Changes in Hand Properties of Cotton Crepe Fabrics after Wearing

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Received 10 September 2015; accepted for publication 7 December 2015

Abstract

The aim of this study was to quantify the changes in hand properties of cotton piqué crepe fabrics in terms of mechanical and surface properties after actual wear. Three pairs of pajama pants were tailored from a cotton piqué crepe fabric and worn for 12 to 18 months. The mechanical and surface properties of the fabrics were measured using the KES-FB system and hand values were calculated. The tactile feel of the crepe fabrics was assessed before and after wear.

The extensibility at maximum tensile load of fabrics increased with wear, and the bending and shear properties of fabrics decreased after wear–wash cycles. Primary hand values calculated by equation KN202-LDY show that after wear the Hari (anti-drape stiffness) decreased and Fukurami (fullness) increased. These changes resulted in a softer hand than that of the unworn fabrics, and students evaluated this softness as the preferable hand. Fullness and anti-drape stiffness changed while the piqué surface shape was retained, thus generating additional softness.

1. Introduction

For over one hundred years, Japanese cotton piqué crepe fabrics have been used for men’s underwear because of the fabrics’ suitability to Japan’s hot, humid summers. One reason for this is the good hand of these fabrics. Crepe fabrics are constructed from hard twisted-weft yarns that result in a wrinkled fabric surface, and are currently produced by traditional processing techniques in Takashima, Shiga Prefecture, Japan. This ecofriendly method produces surface crinkling of fabrics without chemical process. Theoretical studies on the crinkling mechanism of crepe fabrics have been conducted previously [1, 2], and the general consensus is that shrinkage of twisted yarn strongly affects fabric crinkling. Yang and Li [3] presented an evaluation and control principle for the crepe effect on fabrics, and found that crepe level can be controlled by adjusting the fabric width in the finishing process.

With growing environmental awareness in society, it is worthwhile to investigate the changes in hand properties of cotton crepe fabrics after wear–wash cycles. Wear trials to find changes in hand properties are very time consuming, and conditions are difficult to control. There are therefore only limited research results in the literature, and no data have been published for this particular fabric. This work is a case study with the participation of three inpatients who wore pajama pants made from cotton piqué crepe fabrics. Subjective evaluation of fabric hand and wearing comfort is problematic, so hand was calculated from the mechanical and surface properties of sample specimens from the worn pants. University students performed subjective hand evaluation of the crepe fabrics.

In a previous study [4], we examined the mechanical properties and hand of cotton crepe fabrics to establish a basis for the hand design of traditional cotton crepe fabrics for women’s soft dresses and summer jackets. We consider pajama pants using cotton crepe fabrics to be suitable for inpatients for a long time if the fabric retains good hand after repeated wear–wash cycles. This study focuses on the hand properties of piqué cotton crepe fabrics after repeated wear–wash cycles to evaluate their potential for use as a comfortable fabric, in addition to possible ecological benefits of their use.

2. Experiment

2.1 Fabric specimens

Table 1 shows details of the fabric specimens. These fabrics were typical cotton embossed piqué crepe fabrics for outerwear. A grey
fabric (N0) with the same warp and weft yarns (9.84 x 2 tex, 29.53 tex) was finished with two warp yarn densities as specimens N1 and N2. In the hospital patients' nightclothes were washed using hot water and dried in a dryer at high temperature, so specimen N1 was washed under the laundry conditions used in the hospital: washing at 40 °C, followed by 30 min drying at 80 °C. This laundered fabric is coded as N1L and it was used for making pajama pants to investigate durability under a similar history. Figure 1 shows micrographs of N1L before and after repeated laundering. The number of embossed piqué was 6 piqué/cm.

2.2 Wear trial procedure

Three pairs of pajama pants were tailored from fabric N1L on the same production line at an apparel factory. Three inpatients for a long time wore the pants for 12 to 18 months, during which time the pants were laundered about 100 to 200 times (1500 to 3500 h of wear). Table 2 shows the numbers of launderings for each specimen. The three participants in this study spent most of their time in bed with limited mobility. We thus consider changes in material mechanical and surface properties to be largely influenced by laundry. After the wear trial, we cut out three fabric specimens (20 cm square) from the seat, back knee, and hem area of pants to investigate differences in the properties.

