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The Evaluation of Stiffness and Drape Behaviour of Wool Fabrics

Yün Kumaşların Rijitlik ve Dökümlülük Davranışlarının Değerlendirilmesi

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THE EVALUATION OF STIFFNESS AND DRAPE BEHAVIOUR OF WOOL FABRICS

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ABSTRACT: Stiffness is an important mechanical property that influences fabric handle, clothing appearance and fit. The circular bending stiffness, fabric formability and drapeability have high influence on fitting the cloths to human body. In this study, the comparison of circular bending stiffness and drape of wool fabrics were analyzed. Comparison of experimental data of fabric parameters shows reasonable agreement between circular bending stiffness and drape behavior.

Keywords: Circular bending stiffness, drape behaviour, wool fabrics

YÜN KUMAŞLARIN RİJİTLİK VE DÖKÜMLÜLÜK DAVRANIŞLARININ DEĞERLENDİRİLMESİ

ÖZET: Rijitlik kumaş tuşesi, giysi görünüşü ve formunu etkileyen önemli bir mekanik özelliktir. Dairesel eğilme rijitliği, kumaş şekillendirilebilirliği ve dökümlülük insan vücudunun giysi ile donatılmasında büyük bir öneme sahiptir. Bu çalışmada, dairesel eğilme rijitliği ve dökümlülüğün karşılaştırılmalı analizi yapılmıştır. Kumaş parametreleri ile deneysel verilerin karşılaştırılması dairesel eğilme rijitliği ile dökümlülük arasında makul bir ilişki olduğunu göstermiştir.

Anahtar Kelimeler: Dairesel eğilme rijitliği, dökümlülük davranışı, yün kumaşlar

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1. INTRODUCTION

Drape is the deformation of fabric produced by its own weight only if it is directly supported [1]. In other words, the drapeability of a fabric refers to the manner in which the fabric falls, shapes, gathers or flows with gravity when only part of it is directly supported. Drape is an important component of aesthetics of garments and is a complex combination of fabric structural and mechanical properties [2].

Stiffness or flexural rigidity is one of the important physical properties of textile materials and widely used to judge bending rigidity and fabric handling. The bending behavior of woven fabric is very important for fabric producers, designers of clothing and also for apparel production. Bending stiffness of textile materials is defined as the resistance to bending phenomena and it is an important mechanical property that influences its handle thought production process of clothing and fitting the cloths to the human body [3].

Studies of drape started with researches of Pierce [4]. He developed an instrument to measure the angle through which a specimen of cloth dropped when a definite length was held out over an edge. Chu et al. designed a drapemeter and determined drape coefficient which is the ratio of the projected area to the specimen's original area [5,6]. Then Cusick developed an instrument based on the principle of the drapemeter designed by Chu et al. [1,5]. Hu and Chan investigated the relationship between the fabric drape coefficient from Cusick drapemeter and mechanical properties tested on the Kawabata Evaluation System for woven fabrics [2]. Vangheluwe et al. developed a computerized image analysis method to evaluate the drape structures of the samples [7]. Shyr measured static and dynamic drape coefficients of fabrics by using a new dynamic drape measuring system integrating Cusick's drapemeter principle with image analysis technique [8].

Shyr et. al. focused on the use of subjective and objective evaluation methods to determine the peak-trough threshold of the drape fabric node [9]. Nineteen different dynamic drape images of fabric were used to evaluate the fabric node number and the fabric drape coefficient. The greater the rotation speed, the greater the drape coefficient of wool woven fabrics. The smaller the distance from the peak and through to the center point, the smaller is the node number. Sun proposed a new tester which uses a cross-shaped specimen to measure fabric drape and stiffness [10]. Sun obtained a strong correlation with measurements made using the Shirley stiffness tester and the Fabric Assurance by Simple Testing (FAST)-2 bending meter of FAST system. Mizutani et. al. developed a new drape elevator that measure drape shape, including node generation at various stages during drape formation [11]. A new parameter R, evaluating the shape of the drape, was defined in terms of the drape projection. Both the R parameter and the drape coefficient were expected to be useful parameters for the quantitative analysis of fabric drape formation.

