The shear properties of a fabric determine its performance properties as well as the appearances where it is subjected to a wide variety of complex deformations during usage as apparel. In this paper, woven fabrics have been made of cotton spun yarns with three different spinning techniques (ring spun, open-end spun and compact ring spun yarns) in weft direction. Some twill based weave structures were manufactured on the weaving machine with varying the weft density level. The Kawabata Evaluation System was used to measure the shear properties; shear rigidity, shear hysteresis at 0.5 deg shearing angle and shear hysteresis at 5 deg. shearing angle. A statistical analysis was performed to get the effect of decided parameters on shear. A highly significant effect of the weave structures and weft density on the measured shear properties were found, while the type of weft yarns has insignificant effect. A multiple linear regression equations were derived to get a mathematical relationship between the influencing parameters; (the float length, yarn diameter, and weft density) and the shear properties. The derived regression equations had high correlation coefficients values.

**Keywords:** Woven fabric, Shear angle, Spinning techniques, Weave structure, Apparel fabrics, Kawabata Evaluation System, Regression analysis.

### Introduction

The shear behavior of a fabric determines its performance properties when subjected to a wide variety of complex deformations in use. The ability of a fabric to be deformed by shearing distinguishes it from other thin sheet materials such as paper or plastic films. Juriga and Eugenija[1] stated that this property enables fabric to undergo complex deformations and to conform to the shape of the body. They added that shearing influences draping, flexibility and also the handle of woven fabric. Shear properties are important not only for fabrics and/or clothing but for textile composites as well. Lo and Hu [2] stated that shear properties of woven fabrics are important in many applications the understanding of fabric shear behavior were introduced by many early trials of measuring it. Dreby [3], Go et al[4], Mornerand Eeg-Olofssof [5], and Kawabata [6, 7] each introduced a shear apparatus to measure fabric shear properties.

### Fabric Objective measurements

Cusick [8], Lindberg et al. and Grosberg and Park [9] used a qualitative method to describe shear properties with a model which are based on the concept of Low-Stress Mechanical Properties of Fabrics. They indicated that the hysteresis produced during shearing is determined wholly by the frictional restraints arising in the rotation of the yarns from the intersecting points in the fabric.

### Fabric Hand, Drape, and Appearance

Many literature proves that the shear mechanism is one of the important properties influencing the draping, pliability, and handle of woven fabrics [6, 7, 11]. Shear deformation of woven fabrics also affects their bending and tensile properties in various directions other than just the warp and weft directions [3, 9, 12].

In addition some literature [12,13] have shown that shear rigidity can be calculated from the tensile properties of a fabric in bias (45deg) direction based on the interrelations of the in plane
properties of a plate. The uniaxial tension of a bias-
cut fabric specimen is relatively simple and may
be carried out on any extensometer. This method
of fabric properties investigation is therefore the
most appropriate for industrial use. However,
when this test is applied to fabric, shearing is
non-uniform throughout the specimen due to
the distortion of width uniformity. Shear angle
is one of the main criteria for characterizing the
formability of fabrics. As the fabric is fitted onto a
superficial surface, shearing occurs incrementally
until the critical shearing angle is reached. When
this angle exceeds a strict value, the specimen
starts to buckle. wrinkling is observed.

Objectives of this article are Studying the
effect of the weave structure, type of weft yarn
spinning and weft density on the shear properties
measured on Kawabata Evaluation System;
KES-F (shear rigidity, shear hysteresis at 0.5 deg.
shear angle and shear hysteresis at 5 deg. shear
angle). In addition to deriving a mathematical
relationship between the influencing parameters;
(the float length, yarn diameter, and weft density)
and the measured shear properties, to be used as
reliable predictive models.

Experimental

Fabric samples:
The weaving machine: Rapier Vamatex HS,
Italy
Three weave structures (shown in Table 1)
Warp yarns:
Ring spun (Giza 86 cotton ), count Ne 40/1
Weft yarns:
Compact spun (Giza 86 cotton ), Ne 40/1
Ring spun (Giza 86 cotton ), count Ne 40/1
OE spun (Giza 86 cotton ), count Ne 40/1
Weft densities:
36, 42, and 50 picks per cm
Warp density:
42 picks per cm
Fabric shear measurements:
The KES-F system:
The Tensile and Shear module
Sukuagira Lab;
Kyoto institute of technology,
Kyoto, Japan

Results and Discussion

The KES shear measurements

The measured shear properties G, 2HG, and
2HG5 of the fabrics under study are shown in Table
1. The 27 fabric samples contain 3 weave structures,
3 weft spun yarns, and 3 weft densities.

To achieve the objective of deriving mathematical
reliable predictive models some calculations and
measurements are developed to characterize both
weave structures and weft spun yarns numerically.

