

Test Method for Compression Resilience Evaluation of Textiles

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Abstract

A test method was proposed and a measurement system was developed to characterize the compression resilience properties of textiles based on the mechanical device, microelectronics, sensors and control system. Derived from the typical pressure-displacement curve and test data, four indices were defined to characterize the compression performance of textiles. The test principle and the evaluation method for compression resilience of textiles were introduced. Twelve types of textile fabrics with different structural features and made from different textile materials were tested. The one-way ANOVA analysis was carried out to identify the significance of the differences of the evaluation indices among the fabrics. The results show that each index is significantly different among different fabrics. The denim has the maximum compressional resilience and the polar fleece has the minimum compressional resilience.

Keywords: Compression resilience, Test method, Evaluation, Textiles

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1. Introduction

The compression properties including compression resilience are very important attributes of textiles, which are related to the sensations of comfort. Modern consumers consider comfort as one of the most important attributes in the purchase of textile and apparel products, and the comfort sensations such as handle of clothing material are getting more priority in the quality evaluation of textiles such as fabrics. The fabric handle mainly depends on its basic physical and mechanical properties, especially the initial low-stress region of those properties. The low-stress physical and mechanical properties of fabric such as compression, bending, tensile, shear and surface friction have become essential facets of fabric [1-3]. The objective measurement of the fabric physical and mechanical properties like surface compression properties and its applications to the objective evaluation of fabric quality and apparel engineering surely help to produce high quality fabrics [4-5]. Therefore, it is required and important to investigate the compression properties of fabrics beforehand.

Many researchers carried out studies in compression property evaluation methods of fabrics, together with the fabric handle evaluation methods, and the most commonly used instruments to evaluate fabric compression property are parts of KES system (Kawabata Evaluation System for Fabrics) and FAST (Fabric Assurance by Simple Testing) systems. KES system includes four instruments: Tensile and Shearing Tester, Pure Bending Tester, Surface Tester and Compression tester. The instrument of compression tester is designed to measure the compressional deformation properties of fabric. FAST system was a set of instruments and test methods developed by the CSIRO in Australia. FAST-1 compression meter, one instrument of the FAST system, was developed to measure fabric thickness and, in addition, the variability and the durability of the thickness of the fabric surface layer [6].

The compression resilience property of fabrics is one of the basic mechanical properties, closely related to fabric handle, softness and fullness. The fabric compressibility and thickness also have a linear relationship with thermal conductivity [7-9]. Ajayi investigated the effect of fabric compression on frictional properties of woven, knitted and non-woven fabrics. The results show that as the fabric compression increases, the difference between the static and kinetic friction forces increases [10]. Dominique Dupuis's study demonstrated that interlacing is the major factor that influences the compression properties of fabric not the fiber arrangement, based on the KES system [11]. P.M. Taylor investigated the impact compression on fabric by using the impact compression tester and concluded that the compression energy

loss, calculated from the static characteristics, gives only a rough guide to the impact compression losses [12]. Wensheng Huang described a method and an online measurement, based on the analysis of fabric deformation while the fabric moves through a nip, to measure the fabric compressional behavior [13]. Shunjun song studied the compressive response of carbon 2D triaxial braided composites (2DTBC) and accounted for the braid microstructure and inelastic properties of the matrix via use of the finite-element method [14]. X. Cheng developed a practical model to predict the compression property of a 2D plain weave fabric (PWF) composite by using the minimum complementary energy principle based on apt geometrical approximation and assumption for PWF composites [15]. Fredrik Edgren investigated the mechanical and failure behavior of fabric composite and predicted the compression failure which caused by kinking under multiaxial (axial compression and shear) loading in non-crimp fabric composite via use of a failure criterion [16].

Although, there are some standard methods and instruments can be employed to measure the fabric compression properties, but most of them only can be used to evaluate the fabric compression property under static conditions, and can not simulate the process during clothing contacts with human skin. This paper reports the development of a new test method and measurement system based on the mechanical device, microelectronics, sensors and control system for characterizing the compression property of textiles such as fabrics. The test method and the measurement system can measure the compression properties by simulating the dynamic compression contacts between the skin and textiles.

