(REFEREED RESEARCH)

EVALUATION METHODS FOR FABRIC “WAVE” PLASTICITY

KUMAŞ “DALGA” PLASTİKLİĞİ İÇİN DEĞERLENDİRME YÖNTEMLERİ

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ABSTRACT

Fabric “wave” plasticity is a shaping element of garment, which makes fabric shape into concavo-convex curved shape above the body surface in order to represent clothing style and design ideas. Fabric “wave” plasticity plays a key role in garment silhouette. The purpose of this paper is to research evaluation methods to quantitatively evaluate the fabric “wave” plasticity. A direct evaluation method which was close to the actual use of fabrics was designed. Concavo-convex curved shapes were produced by a self-made shaping model, and “wave” height “H” was used for characterizing the fabric “wave” plasticity. Moreover, for exploring convenient indirect evaluation method of “wave” plasticity, two novel parameters: residual bending curvature and residual shear deformation, were defined. Test results showed that “wave” heights of the fabrics used for different garment silhouettes differ substantially. Multivariate statistical analysis indicated that shear hysteresis of warp at a 0.5° shear angle could be used for evaluating the fabric “wave” plasticity of warp and 45° direction, and “wave” height of weft could be assessed by residual bending curvature of weft. Evaluation methods for fabric “wave” plasticity could help apparel designers to grasp the material properties more exactly and work out the garments with ideal silhouettes.

Key Words: Fabric “wave” plasticity, Silhouette, Bending property, Shearing property, KES-F, Residual deformation.

ÖZET

Kumaş “dalga” plastikliği, giysi stili ve dizaynını ifade etmek için, beden üzerinde kumaş görüntüsünü konkav-konveks şekle sokan, giysinin bir şekillendirme unsurudur. Kumaş “dalga” plastikliği, kumaş profilinde önemli bir rol oynamaktadır. Bu makalenin amacı, kumaş “dalga” plastikliğinin nicel olarak değerlendirilmesi için değerlendirme yöntemleri araştırmaktır. Kumaşların gerçek kullanımına yakın bir direkt değerlendirme yöntemi tasarlanmıştır. Konkav-konveks şekiller, kendiliğinden şekillendirme modeli ile oluşturulmuştur ve dalga” yüksekliği “H”, “dalga” plastikliğinin karakterize edilmesinde kullanılmıştır. Ayrıca, “dalga” plastikliğinin indirekt olarak değerlendirilme yönteminin geliştirilmesi için, iki yeni parametre: kalıcı eğilme eğriliği ve kalıcı kayma deformasyonu tanımlanmıştır. Test sonuçları, farklı giysi profilleri için kullanılan kumaşların “dalga” yüksekliklerinin oldukça farklı olduğunu göstermiştir. Çoklu istatistiksel analiz, 0.5° kayma açısında çözgü yönü kayma histerezinin, kumaşın çözgü ve 45°yönünde dalga plastikliğinin değerlendirilmesinde kullanılabileceğini ve atkı yönü dalga yüksekliğinin, atkının kalıcı eğilme eğriliği ile değerlendirilebileceğini ortaya çıkarmıştır. Kumaş dalga plastikliğinin değerlendirme yöntemleri konfeksiyon tasarımcılarına, materyal özelliklerini çok daha doğru kavrama ve giysileri ideal profiller ile tasarlama konusunda yardım edebilir.

Anahtar Kelimeler: Kumaş “dalga” plastikliği, Profil, Eğilme özelliği, Kayma özelliği, KES-F, Kalıcı deformasyon

1. INTRODUCTION

Fabric “wave” plasticity is a shaping element of garment, because of this property, fabric can be shaped into a curved surface with certain curvature above the body surface, see Figure 1 (a, b, c, d). Fabric “wave” plasticity plays a key role in some garment silhouettes. Garment silhouette namely the outline of garment, is a decisive factor to apparel design effect.