Fabric float length

The average float length of the 3 fabric structures
are calculated according to the following equation:

Fabric float length; \( AFL = \frac{\text{(no. of threads per repeat/ no. of intersections per repeat)}}{F} \)

Where; F constant based on original weave type (for
twill weave; F=0.39)
TABLE 1. Fabric shear measurements on KES-F (Tensile and Shear).

<table>
<thead>
<tr>
<th>Fabric Code</th>
<th>Design</th>
<th>Spinning system</th>
<th>Weft/cm</th>
<th>Shear rigidity; G (gf/cm)</th>
<th>Shear hysteresis; 2HG (gf/cm)</th>
<th>Shear hysteresis; 2HG5 (gf/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D111</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>2.044</td>
<td>1.391</td>
<td>6.700</td>
</tr>
<tr>
<td>D112</td>
<td></td>
<td></td>
<td>36.0</td>
<td>2.695</td>
<td>2.179</td>
<td>9.082</td>
</tr>
<tr>
<td>D113</td>
<td></td>
<td></td>
<td>36.0</td>
<td>3.154</td>
<td>2.345</td>
<td>8.823</td>
</tr>
<tr>
<td>D121</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>2.327</td>
<td>2.556</td>
<td>8.610</td>
</tr>
<tr>
<td>D122</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>2.301</td>
<td>2.594</td>
<td>7.984</td>
</tr>
<tr>
<td>D123</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>3.862</td>
<td>2.410</td>
<td>9.432</td>
</tr>
<tr>
<td>D131</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>2.445</td>
<td>2.574</td>
<td>8.946</td>
</tr>
<tr>
<td>D132</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>3.266</td>
<td>3.158</td>
<td>10.928</td>
</tr>
<tr>
<td>D133</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>3.022</td>
<td>2.762</td>
<td>9.114</td>
</tr>
<tr>
<td>D211</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>2.170</td>
<td>2.183</td>
<td>6.855</td>
</tr>
<tr>
<td>D212</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>1.916</td>
<td>1.944</td>
<td>6.077</td>
</tr>
<tr>
<td>D213</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>1.934</td>
<td>2.225</td>
<td>5.835</td>
</tr>
<tr>
<td>D221</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>1.131</td>
<td>1.312</td>
<td>3.948</td>
</tr>
<tr>
<td>D222</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>1.575</td>
<td>1.515</td>
<td>5.543</td>
</tr>
<tr>
<td>D223</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>2.427</td>
<td>2.276</td>
<td>8.319</td>
</tr>
<tr>
<td>D231</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>1.162</td>
<td>1.391</td>
<td>4.071</td>
</tr>
<tr>
<td>D232</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>1.901</td>
<td>1.509</td>
<td>5.103</td>
</tr>
<tr>
<td>D233</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>2.478</td>
<td>2.056</td>
<td>8.157</td>
</tr>
<tr>
<td>D311</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>0.572</td>
<td>1.117</td>
<td>2.505</td>
</tr>
<tr>
<td>D312</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>0.867</td>
<td>1.365</td>
<td>3.758</td>
</tr>
<tr>
<td>D313</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>0.931</td>
<td>1.497</td>
<td>4.072</td>
</tr>
<tr>
<td>D321</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>0.718</td>
<td>1.303</td>
<td>3.117</td>
</tr>
<tr>
<td>D322</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>1.013</td>
<td>1.487</td>
<td>4.378</td>
</tr>
<tr>
<td>D323</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>1.311</td>
<td>1.709</td>
<td>5.610</td>
</tr>
<tr>
<td>D331</td>
<td></td>
<td>Compact yarn</td>
<td>36.0</td>
<td>0.591</td>
<td>1.308</td>
<td>2.932</td>
</tr>
<tr>
<td>D332</td>
<td></td>
<td>Compact yarn</td>
<td>42.0</td>
<td>0.739</td>
<td>1.579</td>
<td>2.983</td>
</tr>
<tr>
<td>D333</td>
<td></td>
<td>Compact yarn</td>
<td>50.0</td>
<td>1.595</td>
<td>1.859</td>
<td>6.430</td>
</tr>
</tbody>
</table>

TABLE 2. The average float length of the 3 fabric structures.

<table>
<thead>
<tr>
<th>Design Code</th>
<th>Weave structure</th>
<th>AFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>D2</td>
<td></td>
<td>1.3</td>
</tr>
<tr>
<td>D3</td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>

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Yarn diameters:

The selected spun yarns used for weft insertion had different yarn diameters:

- Ring spun yarn: 0.19mm
- Compact spun yarn: 0.17mm
- OE spun yarn: 0.21mm

Regression analysis

To perform regression analysis, 3 predictors are used:

- X1: average float length AFL
- X2: yarn dia (mm)
- X3: weft density/cm

The response is the KES shear properties measured.