Moore et. al. investigated the effects of skewness on drape of four-gore skirts, the level at which skewness becomes excessive, and the relationship of shear hysteresis to skewness [12]. Lin et.al. analyzed the dynamic drape coefficient of four natural-fiber fabrics at speeds of 0—450 rpm [13]. A linear model, a growth model and a nonlinear logistic model were used to analyze the dynamic drape coefficient curve fit, and the F-test was used for validation. The results showed that the nonlinear logistic function could be used to fit the drape coefficient curves throughout the static state and the dynamic stable region.

Ucar et. al. analyzed the effect of five-thread overlock seams (stitch type 516, seam type Ssa-1) on the drape behavior of heavy weight knit fabrics to provide prediction equations for drape [14]. Results are statistically analyzed. From the regression analysis, the drape coefficients of seamed heavy weight knit fabrics and the rating values obtained from subjective analyses are predicted with 0.80 and 0.86 correlation coefficients, respectively. Pattanayak et. al. investigated the relationship between the fabric drape parameters such as drape coefficient, drape distance ratio, fold depth index, amplitude and number of nodes and low stress mechanical properties [15]. Drape parameters were tested on a specially developed instrument based on a digital image processing technique and the low stress mechanical properties were tested by the Kawabata evaluation system. As a conclusion, it was observed that bending, shear and aerial density affect the drape parameters most whereas the tensile and compression have little effect on the drape parameters.

Stiffness is one of the most widely used parameters to judge bending rigidity and fabric handling. Fabric stiffness and handling is an important decision factor for the end users. In his paper, Peirce described the stiffness and hardness of a cotton cloth [4]. Later, Guthrie et al. focused on the bending and torsional rigidity of fibers with static and dynamic methods because the stiffness of a fabric is directly dependent on the stiffness of fibers [16]. Cooper gave analytical and experimental results about the stiffness of fibers, yarn, and woven fabrics. His study was based on the fundamental works done by Peirce and Guthrie [17]. McGregor and Postle investigated the effect of cashmere in blends with superfine wools on the mechanical properties of single jersey knitted fabrics. They found that the cashmere blend ratio and fiber curvature/crimp of wool affected fiber properties [18].

Although there are many studies related to the drape structure, there is not enough study in the literature to evaluate the relationship between circular bending stiffness and drape behavior of wool fabrics. To date many researchers have studied especially the drape structures and drapemeter to analyse the draping behavior of fabrics. Drape coefficient is still valid as the primary attribute for explaining drape but on the other hand, it is insufficient for completely describing it. Two fabrics, for instance, with the same drape coefficient, could have completely different drape shapes. Drape is measured visually and evaluation is made according to the images and drape figures. On the other hand stiffness measurement gives a force value related to fabric stiffness. For this reason, the objective of this study is to compare and associate the measurements of the circular bending and drapeability.

In this study, the relationship between drape and circular bending stiffness behavior of woolen fabrics are analyzed. Comparison of experimental data show that there is reasonable agreement between circular bending stiffness and drape behavior.

2. MATERIAL AND METOD

2.1. Material

Table 1 shows the fabric properties used in the experiments. All the fabrics below processed with super finish machine under the settings of 18 m/min and 100 bar pressure.

Table 1. Fabric properties used in experiments

Fabric Code	Weave Type	Weft Density	Warp Density	Fabric Weight	Material Type
Fabric 1	2/1 Twill	30	41	232.0	100 Wool %
Fabric 2	Plain weave	21	22	169.1	50% Wool-50 % Pet
Fabric 3	2/1 Twill	30	32	198.0	98% Wool-2% elastane
Fabric 4	Plain weave	27	28	150.7	100 Wool %
Fabric 5	2/1 Twill	26	30	156.3	50% Wool-50 % Pet
Fabric 6	2/1 Twill	25	31	175.5	54% Pet -44% Wool -2 % elastane
Fabric 7	Plain weave	32	44	183.0	54% Pet -44% Wool -2 % elastane
Fabric 8	Plain weave	26	28	198.4	98% Wool-2% elastane
Fabric 9	2/1 Twill	28	28	182.2	100 Wool %
Fabric 10	2/1 Twill	23	30	186.3	100 Wool %
Fabric 11	2/1 Twill	29	33	143.8	100 Wool %
Fabric 12	Plain weave	25	25	138.7	50% Wool-50 % Pet

2.2. Method

Test method D 4032 was used for testing circular bending stiffness of fabrics. The circular bend procedure gives a force value related to fabric stiffness, simultaneously averaging stiffness in all directions. A plunger forces a flat, folded swatch of fabric through an orifice in a platform. The maximum force required to push the fabric through the orifice is an indication of the fabric stiffness (resistance to bending) [3].

The specimens were cut into size of diameters d_1 = 30 cm. A Cusick drape meter with Drape Analyzer was used for determining drape parameters [1].

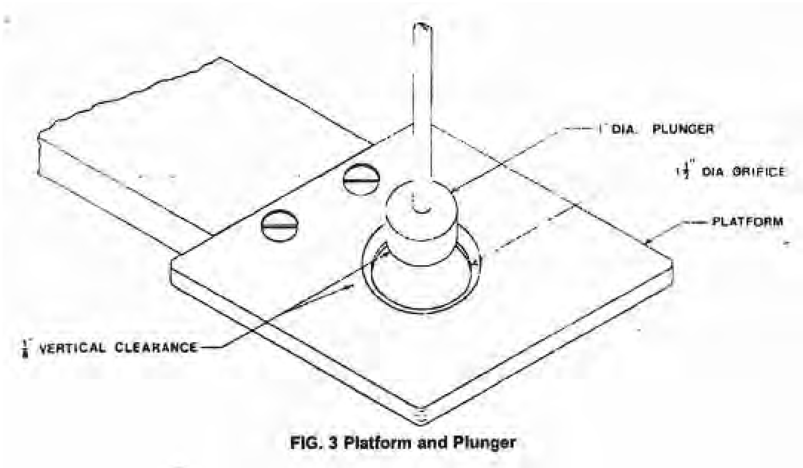

Figure 1. (a) Measuring principle and (b) photograph of circular bending stiffness tester [3]

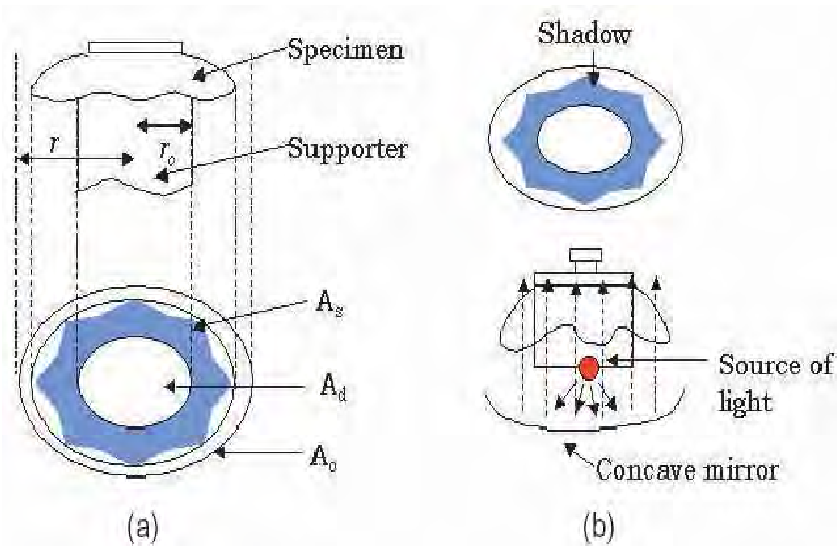

Figure 2. (a) Measuring principle and (b) photograph of drape tester [1]

The drape coefficient is calculated as [1]:

$$DC = \frac{S_p - \pi d_1^2}{\pi d_2^2 - \pi d_1^2} \quad (1)$$

where: DC-drape coefficient, S_p -projection area of draped specimen including the part covered by the horizontal disc, mm^2, d_1 -radius of horizontal disc, mm, d_2 -radius of non-deformed specimen before draping in mm.

The analyses were evaluated by using paired-samples t test, one-way ANOVA and arithmetic mean, standart deviation. Statistical analyses have been carried out by using SPSS 15 statistical programme. The selected value of significance level (α) for this procedure was 0.05. Each hypothesis was a two-tailed hypothesis.

3. RESULTS

Twelve different wool fabric types were used in the stiffness-drape measurements (Table 1). The fabrics were made of 100 % Wool, 50% Wool-50 % Pet, 98% Wool-2% elastane and 54% Pet-44% Wool -2 % elastane with three different weave types (twill, plain, mixed). Table 2 and Table 3 show drape and stiffness values of fabrics according to the weave type and material type. Twill weave has the highest drape coefficient and stiffness value. Plain weave comes after twill weave.

First, reliability tests were conducted to see the Cronbach's alpha values of variables and high values obtained as a result of tests. Reliability statistics yielded a high Cronbach's Alpha value of 0.870 for drape and stiffness measurements.