“wave” plasticity is one of the inherent properties of fabric. However, little attention was given to it in the past. Maybe the fabrics used before had weaker “wave” plasticity. Therefore, concavo-convex curved shapes of adult clothing mainly relied on accessories, such as the aristocratic women's apparels in early Europe and some acting clothes in the modern, see the first two of figure 1(a, b), and only children clothes which were smaller or lighter could obtain

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concavo-convex curved shapes by fabric performance. Poly(trimethylene terephthalate) (PTT) shape memory fabrics and poly(ethylene terephthalate) (PET) imitation shape memory fabrics which have emerged in recent years have a strong performance of shaping concavo-convex curved shapes (1), making a layer of thin fabric shape into a perfect curved surface. The fabrics used for concavo-convex curved shaping are classified as concavo-convex curved shape type fabrics in this paper. The emergence of the fabrics makes the exaggerated shape fashions shown in Figure 1 come into the lives of ordinary people and stands out the “wave” plasticity of fabrics. Garment silhouette is shaped by fabrics, and different fabrics have different style features, such as light or heavy, thin or thick, crisp or drape are all reflected by silhouettes. Well familiar with fabric properties and shape silhouette freely beyond the body, basing on basic human shape, is the goal of every apparel designer.

Until now, evaluation method and characterization parameter of fabric “wave” plasticity have not been studied yet. Japanese scholars had studied deeply on the relationship between silhouette and mechanical properties of fabrics, such as bending and shearing properties. They classified garment silhouette into three types: Tailored type, Hari type and Drape type, and had developed discriminant equations for the three types (2, 3). Among the results, Tailored type and Drape type had a highly practical value. However, the range of the Hari type was too wide, including concavo-convex curved shape type garments and 2-dimensional shape type garments (shirt, jacket, windbreaker, etc.), which had different requirements to the performance of fabrics. Moreover, the discriminant equations based on the experimental data of fabrics at that time were not suitable for all the fabrics emerged recently. For example, PTT shape memory fabrics with lower bending rigidity and higher shear rigidity, bending hysteresis and shear hysteresis, did not exist ten years ago. So the equations to these fabrics are unreasonable. Avoiding the complex relationship between fabric performance and silhouette, only evaluation methods of fabric “wave” plasticity were discussed in this paper.

2. DIRECT EVALUATION METHOD FOR “WAVE” PLASTICITY

Garments with concavo-convex curved shapes means that they maintain stable curved surfaces, see Figure 1, whose macro performance are similar to the traditional sense of fabric bagging. Therefore, fabric bagging testing methods were consulted to quantitatively evaluate the fabric “wave” plasticity (4).

2.1. Sample Preparation

In order to deeply investigate fabric “wave” plasticity, 10 categories and 27 kinds of fabrics with different raw materials, textile structures, process technology and silhouettes were collected from garment enterprises, shown in Table 1. PTT shape memory fabrics which are very popular in the market recently belong to A class. Their shape style resembles mixed-fiber fabrics with shape memory metal fibers, suitable for the concavo-convex curved shape type and 2-dimensional shape type garments. The first two of the B class are commonly known as PET imitation memory fabrics, using PET filaments as materials, and their yarn construction, fabric specification and finishing technology are similar to those of PTT shape memory fabrics. G type chooses PTT filaments and PET filaments as warp and weft, respectively. These fabrics have similar structures to those of PTT shape memory fabrics as well, commonly called PTT/PET semi-shape memory fabrics. PTT/PET semi-shape memory fabrics and PET imitation shape memory fabrics are also popular textiles. They come into used gradually after PTT shape memory fabrics were developed. Shape memory fabrics have the common characteristics of dense textures, light and finishing without deweighting process technology. The rest are conventional fabrics. Raw material, yarn size, fabric weight, weave, cover factor of warp and weft and total cover factor were given by Table 1 since they had a big influence on fabric properties (5).

According to the former research (6), cover factors of warp and weft and total cover factor were important for fabric “wave” plasticity. So, they were calculated by the following formulae (7), respectively.