The multiple linear regression model was performed and coefficient of correlation was calculated to check the linearity of the relationship.

Shear rigidity; G (gf/cm)

The following table summarizes the Regression Statistics of Shear rigidity; G.

**TABLE 3. Regression Statistics of Shear rigidity; G.**

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>4.92121584</td>
</tr>
<tr>
<td>X1</td>
<td>-4.65009722</td>
</tr>
<tr>
<td>X2</td>
<td>2.378777778</td>
</tr>
<tr>
<td>X3</td>
<td>0.059333168</td>
</tr>
</tbody>
</table>

From the previous table it could be concluded that linear regression model is acceptable for predicting Shear rigidity; G as coefficient of correlation R=0.94.

Both x1 and x3 have significant effect on G (p-value=1.88E-11 and 1.65E-05 resp.), while insignificant effect is found by x2 (p-value=0.542142.) which may indicate that the yarn diameters are close to each other.

Shear hysteresis at 0.5 deg. shear angle; 2HG (gf/cm)

The following table summarizes the Regression Statistics of Shear hysteresis; 2HG.

**TABLE 4. Regression Statistics of Shear hysteresis; 2HG.**

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.700397898</td>
</tr>
<tr>
<td>X1</td>
<td>-2.42941667</td>
</tr>
<tr>
<td>X2</td>
<td>5.413611111</td>
</tr>
<tr>
<td>X3</td>
<td>0.031416907</td>
</tr>
</tbody>
</table>

From the previous table it could be concluded that linear regression model is acceptable for predicting Shear hysteresis; 2HG as coefficient of correlation R=0.83.

Both x1 and x3 have significant effect on G (p-value=2.14E-06 and 0.00912 resp.), while insignificant effect is found by x2 (p-value=0.175731.).

Shear hysteresis at 5 deg. shear angle; (gf/cm)

The following table summarizes the Regression Statistics of Shear hysteresis; 2HG5.

**TABLE 5. Regression Statistics of Shear hysteresis; 2HG5.**

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>13.36515818</td>
</tr>
<tr>
<td>X1</td>
<td>-12.1761667</td>
</tr>
<tr>
<td>X2</td>
<td>13.76694444</td>
</tr>
<tr>
<td>X3</td>
<td>0.143413589</td>
</tr>
</tbody>
</table>

From the previous table it could be concluded that linear regression model is acceptable for predicting Shear hysteresis; 2HG5 as coefficient of correlation R=0.91.

Both x1 and x3 have significant effect on G (p-value=1.01E-09 and 0.000465 resp.), while insignificant effect is found by x2 (p-value=0.276666).
Fig. 2. Predicted shear rigidity vs actual shear rigidity.

Fig. 3. Predicted shear hysteresis 2HGvs actual hysteresis 2HG.

**Conclusion**

The shear properties of apparel fabrics need to be measured and predicted accurately by both the fabric and clothing manufacturers for expecting its performance, hand, drape, and appearance. Shear properties executed by KES-F system can be easily mathematically predicted accurately using liner and/or nonlinear regression models from simple measurements for the fabric float length, density, and yarn diameter.

The fabric hand and drape have a direct relationship with the KES shear measurements.

More efforts are needed from researchers and product developers to facilitate shear characteristics by simpler and reasonable ways.

**References**


دراسة خصائص القص لأقمشة الملابس باستخدام خيوط مغزله مختلفة

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تحدد خصائص إجهاد القص للقمصان المنسوج خصائص أدائها وكذلك مظهره. حيث يتعرض فيها لمجموعة واسعة من التشتوات المعتدلة أثناء الاستخدام كملابس. في هذا البحث، تم صنع أقمشة من قطن، وغزل منها بثلاثة أساليب مختلفة: غسل للحمة، غسل طريق مفتوح، غسل مدمج في الوجه. تم استخدام نظام تقييم كواباتا لقياس خصائص القص. وهستريسس القص عند زاوية قص 0.5 درجة. وتستريسس القص عند زاوية قص 5 درجة.

تم إجراء تحليل إحصائي على تأثير التعاملك المحدود على القص. وجد أن هناك تأثير كبير للغاية للتركيب النسيجي وكثافة اللحمة على خصائص القص المتساوية. في حين أن نوع خيوط اللحمة له تأثير ضئيل. تم استخدام معادلات التحليل للحصول على علاقة رياضية بين العوامل المذكورة، (طول الشيف، قطر الخيط، وكثافة اللحمة) وخصائص القص المفسحة. كان تم合う معاملات التحليل المشتقة في معاملات ارتباط عالية.

References: