RESEARCH ARTICLE OPEN ACCESS

Dynamic Drapen Behavior of Textile Fabric: Part II - Attributes of Various Fabric Parameters

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Abstract
Substantial amount of work has been done on static drape behavior of fabric by Cusick in 60s. In 70s & 80s, it was felt that drape is not much important. Therefore the main focus during this period was on tensile behavior of the fabric. But during 90s, due to rapid growth of readymade garment along with computerized manufacturing system, it was felt by various research workers and market surveyors that drape is very important property. So, one need to look into the matter to give proper shape to a garment after its cutting and sewing. Moreover, to meet the customer requirement and stringent competition from the market one need to give the best quality of the fabric, so that when one uses the fabric its drape property does not change much from morning to evening. The crease resistant fabric with special finish has come into existence because of this development. Therefore a need was felt on evaluating dynamic drape properties of fabric when its static condition is disturbed. To find dynamic drape coefficient, we need to simulate body motion or the actual condition of use of fabric. Therefore, an instrument has been developed as reported in the last paper in this series. Here in this part the study conducted on dynamic drapeabilty of fabric in the newly developed instrument is reported.
Keyword:- drape, static drape, dynamic drape, instrument, simulation

I. INTRODUCTION

Drape is important for selection of textile material for apparel application. Drape is defined as the extent to which a fabric will deform when it is allowed to hang under its own weight. Chu *et al.* [1] first studied drape using FRL drapemeter developed by them. From a simple draping experiment Cusick (1965) [2] calculated the drape coefficient of the sample, which is the ratio of the projected fabric area after draping to that before draping and compared it with experimental results. IS 8357:1977 is the most widely accepted method of drape test.

Earlier researches in textile mechanics were mainly focused on the understanding of relationship between the mechanical properties of fabrics and those of the yarns as well as fabric structures. An attempt to predict the over-all shape of a draped fabric by using the mechanical properties of woven fabric and the plate theory was introduced by Shananhan *et al.* (1978)[3]. Lloyd *et al.* (1980) [4] later simulated the stretching behaviour of a fabric deformed by a projectile by using non-linear finite-element method. The bending behaviour of fabric was incorporated by Imaoka *et al.* (1988) [5] in an attempt to predict the draped shape of a fabric. Using a large deformation shell theory, they derived a strain-energy equation considering stretching and bending of fabric in which the energy equation was minimized by using steepest-descent method. Collier *et al.* (1991) [6] presented a finite-element approach for modeling the draping behaviour of a fabric, reviewing the incremental-solution scheme of the equation. Breen *et al.* [7] have worked on particle based model for simulation of draping behaviour of woven cloth.

The simulation of fabric, static to dynamic drapeability gained much attention in last couple of decades. Fischer *et al.*[8] and Leung *et al.* [9] has contributed a lot in simulation of fabric. Matsudaira *et al.* [10,11] draws attention to the researcher on dynamic drape properties during this time.

The present work will be concentrating on the line of approach of static to dynamic condition of the fabric. The instrument used in this study is the newly developed instrument by the researcher as reported in the Part 1 of this series of the paper. This work can further be extended and continuous study of change in drape pattern can be studied with the help of image analysis work by using high-speed CCD camera.

II. STUDY OF DYNAMIC DRAPE

A. Materials and Method

To study the dynamic drape behaviour of fabric, two groups of fabric samples viz. one suiting and one shirting fabric samples were selected covering wide range of gsm (grams per square meter) as well as fibre compositions, as much as possible. In total six suiting fabric samples and five shirting fabric samples were selected for testing. Fabric samples are procured directly from market. The sample particulars are given in the following table no. 1

Table No. 1: Particulars of Fabrics Samples

Sample No.		Count (Ne)		Yarn Density		Weave
		Warp	**Weft**	**EPI**	**PPI**	
Suiting	SU1	33* & 14*	15	64	44	1/2 Twill
	SU2	18	14# & 29#	112	68	2/2 Twill
	SU3	13	16	76	56	2/1 Twill
	SU4	14	14	56	52	Plain
	SU5	14	15	60	48	2/1 Twill
	SU6	11	12	64	52	Plain
Shirting	SH1	43	41	112	80	Plain
	SH2	41	41	76	76	Plain
	SH3	62	29	112	64	Plain
	SH4	38	42	132	76	Plain
	SH5	93	93	124	72	Jacquard Design

* Two series of warp yarns, # Two series of weft yarns

B. Instrument Used:

To study the effect of dynamic state of fabric, the newly developed instrument i.e. dynamic drape tester (as mentioned in the part I of this series of the paper) is used. To measure the draped area of the fabric planimeter, PLACOM DIGITAL PLANIMETER, MODEL: KP-90N (Japan) is used. This Planimeter has a pointer which need to move along the path of the outer boundary of the area whose area to be measured and there is a LCD display which gives the enclosed area. Unit could be selected as desired like cm^2, in^2, ft^2, etc. There are some more features, but are not discussed here in details. To study the correlation of Bending length, bending rigidity and bending modulus with the above mentioned dynamic drape properties of fabric, bending properties of the fabric were measures using Shirley Stiffness Tester.

C. Results and Discussions:

Six Suiting Fabric Samples (SU 1 to 6) and five Shirting Fabric Samples (SH 1 to 5) were measured for drape coefficient at the five levels of rotations (clockwise) i.e. 0, 25, 75, 125 & 175. The test data for drape coefficient at different rotation are given in Table No. 2 and the number of nodes formed at different rotations are given in Table No 3.

Table No. 2: Drape coefficient at different rpm

Sample No.	Drape coefficient at different rpm, rotating clockwise									
	Face					Back				
	0	25	75	125	175	0	25	75	125	175
SU1	42.7	43.5	43.0	46.0	47.6	41.4	41.6	43.8	46.8	50.3
SU2	48.7	49.8	50.3	56.3	59.0	47.6	47.9	50.1	52.8	60.9
SU3	57.4	58.5	58.7	61.5	62.0	56.3	56.6	59.3	60.4	61.5
SU4	43.0	43.8	44.4	46.3	47.3	41.6	41.6	45.4	48.2	49.8
SU5	65.8	65.0	64.5	63.1	62.3	64.5	62.8	62.0	62.3	61.7
SU6	61.2	63.1	64.2	65.8	65.0	47.6	47.9	50.1	52.8	60.9
SH1	61.7	58.2	61.7	66.4	72.3	60.4	59.6	63.1	65.5	68.8
SH2	55.2	52.8	58.2	69.9	60.4	56.3	54.7	58.7	60.9	63.4
SH3	51.7	53.9	53.0	60.6	59.8	52.2	52.2	51.4	58.2	60.9
SH4	61.7	53.6	58.5	67.2	72.6	58.7	58.5	66.4	65.3	66.4
SH5	79.4	78.6	81.3	85.6	86.7	82.1	83.7	84.8	88.9	90.5

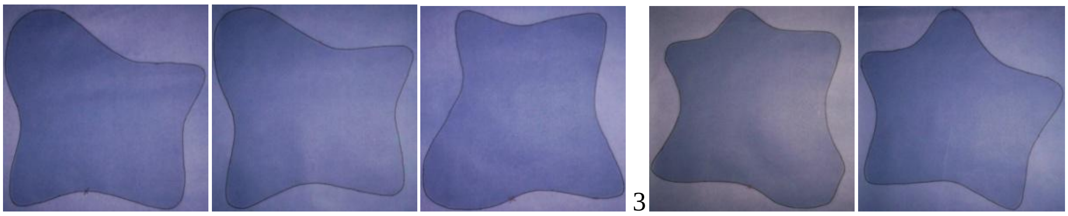
Table No. 3: Number of nodes at different rpm

Sample No.	Number of nodes at different rpm, rotating clockwise									
	Face					Back				
	0	25	75	125	175	0	25	75	125	175
SU1	5	5	5	5	5	5	5	5	6	7
SU2	4	4	4	4	5	5	5	5	5	6
SU3	5	5	5	5	5	5	5	5	6	7
SU4	5	5	5	6	7	4	4	5	7	8
SU5	4	4	4	4	4	4	4	4	4	4
SU6	4	4	4	4	4	4	4	4	4	4
SH1	4	5	5	5	5	4	4	5	5	5
SH2	5	6	6	7	6	5	5	6	6	6
SH3	4	4	4	5	5	4	4	4	6	7
SH4	4	4	4	5	6	4	4	5	5	5
SH5	4	4	4	4	4	5	5	5	5	5

From the table 2, in general it can be seen that for almost all the cases except SU5, there is increase in drape coefficient with the increase in r.p.m. It can also be noticed that compare to static (initial drape coefficient without revolutions), the change in drape coefficient with 25 r.p.m. in almost all the cases as well as for some cases with 75 r.p.m. also, is not much. In case of higher r.p.m. i.e. 125 and more there is increase in drape coefficient. From the table 2 & 3 it can also be noticed that that increase in drape coefficient is highly associated with number of nodes. As the number of nodes increases, the drape coefficient also increases. Some of the representative photographs of node are given in Fig. 1 to 3.

Fig. 1(i): Nodes of Sample No. SU4(Face), RPM 0, 25, 75, 125 & 175 respect ively

Fig. 1(ii): Nodes of Sample No.SU4(Back), RPM 0, 25, 75, 125 & 175 respectively



3

Fig. 2(i): Nodes of Sample No.SH3(Face), RPM 0, 25, 75, 125 & 175 respectively

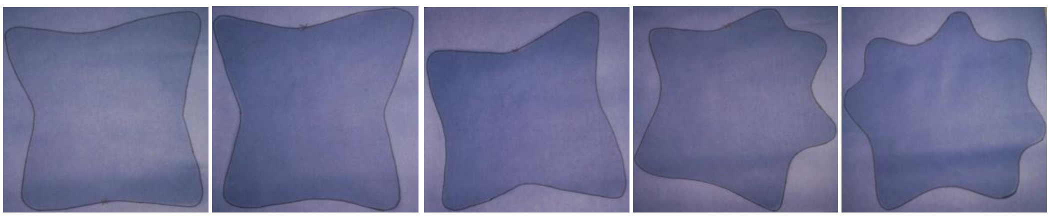


Fig. 2(ii): Nodes of Sample No.SH3(Back), RPM 0, 25, 75, 125 & 175 respectively

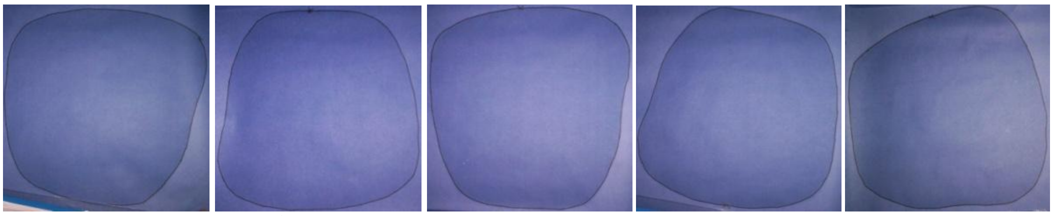


Fig. 3(i): Nodes of Sample No.SU6(Face), RPM 0, 25, 75, 125 & 175 respectively

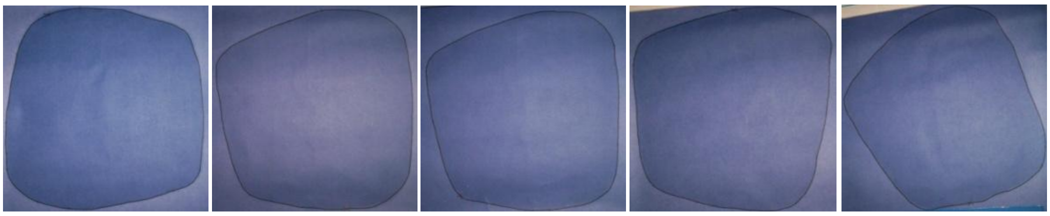


Fig. 3(ii):Nodes of Sample No.SU6(Back), RPM 0, 25, 75, 125 & 175 respectively

It can be seen from the Fig. 1(i) & (ii) and 2(i) & (ii) and Table 2 & 3 that in both the cases i.e. sample no. SU4 & SH3, both face and back, as the number of nodes has increased, drape coefficient has also increased.

The face and back are not identical in many cases and it is quite natural particularly for twill, satin/sateen weave, etc., but in general it can be seen that as the number of nodes increases, the drape coefficient also increases. Matsudaira *et al.* [9,10] observed similar phenomena in their work.

From the Fig 3(i) & (ii), and Table 2 & 3, it can be seen that in case of Sample SU6, there is no change in number of nodes and the increase in drape coefficient with revolutions of fabric sample also marginal.

It can also be seen from Table 2 & 3 that the drape coefficient of fabric sample SU5 has decreased marginally which is opposite phenomenon from the rest of the sample. There is no change in number of nodes. From the table, it can be seen that the drape coefficient of the said fabric sample is very high compared to similar weight range suiting fabric. Therefore, as the fabric is stiff there is no effect of revolutions on the sample, but there is some effect of time dependent factor. Duration of time of revolutions for each step is 5 min and again it takes about 7-8 mins for exposure of shadow i.e. draped area over ammonia paper. Therefore, for each steps time required is approximately 13-14 mins. Initial drape coefficient will not have any time effect as it is the starting point. After that, for the second reading the total time lapse will be 8 mins, for the third reading it will be 21 mins (approximately) and for fourth and fifth reading it will be 34 mins and 47 mins (approximately) respectively. Therefore, as the time is passed, the fabric hangs more, resulting less area of projection, means less drape coefficient.

The above explanations will not hold true for other fabric samples. As the fabric sample rotate, because of centrifugal force, degree of spreading of overhanging of fabric sample with revolutions is more and hence the effect of time dependent effect of previous reading on bending length will be nullified. At the same time the effect of mechanical actions i.e. shear and tensile will have effect on the subsequent reading and the result of the same have already seen as mentioned above.

For all the fabric sample linear as well as logarithmic regression equation and R^2 values were calculated using Microsoft Excel Spreadsheet for the drape coefficient at different rotation and are given in Table No. 3. From the table 3 it can be seen that in majority of the cases, linear relationship gives better fit with high R^2 values as reported by earlier researchers too.

Table No. 3: Trend Line Equations and R-square values

S. No.		Front		Back	
		Trend line equation	**R^2**	**Trend line equation**	**R^2**
SU1	Linear	y = 1.2223x + 40.902	0.8205	y = 2.3088x + 37.86	0.9296
	Log	y = 2.7287Ln(x) + 41.956	0.6606	y = 5.2284Ln(x) + 39.78	0.7701
SU2	Linear	y = 2.7163x + 44.677	0.8890	y = 3.1509x + 42.396	0.8269
	Log	y = 6.1488Ln(x) + 46.939	0.7360	y = 6.9102Ln(x) + 45.232	0.6425
SU3	Linear	y = 1.2223x + 55.95	0.9255	y = 1.4125x + 54.565	0.9494
	Log	y = 2.8858Ln(x) + 56.854	0.8334	y = 3.3807Ln(x) + 55.565	0.8787
SU4	Linear	y = 1.1137x + 41.608	0.9617	y = 2.2817x + 38.484	0.9443
	Log	y = 2.6043Ln(x) + 42.455	0.8496	y = 5.351Ln(x) + 40.206	0.8391
SU5	Linear	y = -0.8964x + 66.815	0.9829	y = -0.5976x + 64.452	0.7658
	Log	y = -2.1313Ln(x) + 66.167	0.8976	y = -1.6198Ln(x) + 64.21	0.909

SU6	Linear	y = 1.0322x + 60.758	0.8261	y = 3.1509x + 42.396	0.8269
	Log	y = 2.7102Ln(x) + 61.259	0.9200	y = 6.9102Ln(x) + 45.232	0.6425
SH1	Linear	y = 2.9336x + 55.271	0.7248	y = 2.2817x + 56.629	0.9032
	Log	y = 6.0786Ln(x) + 58.252	0.5027	y = 5.1386Ln(x) + 58.554	0.7401
SH2	Linear	y = 2.7434x + 51.061	0.4333	y = 2.0372x + 52.69	0.8538
	Log	y = 6.637Ln(x) + 52.936	0.4097	y = 4.5559Ln(x) + 54.44	0.6899
SH3	Linear	y = 2.3088x + 48.888	0.7829	y = 2.336x + 47.991	0.7420
	Log	y = 5.4308Ln(x) + 50.614	0.6998	y = 5.0227Ln(x) + 50.19	0.5541
SH4	Linear	y = 3.5312x + 52.12	0.5673	y = 2.2002x + 56.439	0.7316
	Log	y = 6.8754Ln(x) + 56.13	0.3474	y = 5.5084Ln(x) + 57.765	0.7408
SH5	Linear	y = 2.173x + 75.806	0.8734	y = 2.2002x + 79.419	0.9575
	Log.	y = 4.9173Ln(x) + 77.617	0.7225	y = 5.1712Ln(x) + 81.068	0.8545

III. CONCLUSION

A clear trend has been observed in majority of the cases of the fabric tested. As the rotational rpm of the fabric increased, its drape coefficient also increased. Trend is more prominent for the fabric samples whose drape coefficient is low i.e. limpy fabric. Another interesting thing that was observed in the study is as the rpm of the fabric is increased, number of nodes also increased and as the number of nodes increased, its drape coefficient also increased.

It can be seen from the book "Structural Mechanics of Fibres, Yarns and Fabrics", Volume 1 by J. W. S. Hearle, P. Grosberg and S. Backer, that generally when a fabric is limpy its drape coefficient is low and the number of nodes formed also more. In the said book it is also pointed out that a given fabric does not always drape with same number of nodes. As mentioned by Cusick (1962) that it is also possible to alter the number of nodes by disturbing the fabric. This means that there are a number of configurations where the energy passes through minimum values (corresponding to whole number of nodes) and the fabric does not necessarily fall in to the lowest of these configurations. The same is the case in present situation too. In Cusick's work he found that the drape coefficient of the fabric was not much altered by differences in the number of nodes formed – with 6 nodes, the average value was 70% and with 9 nodes it was 72%. It can be seen that the said work was carried out for only one cotton fabric, but in present case a wide range of fabric samples have been taken and found that drape coefficient have changed from static to dynamic from 4 to 12 %.

The observed trend line equations are also promising. A particular group/category of fabric sample can be tested in future and standardized equations can be fitted for the same and the same can be used as guideline by fabric manufacturer, processers or buyer-seller.

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