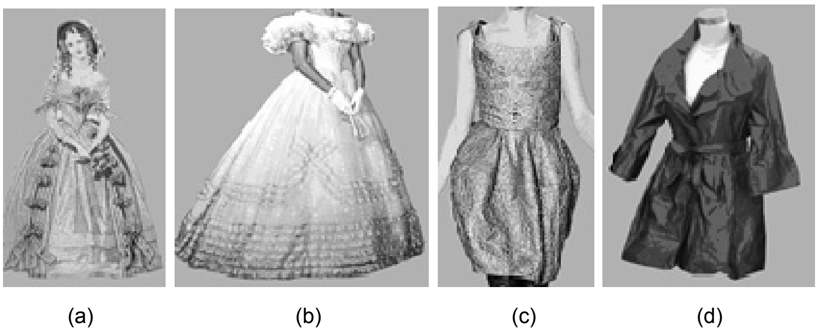
(a) (b) (c) (d)

Figure 1. Garments with concavo-convex curved shapes

Table 1. Specification of fabrics

No.	Material	End use	Textile weave	Yarn size (warp×weft)(Tex)	Weight(g/m^2)	Cover factor (warp×weft) (%)	Total cover factor(%)
A1	PTT×PTT	Concavo-convex curved shape type	$\frac{1}{1}$	10.8×9.05	131	101.9×45.6	101
A2			$\frac{1}{1}$	11.4×9.4	130	97.4×46.1	98.6
A3			$\frac{1}{2}$	8.33×8.33	149	97.2×55.3	98.7
A4			$\frac{1\ 1}{1\ 3}$	9.63×9.15	145	108.9×52.3	104.2
A5			$\frac{1\ 1}{1\ 3}$	8.33×8.33	150	100.9×49.2	100.5
B1	PET×PET		$\frac{1}{1}$	8.33×8.33	127	92.9×44.3	96.1
B2			$\frac{1}{1}$	8.33×8.33	138	93.4×75.3	98.4
B3	PET×PET	Tailored type	$\frac{2\ 1}{1\ 3}$	19.7×17.8	204	119.6×47.8	110.2
B4		2-dimensional shape type	$\frac{1}{1}$	6.35×7.85	82	57.6×52.6	79.9
C1	PA×PA	Tailored type	$\frac{4\ 1}{1\ 2}$	3.33×23.3	130	45.9×57.2	76.8
C2			$\frac{2}{2}$	7.78×15.6	142	80.5×59.9	92.2
D1	Cotton	2-dimensional shape type	$\frac{1}{1}$	9.4×9.8	114	69.8×58.5	87.5
D2			$\frac{1}{1}$	19.2×19.4	117	56.7×39.1	73.7
D3			$\frac{2}{2}$	16.1×14.0	128	70.5×48.5	84.8
E1	Wool	Tailored type	$\frac{2}{2}$	28.3×25.1	173	65×55.6	84.4
E2			$\frac{1}{1}$	32.5×40.5	220	66.4×61.2	87
E3			$\frac{1}{1}$	25.3×22.7	134	50.3×45.8	73.1
F1	Silk	Drape type	$\frac{1}{1}$	5.85×8.55	70	44.3×41.7	67.5
F2			$\frac{1}{1}$	5.18×3.98	46	50.5×31.0	65.9
F3			$\frac{1}{1}$	6.4×7.7	63	50.6×47.2	73.9
G1	PTT×PET	Concavo-convex curved shape type	$\frac{1}{1}$	11.1×9.5	120	101.1×45.6	100.6
G2			$\frac{2}{2}$	10.5×11.1	148	116.3×57.3	107
G3			$\frac{2}{2}$	10.8×12.6	176	108.2×67	102.7
H	Cotton×PTT	2-dimensional shape type	$\frac{1}{1}$	14.3×10.6	109	70×36.1	80.8
I	PET×Cotton		$\frac{2}{2}$	8.33×25	131	63.5×78.6	92.2
J1	T/C×T/C		$\frac{3}{1}$	28.2×28.5	202	92.4×45.4	95.9
J2			$\frac{1}{1}$	14.4×14.7	99	56.2×36.9	72.3

$$E_w = d_w \times P_w \qquad (1)$$

$$E_f = d_f \times P_f \qquad (2)$$

$$E_z = E_w + E_f - \frac{E_w \times E_f}{100} \qquad (3)$$

Where, E_w and E_f are the cover factors of warp and weft, respectively; P_w and P_f are the densities of warp and weft, respectively, that is, the number of warps or wefts per 10 centimetres of fabrics; E_z is total cover factor; d_w and d_f are the diameters of warp and weft, respectively, and

$$d = 0.03568\sqrt{\frac{N_{Tex}}{\delta}}(mm) \qquad (4)$$

Where N_{Tex} is the linear density of warp or weft, and δ is yarn volume weight.

