Changes in dynamic drapability of polyester fabrics with weave density, yarn twist and yarn count obtained by regression equations

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Some new parameters of dynamic drapability, such as revolving drape increase coefficient ($D_r$), revolving drape coefficient at 200 rpm ($D_{200}$), and dynamic drape coefficient at swinging motion ($D_d$), have been defined using a device of dynamic drape tester and the regression equations are derived from mechanical parameters of fabrics obtained from KES system. These equations have been applied to polyester fabrics used for women’s fine dress materials and the effects of weave density, yarn twist and yarn count on these parameters studied. It is observed that $D_r$ and $D_d$ have a maximum value at the optimum weave density. These values increase with the increase in yarn twist in the case of Dechine fabrics. These values decrease in the case of taffeta fabrics, and increase in the case of georgette with yarn count. Changes in $D_{200}$ with weave density, yarn twist and yarn count are found to be little for all the fabrics. Node number decreases and conventional static drape coefficient ($D_s$) increases with weave density.

Keywords: Dynamic drapability, Polyester, Weave density, Yarn count, Yarn twist

1 Introduction

Drapability of fabrics is very important especially for women’s fine dress materials because of its relation to beautiful appearance and/or elegant movement of clothes. Draping behavior of fabrics in static state has been studied and analyzed by many scientists; however, there have been few investigations concerning dynamic drape behavior of fabrics which are mostly related to beautiful appearance of clothes. Only a computer-based vision system developed by Stylios and Zhu is reported recently.

Studies on drape behavior of fabrics have been reported by Matsudaira et al. recently and much progress has been achieved. It has been found that there exists an inherent node number for any fabric, and the conventional static drape coefficient ($D_s$) of the fabrics could be measured by image processing system with high accuracy and reproducibility. Then the regression equation for the coefficient was derived for both isotropic and anisotropic fabrics, and the effect of basic mechanical parameters of fabrics on these static drape shapes was analyzed quantitatively by computer simulation. Further, dynamic drape behavior of fabrics was examined using a device of dynamic drape tester. The revolving drape increase coefficient ($D_r$) which means the spreading ratio of overhanging fabrics with revolution, and revolving drape coefficient at 200 rpm ($D_{200}$) which means the saturated spreading of fabrics at rapid revolution were defined and their regression equations were derived. Finally, dynamic drape coefficient at swinging motion ($D_d$), which is considered to be more similar to the human waist motion at walking, was defined and the regression equation was also derived from the basic mechanical parameters of fabrics.

Then, these dynamic drape coefficients of polyester fibre "Shingosen" fabrics and silk fabrics were investigated widely and peculiar features of these fabrics became clear by these dynamic drape coefficients quite recently.

In this paper, definitions of these dynamic drape coefficients have been explained and the effect of weave density, yarn twist and yarn count on drape coefficients of polyester fabrics investigated using the regression equations developed by Matsudaira et al.
2 Materials and Methods

2.1 Samples

Polyester samples were used for investigating the effects of weave density, yarn twist and yarn count on fabric drapability. The details of standard and normal samples are shown in Table 1. These samples are typical kinds of plain weaves made of polyester fibres and used mainly for women’s fine dress fabrics in Japan now.

Taffeta is the most basic fabric consisted of twist-less continuous filament yarns in both warp and weft directions. Weft yarn density was changed in decreasing and increasing directions from the standard density which was decided empirically. Weft yarn count was also changed to study the effect of yarn count.

Dechine consists of weft continuous filament yarns with high twist and twist-less or low twist warp continuous filament yarns, having small crepes on the surface. Weft yarns with S-twist (left-handed twist) and Z-twist (right-handed twist) are used alternately by 2 yarns (SZ2). Weft yarn density and weft yarn twist were changed for investigation.

Georgette consists of high twist continuous filament yarns in both warp and weft, having small crepes on the surface. S-twist and Z-twist yarns are used alternately by 2 yarns (SZ2) for both warp and weft. Weft yarn density and weft yarn twist were changed for Georgette-1, and weft yarn count was changed for Georgette-2. Georgette-2 has smaller level of twist than Georgette-1.

Pongee is made of false twist continuous filament yarns for both warp and weft. The name Pongee is originally used for silk fine dress fabrics. Weft yarn density was changed.