2.3 Measurement of physical properties

The mechanical and surface properties of fabrics were measured for all samples using the Kawabata Evaluation System for Fabrics under the conditions for women's thin dresses [5]. The primary hand values of women's dress fabrics were calculated by using conversion equations based on the mechanical and surface parameters of the fabrics [5]. The KN202-LDY conversion equations were used to obtain values for Koshi (stiffness), Hari (anti-drape stiffness), Fukurami (fullness), Shari (crispness), Kishimi (scroop), and Shinayakasa (suppleness).

As the crepe fabrics are constructed using hard twist weft yarns that result in a wrinkled fabric surface, we measured the tensile and torsional properties of weft yarns extracted from two fabrics, N1L and F3S in Table 1 and Table 2, respectively. Tensile properties of yarns were measured on a KES-G1S tensile tester (Kato Tech Co., Ltd.). The gauge length of each sample was 30 mm and tensile speed was 1 mm/s. Yarn torsional properties were measured on a KES-Y1 torsion tester (Kato Tech Co., Ltd.) [6]. The length of each sample was 30 mm, maximum angle was ±2π rad/cm, and torsion speed was 0.1π rad/s under a constant weight of 0.2 N. The number of twists in weft yarns sampled from the fabrics before and after wear (N1L, F3S) was also measured by the method defined in JIS L1095:1999. Geometrical changes in fabric piqué were examined using a VR-3000 3D measurement microscope (Keyence Co., Ltd.). A 20 mm length of fabric surface in the weft direction was measured. The average height Re of the piqué was measured from the macrograph images before and after the wear test following the method defined in JIS B0601:2001.
2.4 Subjective evaluation of tactile feel of fabrics

Four fabrics before the wear trial (Table 1) and three fabrics cut from the seat part of pants after wear (F1S, F2S, F3S) were selected for a subjective evaluation of tactile feel. The tactile feel of these fabrics was assessed by 21 female university students (aged from 18 to 24 years). The students evaluated these fabrics by freely touching them by hand. They did not know that the three fabrics (F1S, F2S, F3S) were previously used. The test fabrics were placed behind a curtain to eliminate effects of visual information from the evaluation. The students were asked to evaluate tactile feel in categories of “soft/hard,” “smooth/rough,” and “prefer/not prefer” using a scale from –2 to +2 according to the semantic differential method. Evaluations were performed in random order; we used the mean score of the subjective assessments as the tactile feel of the products.

3. Results and Discussion

3.1 Changes in the mechanical and surface properties after wearing

Figure 2 shows the mechanical and surface properties of all fabrics used in this study. Characteristic values are plotted on a data chart for fabrics used in women’s garments [7], with the horizontal axis normalized by the mean value and standard deviation of each corresponding characteristic value of the fabrics (n = 280). Of these, all samples exhibit larger values for surface properties (MIU, EMT) and extensibility at maximum tensile load (EMT) and tensile energy (WT), but smaller values for tensile resilience (RT) and compression resilience (RC) compared with Western-style women’s garments. These tendencies were attributed to surface crinkling and piqué along the warp direction (Figure 1).

Comparing N1L (unworn) with F1, F2, and F3 (worn), we see that the EMT values increased with wear, and the bending and shear properties decreased after wear. This tendency is more obvious for specimens taken from subject F3, which experienced the longest wear period and largest number of launderings. We consider changes in mechanical and surface properties as being influenced by laundry more than body movement, because the three patients spent most of the wearing time in bed. We calculated the ratio of mechanical properties of worn samples (F) to those of the reference sample (N1). Figure 3 plots the ratios for shear stiffness G and the bending rigidity B against the number of wash cycles. As seen in the changes from the N1L samples, the values of B and G increased after the first wash, and then decreased remarkably with the number of wash cycles.