The bivariate correlations procedure computes the pairwise associations for a set of variables. It is useful for determining the strength and direction of the association between two scale or ordinal variables. High correlation was found between drape and stiffness (Table 4). Also, correlation values were calculated according to material type and weave type (Table 5 and Table 6).

Table 2. Descriptive statistics according to weave type

Weave type		N	Mean	Std. Deviation
Mixed	Drape coefficient	581	0.390	0.395
	Stiffness	581	0.078	0.006
Plain	Drape coefficient	1950	0.417	0.104
	Stiffness	1950	0.118	0.029
Twill	Drape coefficient	3837	0.427	0.096
	Stiffness	3837	0.146	0.033

Table 3. Descriptive statistics according to material type

Material type		N	Mean	Std. Deviation
100 Wool %	Drape coefficient	2664	0.405	0.095
	Stiffness	2664	0.131	0.038
50%Wool-50%Pet	Drape coefficient	1390	0.445	0.087
	Stiffness	1390	0.118	0.026
54% Pet -44% Wool -2 % elastane	Drape coefficient	709	0.329	0.017
	Stiffness	709	0.112	0.008
98% Wool-2% elastane	Drape coefficient	1606	0.465	0.089
	Stiffness	1606	0.152	0.040

Table 4. Drape and stiffness correlation values

		drape	stiffness
Drape coefficient	Pearson Correlation	1	.685(**)
	Sig. (2-tailed)		,000
	N	6368	6368
Stiffness	Pearson Correlation	.685(**)	1
	Sig. (2-tailed)	.000	
	N	6368	6368

Table 5. Drape and stiffness correlation values according to material type

Material type			drape	stiffness
100 Wool %	Drape coefficient	Pearson Correlation	1	.568(**)
		Sig. (2-tailed)		.000
		N	2664	2664
	Stiffness	Pearson Correlation	.568(**)	1
		Sig. (2-tailed)	.000	
		N	2664	2664
50%Wool-50%Pet	Drape coefficient	Pearson Correlation	1	.751(**)
		Sig. (2-tailed)		.000
		N	1390	1390
	Stiffness	Pearson Correlation	.751(**)	1
		Sig. (2-tailed)	.000	
		N	1390	1390
54% Pet -44% Wool -2 % elastan	Drape coefficient	Pearson Correlation	1	.894(**)
		Sig. (2-tailed)		,000
		N	709	709
	Stiffness	Pearson Correlation	.894(**)	1
		Sig. (2-tailed)	,000	
		N	709	709
98% Wool-2% elastane	Drape coefficient	Pearson Correlation	1	.896(**)
		Sig. (2-tailed)		,000
		N	1606	1606
	Stiffness	Pearson Correlation	.896(**)	1
		Sig. (2-tailed)	,000	
		N	1606	1606

** Correlation is significant at the 0.01 level (2-tailed).

Hypothesis test was used to evaluate the relationships between stiffness and drape coefficient of wool fabrics. By using the paired-samples t-test procedure with the selected value of significance level (α = 0.05), the results were obtained and shown in Table 7. According to the p (significance) value in Table 7, there is a positive relationship between the stiffness and drape coefficient. As a result of evaluation, the correlation coefficient was found as 0.685. It can be said that the relationship between drape and stiffness is statistically significant. As the significance value was 0.000 (less than 0.05), the hypothesis H_1 that states there is relationship between drape coefficient and stiffness, was accepted.

To investigate the relationship between the drape coefficient (DC) of fabrics and stiffness, regression coefficient (R^2) values were determined according to the fabric types using regression analysis method in SPSS 15 statistical programme. The R^2 values were computed for each function and high values obtained. The coefficient, R^2, was found as 0.680 for 100% wool, 0.793 for 98% Wool-2% elastane, 0.543 for

50% Wool-50% Pet fabrics and as 0.807 for 54% Pet-44% Wool- 2% elastane fabrics which means that there is a good functional relation between the stiffness and drape.

When hypothesis tests were investigated and tested using the ANOVA Test, it was seen that there was a significant difference in fabric stiffness with respect to the warp and weft densities (Table 8). It was found also that there was also significant difference in the drape coefficient with respect to the warp and weft densities.

