Vibrational Property of Filament Woven Fabrics Based on Shear Deformation

Part 2: Vibrational Damping Behavior at Large Shear Angle

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Abstract

In order to study basic phenomenon of dynamic drape of filament woven fabrics, damping behavior of fabric shear vibration in the large shear deformation region (>0.035 rad); that is, the region in which the vibration damped non-linearly with time, was investigated in detail in relation to shear property of the fabric. It was shown that the non-linearity increased with the shear angle and the change was mainly caused by the increase of shear hysteresis. The damping behavior of silk filament woven fabrics was classified into four patterns and the patterns corresponded well with the four combinations of basic mechanical parameters of shear property; G and $2HG$, in the degree of changes with shear angle, obtained by KES system. Bending vibration behavior changed less than the shear vibration for four typed silk fabrics, and it was suggested that dynamic drape behavior of clothes was more related with shear property than bending property.

1. Introduction

Both good touch and beautiful appearance are required for women's thin dress fabrics as an essential quality, however, the latter seems to be especially important for the clothes such as blouses and dresses. If color, pattern and design of clothes are neglected, beautiful appearance of clothes is mainly dependent on the movement of clothes accompanied with body movement, that is, dynamic drape behavior of clothes.

The author had already investigated vibrational property of woven fabrics based on shear deformation and reported^{[1][2]} the basic theory and fundamental phenomenon of the shear vibrational property. Shear deformation in the same plane is one of the basic mechanical properties of woven fabrics which affects the dynamic drape behavior. The shear vibrational property had been studied in relation to fabric tension for silk filament woven fabrics in the last paper^[3], as the fabrics were considered to be the most beautiful in dynamic drape behavior. In the shear vibrational property of filament woven fabrics, the vibration damped linearly with time at small shear amplitude angle, however, the vibration damped non-linearly at large shear angle. Only the former part is investigated so far, the latter part is studied this time. Further, vibrational property of woven fabrics based on bending deformation is also studied and discussed in relation to shear vibration.

2. Experimental

2.1 Method of experiment

The vibrational damping behavior of woven fabric was measured by a vibration tester which was modified model

of KES-LABO-MODEL-F3 Shear Tester. A bar weight was attached to the bottom end of fabric and a core of differential transformer was attached on the tip of the bar to detect the movement of fabric; u . Mass of the weight bar was selected as 0.5 kg/m constant, which was the condition in which shear vibration continued the longest^[3]. Effective size of sample was 5 cm $\times$ 20 cm, which was used in the standard measurement^[5] of KES system^[4]. Using the same size with KES system, the result of vibration tester was connected with mechanical characteristics of shear property such as shear stiffness, G , and shear hysteresis, $2HG$. A simple model of shear vibration tester is shown in Fig. 1.

Shear property of fabric was measured by KES-FB1 with the same fabric tension as studied for vibrational property. Shear stiffness; G , defined as the slope of shear force – shear angle curve and shear hysteresis; $2HG$, defined as the difference of shear force between forward and backward curves, were obtained from the shear

Fig. 1 Simple model of shear vibration tester with a plate-shaped fabric.

property.

Vibrational property based on bending deformation was obtained by KES-LABO-MODEL-F2 Bending Tester. A simple model of the bending vibration tester is shown in Fig. 2. Fabric was bent and hold between two thin polymethylmethacrylate plates and vibrates according to the motion of pendulum. Vibrational damping behavior of fabric was obtained by this tester.

Bending property of fabric was measured by KES-FB2 and bending rigidity; B , and hysteresis of bending moment; $2HB$, were obtained from bending moment versus curvature relationship.

All the experiments were carried out at temperature $295 \pm 3^\circ\text{K}$, and relative humidity $60 \pm 10\%$ RH conditions.

2.2 Samples

As dynamic drape behavior is important in the women's thin dress fabrics, silk filament woven fabrics, which are considered to be typical fabrics of women's

Fig. 2 Simple model of bending vibration tester with a bent fabric.

thin dress fabrics, were collected to investigate. In the samples used for the last paper^[3], seven fabrics were collected in the point of longer duration time of shear vibration. These fabrics were silk filament woven fabrics used mainly for blouses, one-piece dresses, and other women's thin outer-wears. These fabrics were classified into three groups according to yarn twist. Namely, Habutae; consisting of twistless warp and weft yarns, Georgette; consisting of high-twist yarns of warp and weft, and Dechine; consisting of twistless warp and high-twist weft yarns. All of these fabrics were plain weaves of which sericin had been removed after weaving. Details are shown in Table 1.

3. Results

3.1 Shear vibration and shear property

Two typical examples of the damping behavior of shear vibration were shown in Fig. 3. These curves were obtained from the maximum point of shear amplitude angle of both right and left directions in the damping curve. Shear vibration of these fabrics lasted longer than the other fabrics shown in Table 1. The vibration of Georgette – No.7 damped the most linearly with time (a), and Habutae – No.2 damped the most non-linearly (b). The tendency of non-linearity of the other fabrics were between these two extremes. If shear angle is small (<0.035 rad), the vibration damps linearly with time^[3], however, the vibration damps non-linearly with time at large shear angle, as studied in this paper. The non-linearity depended largely on shear amplitude angle and it became more distinctive at higher shear angle.

The ratio of the change in shear amplitude angle versus that of time (the slope of damping curve) was defined as the damping ratio (k) and the value was obtained at shear angle; 0.035, 0.070, 0.105, 0.140, 0.175 rad for all the samples examined here. Dependency of the damping ratio on shear angle was studied and it was shown that the damping ratio was small at small shear angle and became larger with increasing the shear angle. The tendency was summarized into representative four patterns as shown in Fig. 4 and the other three fabrics followed one of those

Table 1 Details of samples

Fabric Name	Sample No.	Density (/m)		Counts (tex)		Twist (/m)		Weight (g/m ²)	Thickness* (mm)
		Warp	Weft	Warp	Weft	Warp	Weft		
Habutae	1	5500	2800	13.9	11.3	<100	<100	110.7	0.221
	2	5500	2800	8.5	11.1	<100	<100	79.1	0.174
Dechine	3	6100	3700	6.9	6.8	<100	3000	60.4	0.186
	4	5500	3900	7.4	7.6	<100	2800	64.5	0.187
	5	5100	4600	2.7	9.1	700	2900	59.7	0.174
Georgette	6	4600	4100	3.2	3.0	2600	2900	25.4	0.158
	7	6200	4700	2.2	2.1	2800	2900	24.3	0.152

* Thickness is measured at the pressure 49 Pa.

Fig. 3 Typical two examples of the damping behavior of shear vibration; damped most linearly (above) and damped most non-linearly (below).

Fig. 4 Dependency of the damping ratio (k) of shear vibration on shear angle.

patterns also. Those four patterns were explained as follows: No.7[A]; the damping ratio is small at small shear amplitude angle and the dependency of the ratio on shear amplitude angle is also small, No.4[B]; the damping ratio is relatively large at small shear angle, however, the dependency is small, No.3[C]; the damping ratio is relatively large at small shear angle and the dependency is large, No.2[D]; the damping ratio is small at small shear angle, however, the dependency is large. Fabric No.1 belonged to the type [D] and fabrics No. 5 and 6

belonged to the type [B].

Shear properties of those fabrics were measured and it was shown that shear properties were also classified into four types according to the four patterns used in the shear vibrational property mentioned above. The four types are modeled and shown in Fig. 5. Vertical axis; F_s , means shear force and horizontal axis; φ , means shear angle in the figure. If mechanical characteristics obtained from these shear properties are compared with one another, the changes of shear stiffness; G , and hysteresis; $2HG$, are small with increasing shear angle in the case of [A], the change of G is large, however, that of $2HG$ is small in the case of [B], the change of G is small, however, that of $2HG$ is large in the case of [C], the changes of both G and $2HG$ are large in the case of [D]. Namely, fabrics can be classified by means of the combination of G and $2HG$ with the degree of shear angle.

Fig. 5 Four typed patterns of shear property (shear force vs. shear angle) of silk filament weaves.

3.2 Bending vibration and bending property

Vibrational property based on bending deformation is measured as fabric curvature (K) versus time relationship and two examples are shown in Fig. 6. The four fabrics, which were classified into four types according to shear vibrational property mentioned above, were selected and studied their bending vibrational properties. The damping ratio (h) of bending vibration was defined as the ratio of the change in curvature versus that of time and dependency of the damping ratio (h) on curvature (K) was shown in Fig. 7. The differences among four fabrics in the value of the damping ratio and in the dependency of the value on curvature were small and almost similar

Fig. 6 Typical two examples of the damping behavior of bending vibration.

Fig. 7 Dependency of the damping ratio (h) of bending vibration on curvatures (K).

behaviors were shown compared with shear vibration.

Bending properties of those four fabrics were shown in Fig. 8 as the relationship of bending moment (M) versus curvature (K). Although bending stiffness; B , and hysteresis; $2HB$, were small in the case of [A], both mechanical characteristics were large in [D]. Both values were intermediate in the cases of [B] and [C]. Anyway, dependency of bending property on curvature is small and the curve is shown in a similar pattern.

4. Discussion

Shear vibrational properties of silk filament woven

Fig. 8 Bending properties (bending moment vs. curvature) of four typed silk filament weaves according to shear vibration.

fabrics were studied at large shear angle, that is, the region where vibration damped non-linearly with time. Changes of the damping ratio with shear angle were explained by the changes of mechanical characteristics of shear property obtained by KES system and classified into four types of shear properties. In general, the change of the damping ratio of shear vibration is small when both shear stiffness and hysteresis are small, but the ratio becomes large if the shear characteristics are large. On the other hand, change of the damping ratio of bending properties are shown in almost a similar pattern. This suggests that dynamic drape behavior of clothes is dominated by shear property rather than bending property.

In the former papers^{[1]–[3]}, shear vibration was studied only at small shear angle (<0.035 rad), that is, the region where vibration damped linearly with time. In such a case, shear stiffness; G , and hysteresis; $2HG$, become constant and a constant relationship between the damping ratio and $2HG/\sqrt{G}$ was derived^{[1][2]} from the equation of motion of fabric shear deformation. However, shear stiffness and hysteresis change usually with shear angle at large shear angle (>0.035 rad), and the damping ratio also changes greatly with shear angle, simple relation cannot be obtained consequently. In general, non-linearity of vibrational damping behavior becomes remarkable with increasing shear angle. This is caused by enlargement of hysteresis due to a kind of jamming effect of inter-yarn crushing, and means that inter-fiber and/or inter-yarn friction increase at large shear angle. The typical example is shown in the behavior of fabric

Table 2 Shear and bending vibration duration time, drape coefficients, combination of shear and bending parameters for four typed silk filament weaves.

Type	Sample No.	Shear vibration(s)	Bending vibration(s)	Drape coefficient(%)	$2HB/B$ (/m)	$2HB_0/\sqrt{G_0}$ ($\sqrt{N}\cdot\text{rad/m}$)
[A]	7	21	30	37	42.6	0.004
[B]	4	11	29	40	31.3	0.028
[C]	3	9	28	35	34.2	0.034
[D]	2	17	27	42	30.6	0.013

No.2 as notably shown in shear vibration Fig. 3(b) and shear property Fig. 5[D].

Drape coefficient (D_j), which is a criterion of static draping behavior of clothes, is calculated from mechanical characteristics of bending and shear properties and fabric weight using the following equation, and the result is shown in Table 2 together with shear and bending vibration duration time.

$$D_j = -21.31 + 288.06 \left(\frac{B}{W} \right)^{1/3} + 352.55 \left(\frac{2HB}{W} \right)^{1/2} + 5.34 \left(\frac{G}{W} \right)^{1/3} + 27.19 \left(\frac{2HG}{W} \right)^{1/2} \dots \dots \dots (1)$$

where, B ; bending rigidity (gf·cm²/cm)
 W ; fabric weight (mg/cm²)
 $2HB$; hysteresis of bending moment (gf·cm/cm)
 G ; shear stiffness (gf/cm/degree)
 $2HG$; mean value of hysteresis of shear force at shear angle 0.5 degree and 5.0 degree (gf/cm).

Fabrics having smaller values of drape coefficient are considered to hang down well and cling to a curved surface easily. All the fabrics examined here showed small drape coefficients and did not correspond with the duration time of vibration. Bending vibration continues longer if $2HB/B$ is smaller^[7], however, that value is quite similar to the fabrics examined here as shown in Table 2, and this can be another reason of the similar bending vibrational behavior. A combined parameter $2HG_0/\sqrt{G_0}$, which are shear characteristics at zero degree, is also shown in Table 2 and shear vibration continues longer if the parameter is smaller. This agrees well with the results of the last paper^[3]. It is shown that there exists a fabric of which vibration continues longer at small shear angle, even if the vibration damps quickly at large shear angle.

Investigation at larger shear angle (>0.20 rad), where shear buckling will occur, may be necessary in the future because such a case is expected in the clothes in practical use. As bending deformation in bias direction will occur also in that case, the phenomenon is very complex. How-

ever, the study will approach to the dynamic drape behavior of the clothes in practical use. Furthermore, relationship between beautiful appearance and vibrational behavior of clothes will be studied in the near future.

5. Conclusion

Vibrational property of silk filament woven fabrics based on shear deformation was investigated at large shear angle (>0.035 rad), where the vibration damped non-linearly with time, and following conclusions were obtained.

(1) Non-linearity of damping is remarkable at larger shear angle and this is caused by large change of shear hysteresis with shear angle.

(2) Vibrational damping behaviors of silk filament woven fabrics are classified into four patterns from the dependency of the damping ratio on shear angle. This pattern agrees well with the type classified by the change of shear characteristics; G and $2HG$, obtained from KES system, with shear angle.

(3) Difference of bending vibrational property between each fabric is smaller compared with that of shear vibration, and it is suggested that dynamic drape behavior of clothes is dominated by shear property rather than bending property.

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