Table 3 shows the mechanical properties and number of twists in weft yarns extracted from the before-wear (N1L) and after-wear samples (F3S). Each value was the average of ten tests for torsional rigidity, for tensile modulus, and for tenacity and 30 tests for number of twists, respectively. The torsional rigidity obtained from over-twisting, the tensile modulus and tenacity significantly decreased after wear. However, the number of twists did not decrease from the original but rather increase, indicating that fibers or yarn may be weakened by repeated wear–wash cycles. This change in yarn mechanical properties might be related to the decrease of shear and bending stiffness in fabric F3S. Therefore tensile, bending, and shear properties are key parameters in this study.
3.2 Changes in the fabric structure after wearing

Table 4 lists the parameters related to dimensional changes that occurred before and after the wear trials. The values for warp yarn density, thickness, and fabric weight increased after laundering and became almost invariant after 100 launderings (1500 h of wearing).

The value of air resistance \( R \) increased with the number of times worn and the number of launderings because of the increased density. To estimate the change in crinkling and geometric shape of the piqué, the geometrical roughness \( SMD \) and average height \( R_c \) of a sample were examined and listed in Table 5. Each value was the average of five tests. Values of \( SMD \) slightly increase after 150 launderings, but did not show clear changes after 200 launderings. The value of average height \( R_c \) of piqué slightly decreased after wear–wash cycles, depending on the sampled location. Figure 1(B) shows a micrograph of a piqué crepe fabric surface after 200 launderings (F3S). The crinkling shape was found to be retained.

3.3 Changes in the primary hand values

Figure 4 shows the primary hand values of crepe fabrics N1, N1L, F1, F2, and F3 as calculated from their mechanical and surface properties. The grading of feeling intensity for each primary hand value is numerically expressed on a scale of 1 (weakest) to 10 (strongest) [5]. Crepe fabrics N1 and N1L show large values for Hari (anti-drape stiffness) and small values for Shinayakasa (suppleness). Clothing made from such fabrics retains air between the wearer’s skin and the fabric, which facilitates the transfer of heat and moisture and therefore feels comfortable when used for summer clothes [4]. Table 6 shows the primary hand values of crepe fabrics N1L and F3. Each value was the average of three samples. In comparison with unworn samples (N1L), Hari (anti-drape stiffness) decreased with wear, and Fukurami (fullness), Kishimi (scroop) and Shinayakasa (suppleness) increased after wear. These changes resulted in a softer hand than that of the unworn fabrics.
Of these, cotton crepe fabrics showed larger values for Hari and Fukurami compared with Western-style women’s garments. Fukurami is related to the geometric structure of the piqué as well as its thickness. Hari and Fukurami were considered to be the most effective for understanding the changes in hand properties of piqué crepe after use. The retaining shape of piqué of crepe fabric may influence the increase in Fukurami (fullness) and retention of Shari (crispness) that are common features of piqué crepe fabrics.

3.4 Subjective hand evaluation of fabrics

We examined whether these fabric hands were acceptable and preferred. Samples used for the subjective hand evaluation are the four samples listed in Table 1 and three samples taken from the pants seats after wear (F1S, F2S, F3S). Table 7 shows the subjective evaluation scores of tactile feel of fabrics N1L and F3S. Each value was the mean score of the subjective assessments of 21 female university students. In comparison with unworn samples (N1L), softness and smoothness of fabric F3S significantly increased after wear. The worn crepe fabrics were evaluated as softer than unworn fabrics. Figure 5 plots mean values for soft/hard and smooth/rough against prefer/not prefer. The softness of the fabric washed 200 times was softer than unworn fabrics. Students selected this degree of softness as the preferred hand compared with unworn samples. This traditional ecofriendly textile design technique should be preserved and extended to other applications.

This paper is based on one presented at the 43rd Textile Research Symposium held in Christchurch, New Zealand on December 2014 [8].

Acknowledgments

We express our thanks to the patients and staff of Biwako Gakuen Medical and Welfare Center for their cooperation in the wear trials. This work was supported by JSPS KAKENHI Grant Numbers 243000247 and 26282011.

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