Yoryu consists of warp continuous filament yarns with high twist (SZ2) and weft continuous filament yarns with high twist of left-handed twist (S). Large crepes are shown on the surface in warp direction. Weft yarn density and weft yarn twist were changed.

In order to avoid the effect of finishing conditions, these samples have been processed through the same standard and minimum steps of finishing procedure used for polyester fabrics, such as relaxing and scouring, washing, drying, heat setting, and cooling. Dyeing and final finishing treatments were not executed.

2.2 Mechanical Parameters

All the samples, each of the size 20 cm × 20 cm, were measured for their basic mechanical properties by KES (Kawabata Evaluation System for Fabrics) system under the conditions of 20°C and 65% relative humidity. Three pieces were measured for each sample and average value was used for analysis.

3 Results and Discussion

3.1 Calculation of Drape Coefficients

3.1.1 Conventional Static Drape Coefficient

Static drape coefficient of fabrics \(D_s\) and node number \(n\) are calculated using the following equations:

\[
D_s = \frac{4a^2 + 2b^2 + 2a_m^2 + b_m^2 - 4R_0^2}{12R_0^2} \quad \ldots (1)
\]

\[
n = 12.797 - 269.9 B W \sqrt{38060 \frac{B W}{W} - 2.67 \frac{G}{W}} + 13.03 \frac{2HG}{W} \quad \ldots (2)
\]

Table 1 — Specifications of standard polyester fabric samples

<table>
<thead>
<tr>
<th>Fabric</th>
<th>Thread density/m</th>
<th>Count, tex (filament)</th>
<th>Twist, turns/m</th>
<th>Thickness* mm</th>
<th>Weight g/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warps</td>
<td>Wefts</td>
<td>Warp</td>
<td>Weft</td>
<td>Warp</td>
</tr>
<tr>
<td>Taffeta</td>
<td>4370</td>
<td>3310*</td>
<td>8.3(36)</td>
<td>8.3(36)*</td>
<td>0</td>
</tr>
<tr>
<td>Dechine</td>
<td>5120</td>
<td>3540*</td>
<td>8.3(36)</td>
<td>8.3(36)</td>
<td>250(S)</td>
</tr>
<tr>
<td>Georgette-1</td>
<td>3980</td>
<td>3460*</td>
<td>8.3(36)</td>
<td>8.3(36)</td>
<td>2500(SZ2)</td>
</tr>
<tr>
<td>Pongee</td>
<td>4410</td>
<td>3500*</td>
<td>8.3(36)</td>
<td>8.3(36)</td>
<td>0**</td>
</tr>
<tr>
<td>Yoryu</td>
<td>3190</td>
<td>3660*</td>
<td>8.3(36)</td>
<td>8.3(36)</td>
<td>2500(SZ2)</td>
</tr>
<tr>
<td>Georgette-2</td>
<td>3740</td>
<td>3700</td>
<td>8.3(36)</td>
<td>8.3(36)*</td>
<td>1000(SZ2)</td>
</tr>
</tbody>
</table>

*This value was changed in both increasing and decreasing directions.

**False-twisted textured yarn.

*Thickness is measured at the pressure of 49 Pa.
where $R_0$ is the radius of circular supporting stand (63.5 mm); $a$, the constant showing total size of two-dimensionally projected area (mm); $b$, the constant showing height of cosine wave of two-dimensionally projected shape (mm); and $a_n$, $b_m$, the constants showing anisotropy of fabrics. These constants are obtained from the basic mechanical parameters measured by KES system using following equations:

$$a = 35.981 + 1519 \frac{B}{W} - 204300 \frac{B}{W} + 23.27 \sqrt{\frac{G}{W}} + 0.0178G$$  \hspace{1cm} \ldots (3)

$$b = 29.834 - 1.945n - 0.0188G - 91.84 \frac{2HG}{W}$$  \hspace{1cm} \ldots (4)

$$a_n = 9063 \left( \frac{B_1 - B_2}{W} \right)^{\frac{3}{2}}, \quad b_m = 6224 \left( \frac{B_1 - B_2}{W} \right)^{\frac{3}{2}}$$  \hspace{1cm} \ldots (5)

where $B$ is the bending rigidity (mN·m²/m); $G$, the shearing rigidity (N/m/rad); $2HG$, the hysteresis in shearing force at 0.0087 radian (N/m); $W$, the fabric weight (g/m²); and $B_1$ & $B_2$, the bending rigidity in warp and weft directions respectively.

3.1.2 Dynamic Drapability Coefficient

A device of dynamic drape tester is shown in Fig. 1. This tester is composed of a circular supporting stand having the same size with JIS (Japanese Industrial Standard) drape tester (127 mm in diameter) which can rotate from 0 rpm to 240 rpm continuously and also turn-round reversely at an arbitrary angle. Changes in drape coefficient of several representative fabrics with the increase of revolution speed are shown in Fig. 2. It is clear that the difference of drape coefficient between fabrics becomes distinct in the region between 50 rpm and 130 rpm. Therefore, revolving drape increase coefficient ($D_r$) is defined as the slope between drape coefficient and rpm within this region. If the coefficient is larger, the ratio of drape coefficient increase with revolution speed is larger. The regression equation for the coefficient is derived as follows:

$$D_r = 0.792 + 2.374 \sqrt{\frac{2HG}{W}} - 0.6305 \sqrt{\frac{G}{W}} - 6.762 \frac{B}{W} - 2.673 \frac{2HG}{W} + 0.0005W$$  \hspace{1cm} \ldots (6)

On the other hand, if the revolution speed becomes larger than 180 rpm, the drape coefficient does not increase at all with the revolution speed. Therefore, revolving drape coefficient at 200 rpm ($D_{200}$) is defined as saturated drape coefficient at rapid revolution. The regression equation for the coefficient is derived as follows:

$$D_{200} = 61.475 - 37.02 \sqrt{\frac{G}{W}} + 0.1411G + 40.88 \sqrt{\frac{G}{W}} + 0.049W + 436.8 \frac{2HB}{W}$$  \hspace{1cm} \ldots (7)
where 2HB is the hysteresis in bending moment at 0.5 cm² (mN·s/m²).

Projected area of a fabric is shown in Fig. 3 at two maximum turn-round angles in a same angular velocity of 8.4 rad/s. The area increases with the increase in rotated angle and reaches to the maximum area before the set angle, that is the turn-round angle. The area then decreases drastically from the maximum area to the minimum area at this angle. Therefore, the difference of projected area at turn-round angle could be a parameter of dynamic drape behavior of fabrics. Dynamic drape coefficient of fabrics at swinging motion is defined as the change of projected area at turn-round angle as follows:

$$D_s = \frac{(S_{max} - S_{min})}{\pi R_0^2 \times 900} \times 100$$

where $D_s$ is the dynamic drape coefficient at swinging motion; $S_{max}$ the maximum projected area at the turn-round angle; $S_{min}$ the minimum projected area at the turn-round angle; $R_0$ the radius of the circular supporting stand (63.5 mm); and $R_0$ the radius of the fabric sample (2R0=17 mm).

The value of $D_s$ at the conditions of angular velocity of 9.42 rad/s and turn-round angle of $\pi$ rad, is calculated from following equation:

$$D_s = 90.217 + 0.1183W - 720.7 \sqrt{\frac{B}{W}} - 41.1 \sqrt{\frac{G}{B}}$$

### 3.2 Effect of Fabric Parameters

#### 3.2.1 Effect of Weave Density

Effects of weave density on node number and conventional static drape coefficient ($D_s$) are shown in Fig. 4. It is clear that the node number decreases and $D_s$ increases with the increase in weft yarn density for all the fabrics studied. As node number and $D_s$ are mostly affected by bending rigidity ($B$) of fabric, this phenomenon is explained by the increase of $B$ with weft yarn density.

Three dynamic drape coefficients, such as revolving drape increase coefficient ($D_r$), revolving drape coefficient at 200 rpm ($D_{200}$) and dynamic drape coefficient at swinging motion ($D_s$) are shown in Fig. 5. It is found that $D_s$ has the maximum value at the optimum weave density of weft yarn for all the fabrics. In the case of Taffeta fabrics, the maximum point may be at smaller region of the density. As $D_s$ means the change in spreading ratio of overhanging fabric with revolution, there exists an optimum point where each fabric vibrates and overhangs easily by a gentle wind and/or small movement of human body. The parameter $D_{200}$ does not change much with the weave density for almost all fabrics. This means that the saturated spreading of fabrics at rapid revolution shows similar equilibrium state within the region of standard weave density examined here.