Table 6. Drape and stiffness correlation values according to weave type

Weave type			drape	stiffness
Mixed	Drape coefficient	Pearson Correlation	1	.954(**)
		Sig. (2-tailed)		.000
		N	581	581
	Stiffness	Pearson Correlation	.954(**)	1
		Sig. (2-tailed)	.000	
		N	581	581
Plain	Drape coefficient	Pearson Correlation	1	.784(**)
		Sig. (2-tailed)		.000
		N	1950	1950
	Stiffness	Pearson Correlation	.784(**)	1
		Sig. (2-tailed)	.000	
		N	1950	1950
Twill	Drape coefficient	Pearson Correlation	1	.756(**)
		Sig. (2-tailed)		.000
		N	3837	3837
	Stiffness	Pearson Correlation	.756(**)	1
		Sig. (2-tailed)	,000	
		N	3837	3837

** Correlation is significant at the 0.01 level (2-tailed).

Table 7. Drape coefficient and stiffness correlation values according to weave type

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	stiffness & drape coefficient	36	.685	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	stiffness - drape	-,29243	,07634	,01272	-,31826	-,26660	-22,982	35	,000

Table 8. Hypothesis tests results

Hypothesis tests	**Significance (two-tailed)**
H_1: There is significant difference in the drape coefficient according to weft density.	0.000
H_1: There is significant difference in the drape coefficient according to warp density.	0.000
H_1: There is significant difference in the stiffness coefficient according to weft density.	0.000
H_1: There is significant difference in the stiffness coefficient according to warp density.	0.009

Table 9 shows correlation values between drape coefficient and weft density, warp density and weight values and also between stiffness and weft density, warp density and weight values. Stiffness measurement was evaluated as a good indicator to show the correlation according to weight change. There was a positive correlation between drape-weight and stiffness-weight. As the fabric weight increased, the fabric stiffness and drape coefficient values increased. The warp and weft density values had a reverse relationship with the fabric stiffness and drape coefficient.

Table 9. Correlation values according to weft density, warp density and weight

	Weight	Warp Density	Weft Density
Stiffness	0.570	-0.070	-0.113
Drape	0.062	-0.408	-0.173

4. CONCLUSION AND DISCUSSION

Fabric drape is an important factor when presenting the aesthetics and functionality of both, the fabric and the created garment. Drapeability is described as a phenomenon of fabric folds formation, which arises when a fabric hangs down without the influence of external forces. Basically, fabric drape is not an independent fabric property. The shape of the fabric depends on the fabric's parameters such as structure, yarn type, fiber content. Stiffness of fabrics is also an important mechanical property that influences its handle and clothing fit. The objective of this study was to compare the measurements of bending stiffness of some wool fabrics with the draping behavior. Stiffness is one of the most widely used parameters to judge bending rigidity and fabric handling.

As a result of experiments it was found that, there was a high correlation between drape coefficient and stiffness values of wool fabrics as stated with Cusick, Pattanayak and Uçar. Moreover a positive correlation was found between fabric weight and drape behavior. As the fabric weight increased, drape coefficient and fabric stiffness values increased due to the increase in fabric tightness. Another important result obtained from this study was that a change in the level of fabric density caused to a significant effect on the drape coefficient of fabrics which was also parallel to the findings of Uçar et. al. This result can be explained like that an increase in fabric density causes a decrease in fabric drapeability because fabric drapeability is negatively affected by bending, shear and areal density as stated by Pattanayak et. al..Therefore an increase in fabric density leads to an increase in bending and shear rigidity of fabrics.

Most researchers have focused on the relationship between the fabric drape coefficient and mechanical properties of different fabrics but less attention has been paid to the effects of weave and fiber type on the drape and stiffness values of woven fabrics. The regression coefficient, R^2, was found as 0.680 for 100% wool. As 2% elastane was added to the fabric structure, R^2 increased to 0.793 for 98% Wool-2% elastane. If the fabric structure was constructed as 50% Wool-50% Pet fiber, it was found a regression coefficient of 0.543 which means poliester fiber makes the fabric structure unstable. For 54% Pet-44% Wool- 2% elastane fabrics, R^2 was found as 0.807 which means that there is a good functional relation between the stiffness and drape. As a result we can generalize that fiber type has a great influence on fabric drape and stiffness behavior. Weave type also has a significant effect on drape coefficient. As a result of experimental studies, it was obtained that twill weave had the highest drape coefficient because of more stiff fabric structure. Plain weave had more stable fabric structure and DC value had a value in the second range.

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