2. Test principle and evaluation method

2.1. Test principle

As shown as in Figure 1, the mechanical device of the measurement system consists of the following four main components:

- (1) Driving system 1;
- (2) Upper measuring head component 2;
- (3) Lower measuring head component 3;
- (4) Measuring device frame 4.

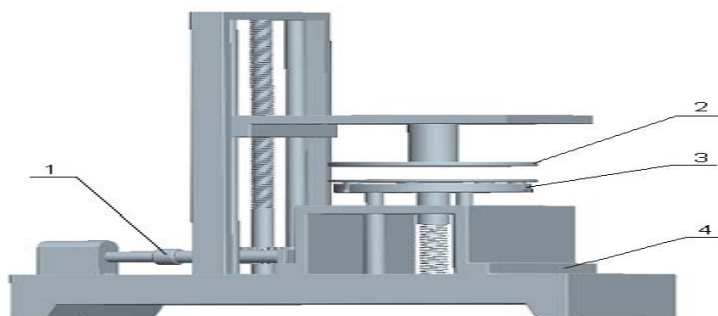


Figure 1. Mechanical Device of the Measurement System

There are three pressure transducers between the copper measuring plate and the main frame of the lower measuring head, together with another one installed between the lower measuring head and the measuring device frame for measuring the pressure load which is applied to the test sample.

Before testing, the upper measuring head is located at the initial position. When the measurement starts, the upper measuring head moves down and fixes the sample between the free surfaces of the upper measuring head and the copper measuring plate of the lower measuring head. Due to the applied pressure, the pressure transducers and the microelectronics start to record data. When the pressure achieves the setting value of pressure (4200Pa), the motor of the driving system stops rotating and the upper measuring head stops moving down, and the sample is kept at static condition. Two minutes later, the motor starts to

rotate in reverse, and the upper measuring head rises up and automatically return to the initial position.

2.2. Evaluation method

Figure 2 is a typical pressure-displacement curve from the compression testing. Derived from the measuring curves and the test data, a set of indices have been defined and calculated for evaluation of surface compression properties of textiles such as fabrics.

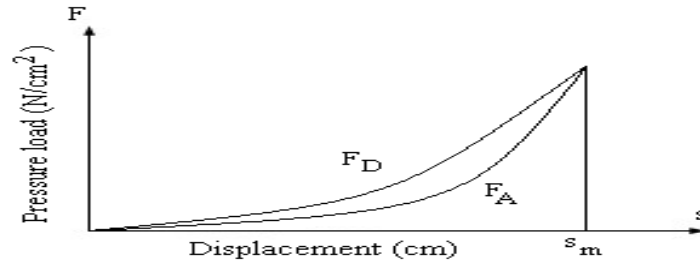


Figure 2. Typical Pressure Load – Displacement Curve For Compression Measurement

1) The compression work is done during the compression stage: W_D ,

$$W_D = \int_0^{s_m} F_D(s) ds \quad (1)$$

where $F_D(s)$ is the pressure load during the compression stage, s is the displacement, s_m is the maximum displacement.

2) The compression work is done during the compression recovery stage: W_A ,

$$W_A = \int_0^{s_m} F_A(s) ds. \quad (2)$$

where $F_A(s)$ is the pressure load during the compression recovery stage.

3) The compressional resilience: RC ,

$$RC = \frac{W_A}{W_D} \times 100\% \quad (3)$$

Indices W_D and W_A are related with the dynamic compression properties during the contacts between the skin and textiles. The difference of W_D and W_A reveals the compressional resilience. From W_D and the thickness changes during the compression process, another index LC can be defined to characterize the property of the compression thickness linearity.

4) The linearity of compression thickness curve: LC ,

$$LC = \frac{W_D}{(TO - TM)P_m / 2} \quad (4)$$

where TO (mm) is the thickness of sample at $P_0 = 0.5 \text{ gf/cm}^2$, TM (mm) is the thickness of sample at $P_m = 50 \text{ gf/cm}^2$.

In the analysis of the test results and the evaluation of the compression resilience property of the test samples, this paper will focus on the indices of compressional resilience (RC) and the compression work W_D and W_A .

