NC STATE
College of Textiles
JTATM
Journal of Textile and Apparel, Technology and Management

Volume 10, Issue 3, 2018

New Methods of Assessment of Fabric Drape

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ABSTRACT

New methods and parameters are proposed for measuring the drape of fabric in the present research paper. The authors also consider that using flat fabric methods does not accurately reflect garment drape. This paper avoids the usual cumbersome methods of assessment of projected drape area including image analysis techniques and replaces by a new geometrical analysis technique.

Keywords: Drape parameters, Drape polygon, Fabric drape, Garment drape

1.0 Introduction

Fabric drape is the ability of a fabric, in a circular form and of a standard size, to deform gracefully under its own weight in specified conditions (5-8). Fabric drape along with luster, color, texture, etc. defines fabric and garment appearance. Drape is generally evaluated by textile and apparel technicians in the fabric and garment design and manufacturing industry. To measure drape, it is important to find a reliable, efficient and accurate method to reflect fabric drape characteristics realistically. Different studies have been carried out concerning the development of drape meters to make the measurement process easier, more accurate, less dependent on operator skills and to arrive at a satisfactory quantification for drape. Proposing alternative fabric drape parameters which were a result of drape meter development has also taken place. Moreover, the development of dynamic drape-meters enabled researchers to study dynamic drape behavior similar to the human body motion.

1.1 Conventional Methods

Measurement of fabric drape started with Pierce in 1930. Bellinson set a drape tester at the M. I. T. Textile Research Laboratory. A fabric specimen was attached to the edge of a horizontal circular disc movable vertically and supported on a column to be suspended vertically. The specimen width equals the semi-circumference of the disc. The greater the drape length, the more flexible the material would be. The radius of curvature of the sample and its variation along sample tested length was also used to compare between the fabrics' drape. It had a negative relation with fabric drape. Fabric drape was not clearly determined by those tests based on a two-dimensional distortion of the sample tested, as they measured bending properties rather than drape.

Monoplanar drapemeters were not reliable testers for fabric drape measurement. Consequently, a three-dimensional distortion apparatus was introduced by the Fabric Research Laboratories in Massachusetts. This tester measured drape quantitatively in a way which shows its significant anisotropic properties. In this optical apparatus, the sample tested was sandwiched between two circular plates mounted on a movable (up and down-wards) pedestal, and positioned so that it could not touch the apparatus base. The optical system of this apparatus was used to cast the image of the sample draped on the ground glass. It was placed above the circular plates - which were traced by the operator.

The "Drape coefficient" F was developed as a parameter to analyze drape test data/image. It was defined as the fraction of the area of the annular ring placed concentrically above a draped fabric covered by the projection of the draped sample (see Fig.1). The higher the drape coefficient, the lower the drape of the fabric. It is noteworthy that this drape coefficient was used in most drape studies (as seen in Table 2).

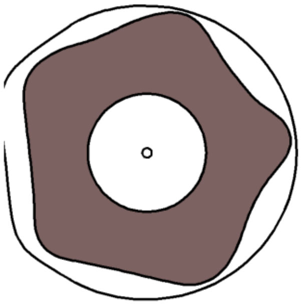

Figure 1. Drape diagram (dark area) is shadow of the drape sample on the annular ring

A study on the accuracy of this apparatus reveals that there were errors which reached 17% in the measured area for 1-inch different elevation levels of fabric edge. (as fabric drape occurs with double curvature). The principle of F. R. L. drapemeter of draping the sample tested on a circular disc was the basis of almost all the further developed drapemeters. Improvements were carried out only to obtain more expressive and accurate data easily.

An improved F. R. L. drapemeter was developed to cope with the error in the original drapemeter. In the improved tester, a sample (25 and 30 cm diameter) was draped on a circular disc (10 or 12.5 cm in diameter) which was one of two synchronized turntables, and a standard circular chart was mounted on the other one. An optical system mechanically connected to a pen was used to scan the edge of the sample tested continuously and automatically in order to draw/trace the scanned edge on the chart. A planimeter was used to obtain the drape coefficient using area ratio.

A further upgrade was carried out for the F. R. L. drapemeter by Cusick in 1962. In this tester, the sample tested was also sandwiched between two horizontal sample discs. The sample's shadow was projected on a table underneath the apparatus using a light source and spherical mirror positioned above it which produced near a parallel vertical light. The projected shadow was drawn on a sheet of paper placed on the table. A planimeter was used to measure the drape coefficient DC. The sample disc with 18 cm diameter and the sample with 30 cm diameter were found to be the best standards and the most sensitive to a wide range of fabrics from limp to stiff which produced DC's from 30 to 98 %. Drape coefficient value errors were greatest at high values of DC.

Cusick in 1968 further improved the F. R. L. drapemeter in terms of obtaining more accurate drape coefficients with less tedious and costly procedures. He suggested three proposals in this drapemeter development. First, three different sample sizes, 24, 30, and 36 cm in diameters were chosen. They were chosen as the smallest and largest samples. It turns out that the smaller samples were more sensitive for limp and stiff fabrics. A second, alternative proposal is the use of a less expensive optical system (divergent of light). Third, a cut and weigh method was proposed to measure the drape coefficient rather than using a planimeter. This drape coefficient was measured using weight ratio [8]. In 2003, Behera and Pangadiya developed a drapemeter with an optical system based on the principle of Cusick's drapemeter but in a turned over position, and it was devised with a camera to capture images of tested fabrics [3].

Three British standards published by the British Standards Institution were found for measuring fabric drape coefficient. First: Method for the assessment on the drape of fabrics (BS 5058:1973), second: Textiles - Test methods for nonwovens - Part 9: Determination of drape Coefficient (BS EN ISO 9073-9:1998), and third: Textiles - Test methods for nonwovens Part 9: Determination of drape including drape coefficient (ISO9073-9:2008).

1.2 Image Analysis Technique

Researchers investigated the use of image processing technology in studying drape. In this method, a digital camera is attached to a drape tester in order to capture images for draped samples. By means of computer software, detailed data such as drape shape parameters and statistical information including drape wave amplitude, wavelength, and number of nodes were developed and computed from drape profile image.

Moreover, it enabled researchers to carry out studies such as fabric drape dependence on time from minutes to hours and to investigate drape value instability and repeatability. Studying the relation between the rotation speed of the fabric tested and its drape was difficult without employing an image analysis method.

Jeong found that conventional measurement of drape coefficient was very time consuming and needs a skilled operator. Correlation between the conventional method and the image analysis method for measuring DC was found with $R^2=0.8$ and good agreement of p-value > 0.05. However, image analysis method had better repeatability [12,13].

Kenkare investigated the correlation between cut and weigh and image analysis techniques. The overall drape coefficients of 10 fabrics were calculated using both methods. Pearson product-moment correlation was 0.99. Differences between digital and conventional drape coefficients of each fabric tested were calculated. They found that the differences were 3 percent or less [14]. Also, Behera and Mishra found good correlation between conventional and image analysis methods [2].

Farajikhah et al. studied the virtual reconstruction of draped fabric using shadow moiré topography employing front lighting and linear grating. A captured image's center and points located in the fringes were determined. The intensity and height of all pixels in the fringes were determined and plotted against the radius of the fabric edges. Using the radius (x), intensity (y) and height (Z) values calculated by given equations, 3D profiles of draped fabrics were generated.

1.3 Dynamic Drapemeter

Drape researchers were concerned with obtaining drape values which correlated with real fabric drape and movement. Different fabrics would have similar static drape behavior, while differing in dynamic drape behavior. The dynamic drape presented the real fabric performance and would help textile, clothing, and design workers in quantifying realistic drape behavior of fabrics.

Ranganathan et al. used a dynamic apparatus to measure fabric drape. The test procedure was inspired by the shape and dimensions of the sample from the bending behavior and shape of real folds constructing fabric drape. The sample was clamped in the apparatus using a needle and an arm and was used to rotate the sample. The movement of both the arm and the response of the needle (sample) were recorded using a protractor to obtain a hysteresis diagram. The maximum value at 45° rotation and the area of the hysteresis loop were used as parameters of drape behavior [21].

Dynamic drape behavior was studied later using a system consisting of a drapemeter with a circular rotatable supporting disc and image processing devices (CCD camera and PC). The camera used should be able to capture images of the tested sample at very short intervals at every $1/30^{th}$ second. The range of the revolution speed changes according to the investigation.

Matsudaira and his colleagues published a series of papers focused on dynamic drape. The tester consisted of a rotatable circular supporting disc with speed ranged between 0 - 240 r. p. m. An image analysis system was employed to capture and analyze the images of the tested draped samples. New dynamic drape parameters were developed. The first property was the revolving drape increase coefficient (DCr) which presented the overhanging fabric's degree of spreading with increasing revolutions (presented by slope of the curve relation between revolutions and drape coefficients in the range between 50 - 130 r.p.m. High DCr value indicated a fabric's ability to change easily with revolutions. Drape at 200 r. p. m. was selected for the dynamic drape coefficient (DC 200) which presented fabric spreading at rapid revolution, as the change of the drape coefficient became lower than the previous stage [17,18].

Lin et al. studied the dynamic drape of four natural fabrics at a wider range of revolution speeds (0 - 450) r. p. m. for a sample disc with 18 cm diameter. The resultant curve (presented the relation between drape coefficient and revolution speed) showed four stages of dynamic drape behavior by the tangent partition method. These were initial growth, fast growth, slow growth and the last stage was the stable dynamic drape -coefficient. Plots of experimental drape coefficients showed that the order of the fabrics was dependant on the revolution speed at which the DC was measured. Their order was changed three times in the fast growth stage and returned to the initial growth order and became stable at the two periods following the fast growth [16].

Stylios 3D drape tester based on 3D scanning of the fabric tested was developed by Al-Gaadi et al. (1). The software was developed to reconstruct a virtual image for the scanned fabric from which ordinary drape parameters were calculated. Annular supporting discs with 21, 24 and 27 cm were used to exert dynamic impact (similar to real dynamic effect of a garment) on the fabric tested, which was already supported by a circular disc (18 cm diameter). Using this tester, they studied fabric drape in terms of the effect of composite yarns twisting direction and exerting dynamic effect on fabric tested [28,29].

Hu and Chung determined drape behavior of seamed woven fabrics in terms of drape coefficient, node analysis, and drape profile. The variability of number of nodes was used as an indicator of fabric drape stability. Regularity of node arrangement, their orientation, location and highest and lowest node length were proposed as drape parameters [11].

Rodel et al. characterized the drape configuration by area, form and, amplitude of the folds, and the number of folds and their position with regard to warp and weft directions [23].

Jeong proposed "Drape distance ratio" as an alternative measure of drape. It increased as the fabric became more flexible and was calculated using the following formula:

$$R_d = (r_f - r_{ad}) / (r_f - r_d) \times 100$$

R_d is the drape distance ratio, r_f is the radius of the undraped sample, r_{ad} is the average radius of draped sample's profile, r_d is the radius of the supporting disk [12,13].

Four virtual parameters were used by Stylios and Wan to define the drape of textile materials as follows: virtual drape coefficient, drape fold number, fold variation, and fold depth [28].

Behera and Pangadiya proposed using a combination of drape parameters namely: drape coefficient, average, maximum and minimum radius, drape distance ratio (DDR) $\left[\frac{r_2-r_s}{r_2-r_1}\right]$, amplitude to average radius ratio (ARR) (4).

2.0 Materials and Methods

2.1 Materials

Samples of two different apparel grade woven fabrics, which are typical examples of commercial materials currently used for the construction of shirting and suiting types. The two woven fabrics include a lightweight 120 gm/sq.m. cotton fabric and a medium weight 304 gm/sq.m. cotton fabric. Further description of the fabric is given in Table 1. As noted from Table 1, the construction of the cotton shirting fabrics is not square but there are approximately twice as many warp yarns as weft yarns. The construction of the suiting fabric is also similar to that of the shirting fabric, also not square woven fabric. The number of parameters for comparison work out to be six (6); for two commercial woven fabrics, three testing methods and one technical quality parameter, that is ‘drape coefficient’ (2x3x1= 6).

Table 1: Fabric Physical Properties

	Weight	**Count**				**Crimp (%)**	
Fabric Type	**Gsm (g/m^2)**	**Warp**	**Weft**	**Ends/inch**	**Picks/inch**	**Warp**	**Weft**
Shirting	120	37^s	41^s	141	78	5.8	8
Suiting	304	$2/34^s$	$2/24^s$	132	70	9.7	6.1

2.2 Methods: Conventional Cusick method and Geometric Analysis of Drape Area method

To accomplish the objective of accurate estimating of the area of drape pattern, selecting a specified geometric area known as ‘drape octagon/ drape polygon’ is suggested.

- An alternative geometrical construction in the form of an octagonal diagram is presented in this work.
- In this drape octagon method, analyzing the drape coefficient is minimally time-consuming.
- The drape octagon is constructed by drawing radial lines mutually subtending at an angle of 45° at the center of the draped pattern.

Since a specified geometric area is used for computation, a standard formula for determining the area of drape pattern can be made possible, even though the draped patterns of different fabrics are widely different and irregular.

Area of Drape Octagon = $1/2\sqrt{2}\ [a_2 (a_1+a_3) + a_4 (a_3+a_5) + a_6 (a_5+a_7) + a_8 (a_7+a_1)]$

Where, $a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8$ ………, are the radial line distances of the drape octagon/ drape polygon.

This selected drape octagon includes and excludes certain nodal projections. However, this included and excluded area does not unduly alter the total area of draped profile. The difference between the areas of the conventional draped pattern and the area of the drape octagon, when exhibits ‘not significant' value, it is self-evident that the new procedure of representing a draped pattern or profile by the newly developed drape octagon, is a valid approach.

A regression graph shows total draped areas of the fabric samples on the X-axis and areas of the drape octagon on the Y-axis. When this shows a higher regression coefficient (R^2>0.9) for the regression equation representing the straight line of best fit, it is evident that the new approach of estimation using drape octagon brings forth reliable results for drape. It means that these two areas are statistically highly correlated, and no significant difference is observed. The statistical tests (T-test, F-test, and Chi-square test) were used and established that the three methods of drape estimates, Cusick Method, Image Analysis Method, and Drape Octagon Method were homogeneous in distribution for the given fabric drape estimates.

By extrapolating the conventional drape co-efficient (DC) in the above regression graph, in the form of a bi-plot, the deviations in DC, if any, due to the newly evolved area of drape octagon can be analyzed. In case these deviations are minimal and within acceptable levels of allowance, it is obviously evident that the drape octagon method produces reliable estimates for drape coefficients. Refining of this estimate may be possible by selecting acute or lower angles for the drape polygon, to the extent of 15˚ between a pair of radial lines.

2.3 Methods: Computer-aided Drape Test

The image data of a draped pattern is processed by the software designed for the system [P. Tamás; J. Geršak; M. Halász, 2006], which can be used effectively for three-dimensional simulation. The computer draws the shadow line on a ring and based on the images it creates a 3D image of the given fabric, which can be rotated in several directions. The program calculates the following data: drape coefficient, DC (%), number of waves (pc), minimal and maximal radius (mm). The minimal and maximal radius is used to describe drape, which is the distance from the center of the circle to the smallest and largest crimp. The tests were made on the Budapest Tech Polytechnic Institution using a Cusick Drape tester. The images of drape were captured using a digital camera that was fixed on the device and the drape coefficient was determined using Photoshop image processing software. The calculation of drape coefficient is based on counting the number of pixels of the inner and outer area of the draped image.

The steps include the use of a backlight to directly acquire a drape image, conversion to a grayscale image, calculation of the gradients of the image, calculation of the threshold value of the gradients using Kittler & Illingworth's threshold method and finding the edge points of the fabric contour from the outer margin. The connection of these points forms a contour, which is then used to calculate the area of the fabric drape and the drape coefficient.

The drape instrument developed an even backlight behind and underneath the fabric to obtain a clear image of the drape contour. Since the light shines up from below, an acrylic plate is placed above the illumination source to diverge the light. This ensures a more even background brightness, enhances the contrast between the background and fabric image, and facilitates tracing of the fabric contour (22, 27,30).

Table 2: Fabric Drape Coefficient (%)

Sl.No	Shirting				Suiting			
	A	(A-d)	(D-d)	F	A	(A-d)	(D-d)	F
1	419	165	453	36.3	484	230	453	50.6
2	410	156	453	34.3	497	243	453	53.5
3	395	141	453	31	500	246	453	54.1
4	432	178	453	39.1	500	246	453	54.1
5	403	149	453	32.8	509	255	453	56.1
			Avg.	**34.7**				**53.7**
6	452	153	453	33.6	475	221	453	48.6

7	415	161	453	35.4	506	252	453	55.4
8	408	154	453	33.9	500	246	453	54.1
9	437	183	453	40.3	502	248	453	54.6
10	408	154	453	33.9	514	260	453	57.2
			Avg.	**35.4**				**54**
11	492	179.6	453	39.5	524	212	453	46.55
12	461	148.8	453	32.7	560	247	453	54.38
13	455	142.7	453	31.3	551	239	453	52.5
14	492	179.6	453	39.5	556	244	453	53.57
15	455	142.7	453	31.4	571	258	453	56.82
			Avg.	**34.8**				**52.8**

DC or F = $\frac{(A-d)}{(D-d)}$x100, where, F is the Drape coefficient; A the projected area; D the diameter of the fabric; d the diameter of the supporting disc.

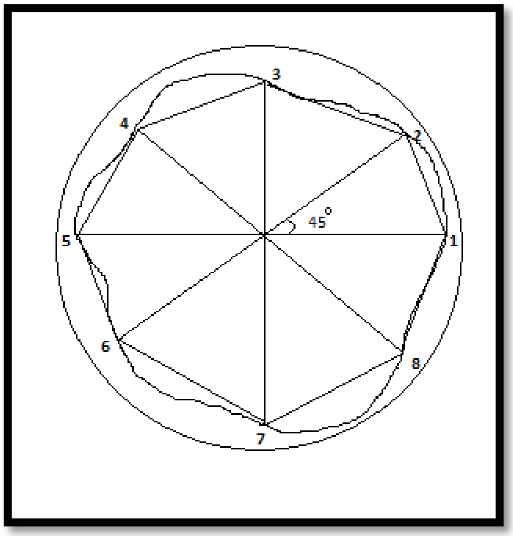

Figure 2. Drape by area of octagonal diagram

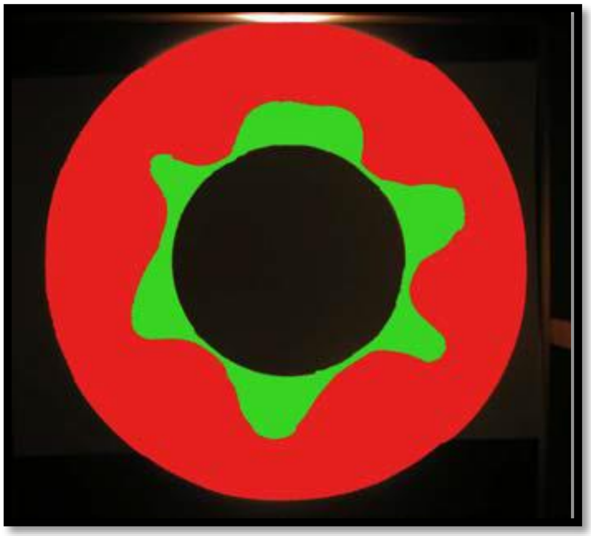

Figure 3. Drape by computer-aided digital image processing

Results and Discussion

The drape patterns from which image area computations are made are shown in Fig. 1 & 2. Referring to Table 2, we find that the Avg. Drape values determined by the three methods, namely, conventional Cusick method, equivalent radius of irregular object by computer software aided image processing method, and geometrical analysis method, are very near to the mean values of the statistical distribution of 15 values each for shirting and suiting fabrics. Statistical significance tests, such as t-test, F – test, and Chi-square test were performed and found no significant difference between the mean values of Drape Coefficient (DC).

Conclusions

Easier and more reliable methods for the measurement of fabric drape have evolved, these are based on computer-aided image processing and geometrical analysis method. The textile industry will be best exploiting the use of these techniques.

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