As can be seen from the above formulae, the linear density (N_{Tex}) and the density of warp or weft P can be tested directly, and yarn volume weight (δ) of conventional yarns can be got from book (7). Therefore, all the cover factors of warp and weft and total cover factors of fabrics in Table 1 can be calculated but the fabrics with PTT yarns, since PTT yarn's volume weight cannot be got from existing books. PTT yarns in the fabrics used in the paper are full drawn yarns (FDY), therefore, volume weight of FDY PTT yarn can be calculated by the following formula:

$$\frac{\rho_1}{\delta_1} = \frac{\rho_2}{\delta_2} \qquad (5)$$

Where, ρ_1 is the volume density of PET fiber, ρ_1=1.38 g/cm^3; δ_1 is the volume weight of FDY PET yarn, δ_1=0.93 g/cm^3; ρ_2 is the volume density of PTT fiber, ρ_2=1.33 g/cm^3. So, δ_2=0.896 g/cm^3, and δ_2 is the volume weight of FDY PTT yarn.

In addition, the end use of the fabrics in Table 1 was given based on Japanese scholars' discriminant equations for Tailored type, Hari type and Drape type (2, 3). Furthermore, because the range of the Hari type was too wide, it had been divided into concavo-convex curved shape type garments and 2-dimensional shape type garments which based on fabrics' styles. The detailed differences of concavo-convex curved shape type garments and 2-dimensional shape type garments in mechanical properties will be studied in future.

2.2. Direct Evaluation Method

The purpose of this experiment is to quantitatively evaluate fabric "wave" plasticity. Taking into account the real existence of concavo-convex curved shapes on garments, with warp shaping and weft shaping, and also exists the diagonal shaping which has a certain angle to the warp and weft. Therefore, three shape types, warp shaping, weft shaping and 45° to warp and weft shaping or called 45° direction shaping, were selected in the direct evaluation method.

The direct evaluation method proposed in the paper includes the following steps: (1) nine 20cm×20cm specimens (three specimens for each direction) were cut from each sample and then conditioned in a constant temperature and humidity environment for 24 hours; (2) put shaping model (shown in Figure 2) on the test bench, covered a specimen on the model, and then made the specimen close to the concavo-convex curved surface of the model by hands (specimen was in a tension-free state and did not have elongation during this procedure); (3) specimen started shaping on the model without any forces for 5 minutes (note: concavo-convex curved shapes should be produced along the tested direction of the fabrics); (4) removed the model gently(tried not to destroy the shape of the specimen) after the specimen was shaped, put specimen on a smooth bench and allowed it to recover for 5 minutes in the absence of any external forces; (5) two concavo-convex curved shapes on the specimen were randomly selected, and vernier caliper was used for measuring the distance from trough to peak, that was, the distance from the upper surface of the platform to the highest point of concavo-convex curved shape.

Each direction of the samples was tested three times(each direction had three specimens), and an average of the 2×3 "wave" height "*H*" was taken as the evaluation index of "wave" plasticity of a direction of fabrics. Shaping effects of different fabrics were obviously different, see Figure 3 (a, b, c) and Figure 4.

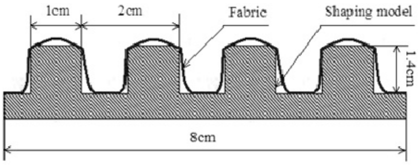

Figure 2. Profile chart of concavo-convex curved shaping model

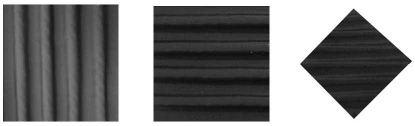
(a) Warp (b) Weft (c) 45° direction

Figure 3. Top view of the different direction of the fabrics on concavo-convex curved shaping

