained in 16 points. The average of all 16 measurements gives the diameter (d) of a tested sample. Drape coefficient is calculated by equations (2) and (3):

$$F = \frac{Sc - Si}{St - Si} = \frac{d^2 - di^2}{dt^2 - di^2} \text{ (cm}^2\text{)} \quad (2)$$

Where:

S_c - surface of the test sample after testing with a measured average diameter (cm)

S_i - surface of the disc with a diameter d_i = 15cm (cm)

S_t - initial surface of sample before testing with a diameter d_t= 25cm (cm)

Then the drape coefficient is:

$$F = \frac{d^2 - 225}{400} \text{ (cm}^2\text{)} \quad (3)$$

3. RESULTS AND DISCUSSION

The results of testing bending stiffness for warp G_1 and weft G_2 direction are shown in Table 2 and Figures 2 and 3 respectively.

Table 2. Bending stiffness of tested fabrics in warp and weft direction

Bending stiffness	Fabric									
	C21DL	**C21DH**	**C21YL**	**C21YH**	**C22DL**	**C22DH**	**MPU**	**MPF**	**MTU**	**MTF**
	Bending stiffness – warp direction									
G_1 [mg cm]	**10.65**	**9.44**	**8.76**	**9.81**	**10.08**	**10.99**	**12.41**	**11.03**	**16.81**	**17.03**
SD [mgcm]	0.55	0.39	0.41	0.49	0.48	0.53	0.62	0.58	0.69	0.72
CV [%]	5	4.13	4.68	4.99	4.76	4.82	4.99	5	4.1	4.22
	Bending stiffness – weft direction									
G_2 [mg cm]	**6.33**	**6.92**	**5.50**	**7.08**	**7.37**	**8.73**	**5.84**	**5.29**	**6.21**	**6.56**
SD [mgcm]	0.35	0.2	0.27	0.38	0.38	0.4	0.22	0.25	0.31	0.33
CV [%]	5.5	2.89	4.91	5.3	5.1	4.58	3.77	4.72	4.99	5

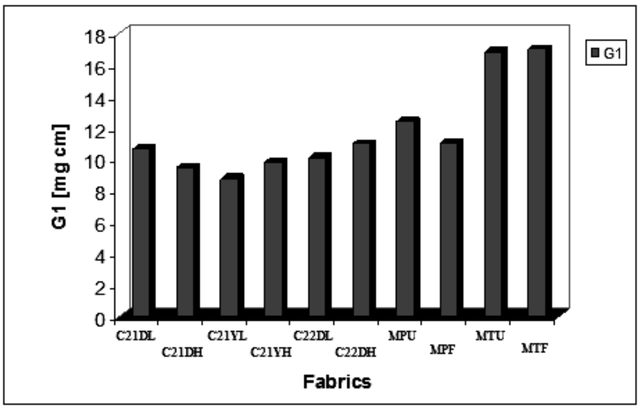

Figure 2. Bending stiffness of testing fabric for warp direction, G_1

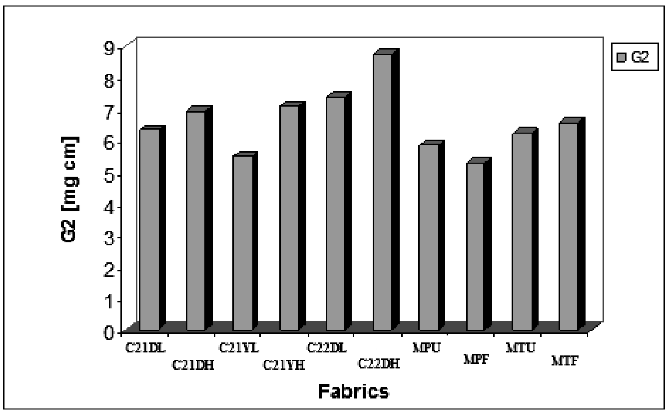

Figure 3. Bending stiffness of testing fabric for weft direction, G_2

From the results in Table 2 it can be seen that due to unbalanced set, the fabrics have higher bending stiffness in the warp direction. Namely, the bending stiffness in warp direction ranges from 8.76 mg·cm up to 17.01 mg·cm, compared to weft direction where it ranges from 5.29 mg·cm to 8.73 mg·cm.

Regarding bending properties of the first pair of fabrics, C21DL and C21DH, we see that increasing of the weft density does not result in increasing the bending stiffness in warp direction. As expected, increase of weft density increases the stiffness in weft direction. So, the higher weft density does not affect the bending stiffness in warp direction, moreover there is slight decrease of the stiffness in warp direction.

The increasing of the weft count in the second pair, (C21YL and C21YH), results in increasing the bending stiffness in both directions. The increasing is much higher in weft direction, but opposite to first investigated pair, there is also increasing in a warp direction. The bending stiffness in warp directions increases from 5.50 mg·cm to 7.08 mg·cm, which represents significant increase of stiffness by 29%. When yarns are woven into fabrics, a wide range of stiffness is possible depending upon the extent to which free movement of fiber is inhibited by fabric structure.