3. Experiments setup

Twelve types of fabrics with different structural features and made from different materials were tested for the compression experiments totally. The sample is cut to the size of

180mm×180mm and any obvious wrinkles are removed. Fabric structural parameters are listed in Table 1. Before testing, all the specimens were kept in a conditioning room, controlled at $21\pm 1^\circ\text{C}$ and $65\pm 2\%$ RH according to ASTM D1776 for at least 24 hours.

All the testings were carried out in the conditioning room. For each set of fabric, 5 pieces of specimens were cut and prepared for testing. During testing, the sample is placed on the lower measuring head in such a way that the sample edges cross symmetrically the straight lines of the lower measuring head. The sample edges, in this arrangement, overlap the straight edge of the measuring plate surrounding the lower measuring head, which is in the same horizontal plane as the level of the lower measuring head.

Table 1. Fabric Structural Parameters

Sample code	Fabric construction	Mass/unit area (g/m^2)	Thickness (mm) at 4.14KPa
1 [#]	Pile fabric-weft knitted	205	0.97
2 [#]	Pile fabric-weft knitted	272	1.35
3 [#]	Mesh fabric-warp knitted	96	0.32
4 [#]	Fleecy fabric- weft knitted	251	1.37
5 [#]	Fleecy fabric- weft knitted	256	1.81
6 [#]	Polar fleece	296	3.06
7 [#]	Denim	359	0.75
8 [#]	Denim-bleached	360	0.86
9 [#]	Velvet	268	0.98
10 [#]	Twill-brushed	290	0.57
11 [#]	Corduroy	308	0.93
12 [#]	Fancy weave	245	0.57

4. Results and Analysis

All the specimens were tested on the measurement system of compression properties by the same testing protocol according to the experiments setup. The mean values of the compression properties measurements are summarized in Table 2.

Table 2. The Mean Values of the Compression Properties Measurements

Fabric	Compression Work W_A ($\text{N}\cdot\text{cm}/\text{cm}^2$)	Compression Work W_D ($\text{N}\cdot\text{cm}/\text{cm}^2$)	Compressional Resilience RC (%)
1 [#]	4.2866	8.8937	48.1979
2 [#]	4.2219	9.5191	44.3514
3 [#]	5.8017	9.3368	62.1377
4 [#]	4.0460	8.5486	47.3289
5 [#]	4.2726	9.6755	44.1592
6 [#]	3.0059	8.7034	34.5369
7 [#]	5.1375	6.1330	83.7688
8 [#]	5.2964	7.4018	71.5554
9 [#]	4.1317	7.4932	55.1399
10 [#]	3.5350	7.0658	50.0304
11 [#]	3.6585	6.9143	52.9114
12 [#]	5.1260	7.8930	64.9437

A one-way ANOVA analysis was carried out to identify the significance of the differences of the evaluation indices among the fabrics using professional statistical software SPSS and the results are summarized in Table 3.

Table 3. One-way ANOVA Analysis Results of Evaluation Indices

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
W_D	72.270	11	6.570	11.302	0.000
W_A	37.560	11	3.415	5.515	0.000
RC	10176.558	11	925.142	11.021	0.000

The one-way ANOVA results indicate that each index is significantly different ($P < 0.05$) among different fabrics in this study. Therefore, the fabrics' behaviors significantly affect the compression properties of all indices.