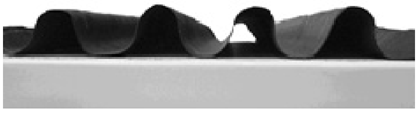

Figure 4. Front view of the effects of concavo-convex curved shaping

2.3. Effect of Evaluation

Fabric "wave" heights of warp, weft and 45° direction of the fabrics are shown in Figure 5, ranged from 0 to 14mm, and the "wave" heights of the fabrics used for different silhouette had significant difference. "Wave" height "*H*" of each direction of the fabrics used for concavo-convex curved shape type garments ranged from 6.5mm to 14mm, well above those of Tailored type and Drape type (most of which were 3.4mm or less), while shirt and jacket fabrics which highlight the 2-dimensional shape had the "wave" height "*H*" from 2.8mm to 5mm. Therefore, the direct evaluation method above could effectively evaluate the effects of "wave" plasticity of different fabrics, and the evaluation index "*H*" could better reflect the general end uses of the fabrics. In addition, minor differences between the "*H*" values of warp, weft and 45° direction of the fabrics had also been noticed. It might result from woven fabrics' anisotropy.

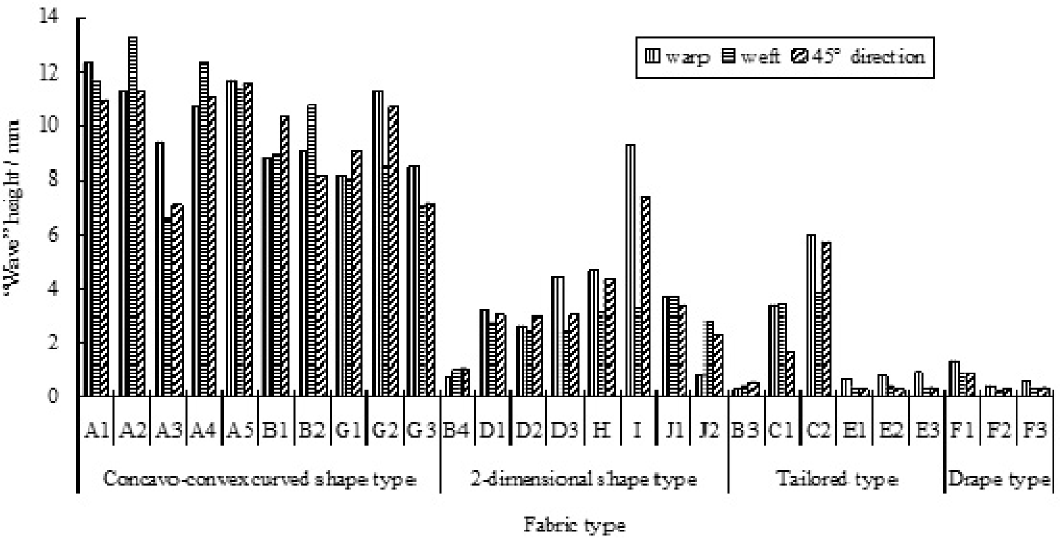

Figure 5. Figure of "wave" height "*H*" of each direction of the fabrics

2.4. Relationship Between "Wave" Plasticity of Different Directions

In order to further research the differences and relation between the fabric "wave" plasticity of different directions, correlation analysis was taken for the "*H*" values of warp, weft and 45° direction of the fabrics. It was found that all correlation coefficients between any two directions were above 0.92. This indicated that although woven fabrics were anisotropy, there was a close relationship between the "wave" plasticity of different directions of fabrics. It was possible to use the fabric "wave" plasticity of one direction to predict that of other directions.

3. EXPLORATIONS OF INDIRECT EVALUATION METHOD FOR "WAVE" PLASTICITY

The evaluation method discussed above can directly test and characterize fabric "wave" plasticity, and it is a basic method, and has important value. However, some random errors are easy to be introduced by manual operation during the test. Therefore, indirect evaluation method for fabric "wave" plasticity is also explored in the paper.

It can be seen from the garments shown in Figure 1(c, d) that concavo-convex curved shapes consist of bending and shear deformation, and the curved shapes without any means of support, such as external force, accessories, etc. In spite of similar appearance, concavo-convex curved shape and fabric bagging differ in deformation mechanism. Concavo-convex curved shape is that fabric can not recover to its initial shape after bending and shear deformation, because of the high frictional forces between the fibers and yarns (6), and the fibers and yarns basically have no elongation. However, fabric bagging is a kind of three-dimensional deformation occuring at the positions such as knees and elbows where occur repeated or prolonged deformation (8), where the elongation of fibers and yarns is the main deformation. Therefore, research on fabric "wave" plasticity should start with fabrics' bending and shearing properties.