In a third pair of fabrics, (C22DL and C22DH), the increase of weft density results in increasing bending stiffness in both weft and warp direction. The increasing is higher in weft direction (18.5%) and lower in warp direction (9%). However, this time, as opposite to first pair, increasing of the weft density results in increasing of stiffness in warp direction as well. There is a question why the same type of variation, (increasing the weft density), affects differently in first and third pair. The answer could be in the scale of increasing weft density. Namely, increasing of the weft density in the first pair is 24.8 cm^{-1} to 26.2 cm^{-1} or 5.6%. Where, in the third pair, increasing the weft density is 25.6 cm^{-1} to 28.2 cm^{-1} or 10.2%. This means that increasing of the weft density is almost 2 times higher at third pair, which accounts for greater effects on fabric stiffness and directions affected.

There is different behavior found at fourth and fifth pair. At fourth pair there is decreasing of bending stiffness at second treated fabric in warp and weft direction. On the opposite, there is slight increasing of stiffness in both direction at treated oilproof and waterproof treated sample. So a clear conclusion of the effect of finishing treatment on bending stiffness can not be produced.

The influence of structural parameters variation on fabric bending stiffness was analyzed by main effects analysis of variance (ANOVA). The results are given in Table 3 for the warp and weft way testing respectively. The results of F-test confirmed the impact of weft density variation on bending stiffness, for the first pair only in weft direction, and for the third pair in weft and warp direction. Also, the test confirms statistically significant influence of the weft yarn count variation on fabric bending stiffness, now in both testing directions.

The correlation between various fabric structure parameters and bending stiffness for all tested fabrics is investigated. The best correlations were found between the bending stiffness in warp direction and: fabric weight 0.72, thickness 0.70 and warp density 0.74. The highest correlation was found between bending stiffness in warp and weft direction and cover factor in warp and weft of 0.91 and 0.89 respectively. So, cover factor in warp and weft can give best indication of fabric bending stiffness in both directions.

The results of fabric drape testing are presented in Table 4.

It can be seen that the drape coefficient ranges from 0.56 to 0.64 cm^2. These values justify the end use of the fabrics intended for clothing where outer fabric does not need to be very drapeable.

The increasing of weft density at first pair of fabrics did not affect increasing the drape coefficient as it was case with bending stiffness. Moreover, sample C21DH of increased weft density has lower drape coefficient. The explanation could be in a smaller magnitude of increasing weft density.

Table 3. F-test for warp (G_1) and weft direction (G_2) samples

Samples	**C21DL/C21DH**	**C21YL/C21YH**	**C22DL/C22DH**
Factor	Weft density	Weft thread count	Weft density
$F_{(G1)}$	2.38	**64.35***	3.38
p	0.2	**0.01**	0.14
$F_{(G2)}$	**55.67***	**80.52***	**31.66***
p	**0.01**	**0.01**	**0.01**

* *F-values and p-values marked with asterisk indicate significant influence of the investigated factors on the measured properties*

Table 4. Drape coefficient of testing fabrics

Drape	**Fabric**									
Coefficient	**C21DL**	**C21DH**	**C21YL**	**C21YH**	**C22DL**	**C22DH**	**MPU**	**MPF**	**MTU**	**MTF**
F [cm^2]	**0.58**	**0.57**	**0.56**	**0.61**	**0.59**	**0.60**	**0.64**	**0.62**	**0.62**	**0.64**
SD [cm^2]	0.46	0.49	0.49	0.52	0.30	0.39	0.52	0.40	0.54	0.53
CV [%]	4.30	4.61	4.61	4.79	2.78	3.61	4.75	3.69	4.96	4.83

The second pair, a fabric as a result of introduction of higher weft thread count (C21YH) shows increased drape coefficient. This is with accordance with increased bending stiffness at this sample. After introduction of higher weft count, this sample has increased warp and weft bending stiffness, increased fabric weight, and increased cover factors, which all account for increased drape coefficient.

Again, the increasing of weft density in a second sample of the third pair (C22DH) resulted in increased drape coefficient. As it was explained previously the scale of increasing weft density is greater compared to first pair of fabric, (10.2% to 5.6%), which is why this variation results in rising drape coefficient.

The fourth and fifth pair of fabrics behave differently on introduction of oilproof and waterproof finishing. Namely, the first pair shows lowering of a drape coefficient, while fifth pair shows increasing of drape coefficient. As it was case with bending stiffness, there is no clear connection between the type of finishing treatment and fabric drape.

Regarding relation between bending stiffness and drape for the investigated samples, there is high correlation between bending stiffness in warp direction and drape coefficient of 0.73. The high correlation was found between the drape coefficient and cover factor by weft 0.75, but only for fabrics of fibre composition 98% wool and 2% lycra and 100% wool.

The results of bending and drape testing showed that the fabric parameters variation has greater effect on bending stiffness than on fabric drape. This was explained in previous investigations, where, the effect of various properties, related to yarn and fabric structure, were linked to drapeability. Marooka and Niwa give the equation for determining the drape coefficient, where beside the fabric weight, fabric drape depends on bending stiffness along warp, weft and in bias directions (23), suggesting more complex relation between fabric drape and fabric structural parameters.

4. CONCLUSION

The influence of fabric structure variations on bending and drape properties for a range of fabrics for tailored garment was investigated.

It was shown that the variation of fabric structure can affect bending stiffness. The effects vary depending of the type of variation and direction of testing.

Introduction of higher count double ply weft thread has a greatest effect on increasing bending stiffness in warp and weft direction and for fabric drape.

The analysis of variance proved that variation of thread density, yarn type and count has significant factors to fabric bending stiffness.

Compared to bending properties, there is lesser effect of fabric structure variation on fabric drape properties. There is good correlation between bending stiffness in warp direction and drape coefficient of 0.73.

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