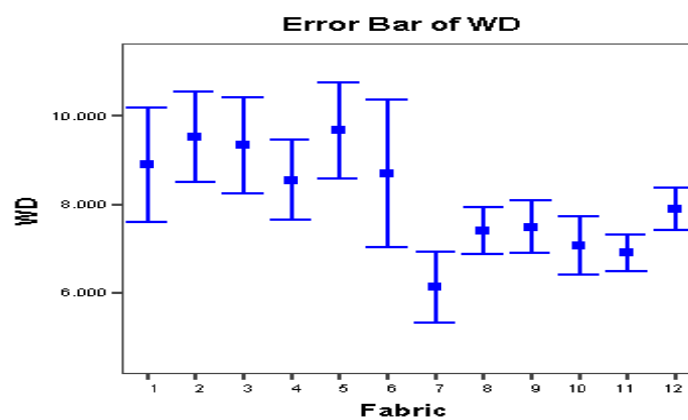


Figure 3. Error-bar of the measurement results of compression work W_D

Figure 3 and Figure 4 are the Error-bar charts of the measurement results for the indices compression work W_D and W_A . In Figure 3, Fabric 5 has the highest value of compression work W_D , and is followed by Fabric 2, where the W_D is 9.6755 and 9.5191 (N.cm/cm²) respectively. Fabric 7 has the lowest value of compression work W_D . As shown in Figure 4, fabric 6 has the lowest value of compression work W_A .

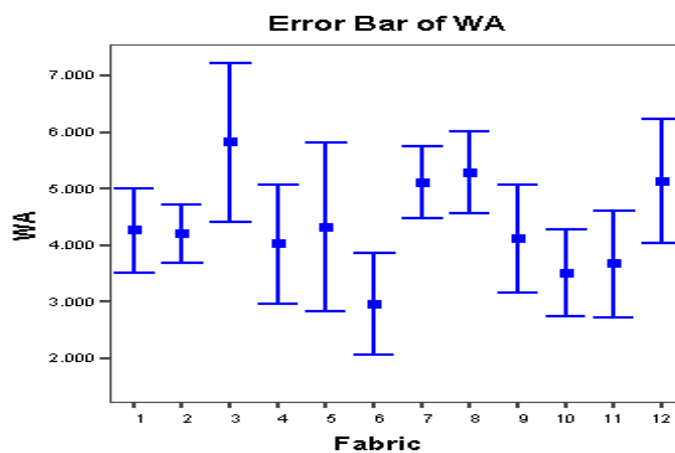


Figure 4. Error-bar of the Measurement Results of Compression Work W_A

The measurement results of evaluation index RC are shown in Figure 5. Fabric 6 has the lowest value of compressional resilience where RC is 34.5369%, and fabric 7 has the highest value of compressional resilience where RC is 83.7688%. The results show that fabric 6 is the softest and fabric 7 is the stiffest among all the test fabrics.

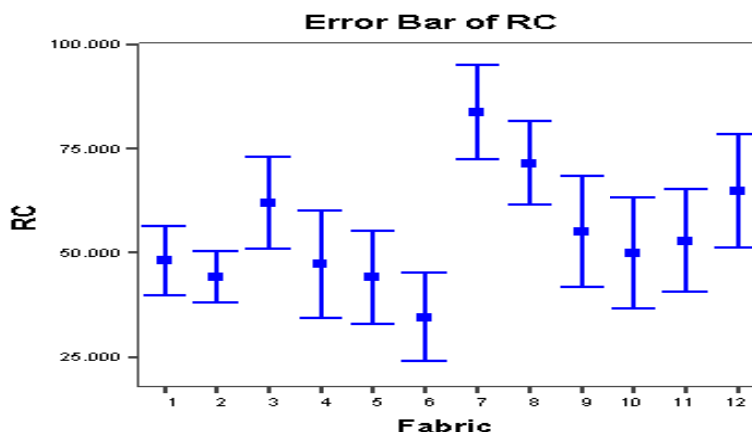


Figure 5. Error-bar of the Measurement Results of Compression Resilience RC

5. Conclusion

Compression properties of textiles, including compression resilience, not only affect softness sensations but also influence their aesthetic qualities, which may motivate consumers to make purchase decisions. A new test method for compression resilience evaluation of textiles was proposed. The test method and the measurement system can measure the compression properties by simulating the process during clothing contacts with human skin under dynamic conditions. A series of indices were defined to characterize compression properties of the textiles derived from the test data. Twelve types of fabrics with different structural features and made from different textile fabrics were tested. The analysis of the variance results show that the test method and the measurement system is able to determine the significant differences in fabric compression resilience properties to all indices with P level <0.05 . The denim has the maximum compressional resilience and the best recovery ability. The polar fleece is the softest fabric and has the minimum compressional resilience.

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