3.1. Extracting of Characteristic Index From the Mechanical Properties of Fabrics

Bending and shearing properties of fabrics were tested by KES-FB-AUTO-A System Tester. It was thought that concavo-convex curved shapes of fabrics were residual bending and shear deformation of fabrics, therefore, two new parameters: residual bending curvature *K* and residual shear deformationφ, are defined basing on the original mechanical parameters of KES System Tester. The former is the residual bending curvature when bending moment back to zero during bending test, and the later is residual shear deformation when shear force back to zero during shearing test, see Figure 6 and Figure 7. Two parameters are calculated as follows.

$$K = \frac{|K_f| + |K_b|}{2} \tag{6}$$

$$\phi = \frac{|\phi_r| + |\phi_l|}{2} \tag{7}$$

Where K_f and K_b are the residual curvatures after fabric bending toward its face or under sides, respectively; φ_r andφ_l are the residual shear deformation after fabric shearing toward its right or left directions, respectively.

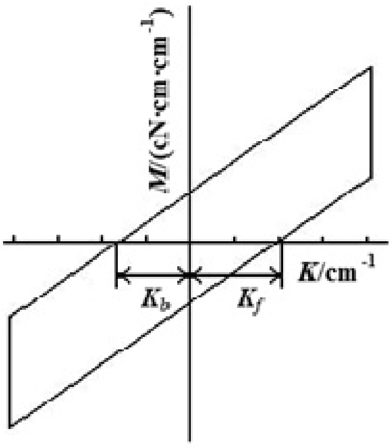

Figure 6. Curve of bending deformation

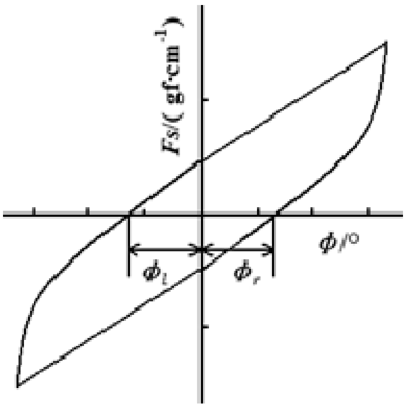

Figure 7. Curve of shear deformation

3.2. Relationship Between Original and New Parameters

Fabric deformation mechanism indicated that new parameters proposed in this paper seem have some relationship with the original mechanical parameters of KES System Tester, such as bending hysteresis 2HB, shear hysteresis at a 0.5° shear angle 2HG and shear hysteresis at a 5° shear angle 2HG5. In order to ascertain whether they are fully equivalent and the existance value of the new parameters, relationship between original and new parameters of KES System Tester was studied. The correlation coefficients are shown in Table 2.

Table 2 showed that, (1) there was high correlation between all the residual bending curvature and residual shear deformation; (2) the correlation between all the residual deformation and bending hysteresis was lower, and they even did not correlate with the bending hysteresis of warp; (3) there was high correlation between all the residual deformation and the shear hysteresis at a 0.5° shear angle, whereas the correlation with the shear hysteresis at a 5° shear angle was relatively lower; (4) compared with bending hysteresis of warp, bending hysteresis of weft had higher correlation with all the shear hysteresis and especially with shear hysteresis at a 5° shear angle; (5) there was high correlation between each shear hysteresis, especially for those at a same shear angle.

It could be concluded from the above analysis that there was high correlation between each residual deformation and deformation hysteresis, which indicated that all of them might have relationship with the friction between fibers and yarns. However, residual deformation could not be substituted by deformation hysteresis, since their correlation coefficients were far less than 1 and each of them reflected different fabric properties. Therefore, residual deformation had existence value. The results also showed that, compared with the shear hysteresis, bending hysteresis had poor relationship with fabric “wave” plasticity, moreover, bending hysteresis of warp had the least contribution to the “wave” plasticity.

3.3. Residual Deformation of Fabrics

Means and standard deviations of residual deformation of different directions of the fabrics in Table 1 were calculated. Results are shown in Figure 8 and Figure 9.