*Fig. 3 — Changes in projected area of a fabric with rotated angle at different turn-round angles (1-□-1.5 rad/s, and 4-●-0.5 rad/s)*

*Fig. 4 — Dependency of node number and $D_s$ on weave density*
The parameter $D_d$ decreases with weave density basically; however, it seems that there exists an optimum point where $D_d$ shows the maximum value. In the case of Dechine and Taffeta fabrics, those points may be at smaller region of the density. As $D_d$ means the degree of draping shape change of fabrics at swinging motion, every fabric has optimum weave density where the fabric is easy to change its draping shape by small force such as light wind and/or swinging motion of human body.

3.2.2 Effect of Yarn Twist

Node number increases and $D_s$ decreases with the increase in weft yarn twist in the case of Dechine fabrics; however, they do not change at all in the case of Georgette-1 and Yoryu fabrics. These phenomena are explained by the decrease in $B$ with weft yarn twist for Dechine fabrics. In the case of Goergette-1 and Yoryu fabrics, warp yarn has originally high twist as 2500 (SZ2) and the effect of weft yarn twist has not been recognized.

The effect of weft yarn twist on $D_r$ is shown in Fig. 6. It is found that $D_r$ increases in the shape of S-letter for Dechine fabrics with the yarn twist; however, it does not change much for Georgette-1 and Yoryu fabrics. The effect of weft yarn density on $D_{200}$ is found to be little for all the fabrics studied, i.e. Dechine, Goergette-1 and Yoryu fabrics.

Results of $D_d$ are shown in Fig. 6. The value of $D_d$ for Dechine fabrics increases with the yarn twist; however, it is saturated at more than 2000 turns/m. The values of $D_d$ for Goergette-1 and Yoryu fabrics do not change at all because of original high twist of warp yarn.

3.2.3 Effect of Yarn Count

Node number decreases and $D_s$ increases largely with the increase in weft yarn count in the case of Taffeta fabrics; however, they do not change at all for Georgette-2. This means that $B$ increases with weft yarn count in the case of Taffeta fabrics; however, it does not increase in the case of Georgette-2.
Geometrical structure of these Taffeta and Georgette-2 was observed and it was found that there was no space between adjacent yarns in Taffeta fabrics; however, there was much space between them in Georgette-2 fabrics. Yarns are flat and wide in Taffeta fabrics; however, yarns are thin because of twist in Georgette-2 fabrics. Therefore, it is supposed that there is more space between warp and weft yarns at the cross-over point and contacting force between them is small for Georgette-2 fabrics. This is the reason why the effect of yarn count does not appear on $B$ for Georgette-2 fabrics and the effect of yarn count appears directly on $D_d$ in the case of Taffeta fabrics.

Dependency of $D_r$, $D_{200}$ and $D_d$ on weft yarn count is shown in Fig. 7. The value of $D_{200}$ increases with the yarn count for both Taffeta and Georgette-2 fabrics. This means that the saturated spreading of fabric at rapid revolution increases with yarn count because of the increase in fabric weight with yarn count.

Results of $D_d$ are found to be similar to those of $D_t$ as shown in Fig. 7. In the case of Taffeta fabrics, the increase in $B$ and $G$ is much larger than the increase in $W$ with yarn count, and brings about the decrease in $D_d$. On the other hand, the changes in $B$ and $G$ are little and bring about the increase in $D_d$ by the increase in $W$ for Georgette-2 fabrics.

4 Conclusions

4.1 Node number decreases and conventional static drape coefficient ($D_t$) increases with weave density.

4.2 Revolving drape increase coefficient ($D_r$) and dynamic drape coefficient at swinging motion ($D_d$) might have the maximum value at the optimum weave density.

4.3 These values increase with yarn twist in the case of Dechine fabrics; however, the effects are smaller for Georgette and Yoryu fabrics.

4.4 These values decrease with yarn count in the case of Taffeta fabrics; however, increase in the case of Georgette fabrics.

4.5 Changes in revolving drape coefficient at 200 rpm ($D_{200}$) are found to be little with weave density, yarn twist and yarn count for all the fabrics studied.

References