Table 2. Correlation coefficents between different residual deformation and deformation hysteresis of fabrics

Index	K_w	K_f	Φ_w	Φ_f	$2HB_w$	$2HB_f$	$2HG_w$	$2HG_f$	$2HG5_w$
K_f	0.704								
Φ_w	0.806	0.8							
Φ_f	0.754	0.862	0.886						
$2HB_w$	0.037	0.06	0.022	0.172					
$2HB_f$	0.412	0.502	0.567	0.595	0.648				
$2HG_w$	0.76	0.906	0.819	0.884	0.154	0.623			
$2HG_f$	0.742	0.892	0.778	0.881	0.237	0.612	0.986		
$2HG5_w$	0.673	0.763	0.761	0.839	0.515	0.802	0.864	0.872	
$2HG5_f$	0.633	0.792	0.728	0.853	0.475	0.804	0.867	0.872	0.975

Note: The subscript w and f identify the warp and weft of fabric.

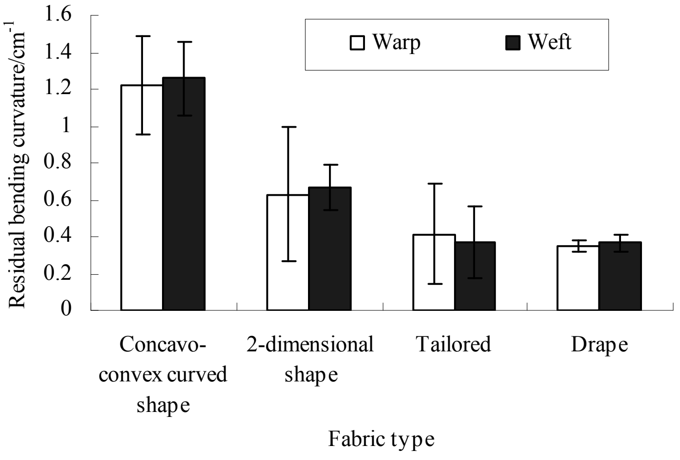

Figure 8. Residual bending curvature of the fabrics with different end uses

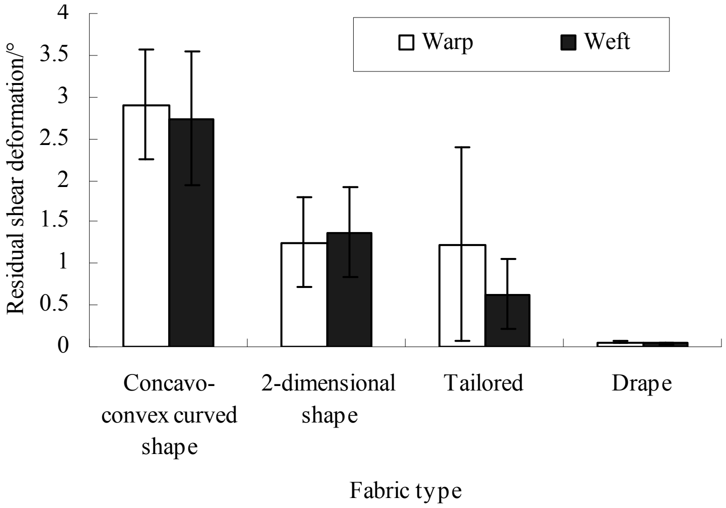

Figure 9. Residual shear deformation of the fabrics with different end uses

Table 3. Regression equations with mechanical parameters for indirectly evaluating fabric “wave” plasticity

Index	Regression equation			Correlation coefficent
“Wave” height	Warp	Multiple regression equation	H_1=－0.548+4.31K_w+0.536(2HG_w)	0.969
		Single-element regression equation	H_1=1.179+0.862(2HG_w)	0.922
	Weft	Multiple regression equation	H_2=－1.488+5.59K_f+0.383(2HG_w)	0.942
		Single-element regression equation	H_2=－2.474+9.302K_f	0.926
	45° direction	Multiple regression equation	H_3=－1.127+3.955K_w+ 0.282(2HG_w) +0.273(2$HG5_f$)	0.967
		Single-element regression equation	H_3=0.978+0.836(2HG_w)	0.915

It was evident that residual bending and shear deformation of warp and weft of concavo-convex curved shape type were the largest, 2-dimensional shape type took the second place, followed by Tailored type, and Drape type had the least residual deformation. Both concavo-convex curved and 2-dimensional shape types of garments belong to the loose-crisp type of garments divided by Japanese(2),(3), which highlight the fabric “body”, and the garment profile is supported by fabric rather than human body. The difference is that the shear rigidity, bending and shear hysteresis of concavo-convex curved shape type of fabrics are higher than that of 2-dimensional shape type except bending rigidity. Therefore, the former is more easily to deform, but is difficult to recover after deforming because of larger internal viscosity in fabrics, which is good for the “wave” plasticity of fabrics. Figure 8 and Figure 9 also indicated that residual bending curvature and residual shear deformation of the four types of fabrics were obviously different, and the two parameters could be used for differentiating the end uses of fabrics.

3.4. Indirect Evaluation for “Wave” Plasticity by Mechanical Parameters

Concavo-convex curved shapes of garments are actually residual bending and shear deformation from the analysis above, so fabric “wave” plasticity should have relationship with residual bending curvature K and residual shear deformationφ, which we have defined above. Furthermore, there was high correlation between all the residual deformation and deformation hysteresis, and all of them had existence value. Therefore, deformation hysteresis of KES System Tester common used at present may also have high correlation with fabric “wave” plasticity. Therefore, the feasibility of using the mechanical parameters above to evaluate the “wave” height of fabrics was studied by stepwise regression method. All parameters in Table 2 (K_w, K_f, Φ_w, Φ_f, 2HB_w, 2HB_f, 2HG_w, 2HG_f, 2$HG5_w$ and 2$HG5_f$) were selected as independent variables. Dependent variables were: “wave” height of warp H_1, “wave” height of weft H_2, “wave” height of 45° direction H_3. Regression equations were got by stepwise regression method at 95% and 99% confidence levels, respectively. Results are shown in Table 3.

Table 3 showed that all “wave” heights of warp, weft and 45° direction of fabrics could be calculated by mechanical parameters, and all the correlation coefficients of multiple regression equations and single-element regression equations were above 0.91. Multiple regression equations appeared to have higher accuracy than that of single-element regression equations. However, “wave” heights of all directions could not be calculated by multiple regression equations at 99% confidence level, but all of the single-element regression equations could reach this confidence level. Moreover, single-element regression equations were more convenient to be calculated, so they had a higher application value. Therefore, shear hysteresis of warp at a 0.5° shear angle (2HG_w) could be used for evaluating the fabric “wave” plasticity of warp and 45° direction, and “wave” height of weft could be assessed by residual bending curvature of weft (K_f). Table 3 also indicated that fabric "wave" plasticity is the comprehensive expression of shear hysteresis and residual bending deformation, and reflects the internal friction of fabrics.

4. CONCLUSIONS

Fabric "wave" plasticity is a new property proposed by our research team, and it is critical to garment silhouette. In order to more exactly grasp the "wave" plasticity of different fabrics, direct and indirect evaluation methods for evaluating the "wave" plasticity were designed in the paper.

The results showed that "wave" plasticity of the fabrics used for different types of garments could be distinguished by the direct evaluation method, and the value of the evaluation parameter, "wave" height "*H*", could reflect fabrics' end uses. "Wave" height "*H*" of each direction of the fabrics used for concavo-convex curved shape type, was larger than those of Tailored and Drape types, while the "wave" heights of shirt and jacket fabrics which highlighted the 2-dimensional shape were medium.

Residual bending curvature and residual shear deformation were extracted from the curves of bending and shear deformation, respectively. The former is the residual bending curvature when bending moment back to zero during bending test, and the later is the residual shear deformation when shear force back to zero during shearing test. The two new parameters together with the mechanical parameters of KES System Tester common used at present were chosen as independent variables, "wave" heights of different directions as dependent variables, multiple correlation analysis was carried out. It was found that shear hysteresis of warp at a 0.5° shear angle could be used for evaluating the fabric "wave" plasticity of warp and 45° direction, and "wave" height of weft could be assessed by residual bending curvature of weft.

In addition, according to the results, the direct evaluation in the paper gives better results for evaluating the properties of shape-memory fabrics due to the measuring principle. Moreover, regression equations with mechanical parameters for indirectly evaluating fabric "wave" plasticity should be perfected based on more samples in future.

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