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Development of a Three Dimensional Approach to Acquire a Drape Contour and Studies on Influential Factors

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Abstract
Drape is one of the important factors influencing the aesthetics and functionality of fabrics. In this paper, the instrument used for measuring fabric drape was slightly modified from the Cusick Drapemeter(DM). Instead of tracing / digitally capturing the shadow of the drape profile, the xyz coordinate values at various locations were measured using the specially designed scale in the DM and analysed using surfer software. It generates the contour lines, vector lines, 3D profile, volume, area and other information like a variogram etc. The area was used to calculate the drape coefficient of fabrics, which was compared with the area generated by the image processing method. Studies with polyester cotton fabrics show that with different seam types and patterns (combinations of stitch direction and stitch type) the image processing method is insensitive in showing the difference due to the seam factor.

Key words: *drape meter, polyester/cotton fabric, drape coefficient, drape contour, drape volume.*

Introduction

Drape is the fabric's ability to deform in space when bent under its own weight. In 1930, Perice found that the draping quality of a fabric had a significant influence on the bending length, and developed the cantilever method for the measurement of fabric bending properties [8]. Chu et al. developed the standard F.R.L. drapemeter for the measurement of three-dimensional drape. Cusick introduced a simple method to calculate the drape coefficient and found that it depends on both the shear stiffness and bending length.

Narahari [40] found that this unique characteristic provides a sense of fullness and graceful appearance, which distinguishes fabrics from other sheet materials. When a fabric is draped, it can bend in one or more directions. Curtains and drapes usually bend in one direction, whereas garments and upholstery exhibit a complex three-dimensional form with double curvature. Hence fabric drape is a complex mathematical problem involving large deformations under low stresses.

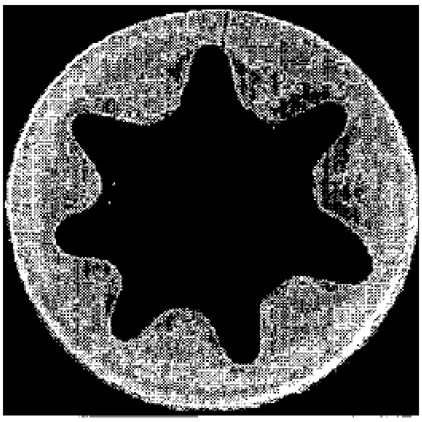

Figure 1. *Specimen draped over a pedestal.*

Initially, fabric is draped rapidly based on its weight overcoming the resistance associated with its stiffness, after which the stiffness of the fabric structure resists further deformation. Fabrics may drape in dramatically different ways depending on the fiber content, type of yarn, fabric structure and type of finish.

Drape prediction can reduce the need for fabric sample production and thus speed up the process of designing new fabrics. The drape to be quantified into a dimensionless value called the drape coefficient, which is calculated as the ratio of the difference between the area of the drape profile to the area of the supporting disc and the area of the undraped specimen to that of the supporting disc (***Figure 1.***).

$$\text{Drape coefficient, in \% (DC \%)} = [A_{dp} - A_s]/[A_u - A_s] \times 100$$

A_{dp} - Area of drape profile
A_s - Area of supporting disc
A_u - Area of undraped specimen

There have been numerous instruments developed for measuring fabric drape either directly or indirectly from the stiffness value or from the drape profile area. The "drape coefficient (DC)" is the main parameter used to quantify fabric drape. Different end uses require different

Table 1. *Yarn particulars.*

S. No	Parameter	Result
1	Linear density (Yarn Count) CV% of count	14.7 tex × 2 2.45
2	TPI CV% of TPI	17.4 3.01
3	CSP CV% of CSP	5298 3.07
4	Blend composition, % Polyester Cotton	 65 35

Table 2. *Fabric particulars.*

S. No	Parameter	Result
1	Ends per inch	62
2	Warp & weft count	14.7 tex × 2
3	Picks per inch	58
4	Fabric weight	0.148 g/m^2
5	Warp crimp	5.12%
6	Weft crimp	7.84%
7	Fabric tensile strength - warp	74.9 N
8	% of elongation	13.16%
9	Fabric tensile strength - weft	65.06 N
10	% of elongation	15.33%
11	Bending length - warp	23.6 mm
12	Bending length - weft	21.8 mm

Table 3. *Sewing thread particulars.*

S. No	Parameter	Result
1	Sewing thread number CV % of count	14.7 tex × 2 2.21%
2	TPI CV% of TPI	18.37 5.6
3	Strength CV % of strength	1.099 N 11.9%
4	% of elongation CV % of elongation	10.9% 7.2%
5	Thread type	Polyester

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amounts of drape, thus it would be desirable to develop a technique to predict the drape of a fabric. Several physical properties have been suggested as contributors to the drape of woven fabrics. Existing techniques do not produce the three dimensional contour of the drape profile. Many fabrics have the same drape coefficient value but they differ in the contour profile. This research focuses on a new method to measure the fabric drape and studying the effect of seams on the drape value in this new technique.

Materials & methods

Materials

Polyester/cotton fabric was produced from yarn and then subjected to bleaching, in which the seams were laid to have the combinations for drape assessment. The details are given in ***Tables 1 - 3***.

Method

The flow chart is presented in ***Figure 2***.

Yarn (procured from mill)
↓
Fabric
↓
Fabric processing
(Scouring & bleaching)
↓
Circular specimen of 0.3 m dia
(sewn by stitch density of 9
with following specifications)
↓
6 different types of seams (S1 to S6)
3 different stitch directions (D1 to D3 : warp-D1, weft-D2, bias-D3)
2 different stitch types [single (sgl), double(dbl)]
2 trails (6 × 3 × 2 × 2 = 72 samples)
↓
Drape coefficient measurement
(of 72 samples)
↓ ↓
Using image processing method | Using surfer method
↓
Comparison between two methods

Figure 2. *Flow chart.*

Circular drape specimens are prepared from P/C blended fabric with varying seam types, and patterns with two trails. The drape coefficients of samples were analysed using the direct 3D drape measurement technique (surfer method) and image processing technique.

Pretreatment

Fabric of 91.44 cm width was produced from 2/40s P/C yarn by the hand loom weaving process. The sizing process was completely eliminated because it has high strength. The following sequences of pretreatment operations were performed to prepare circular samples of 30 cm diameter to measure the fabric drape.

Scouring: This process removes natural and added impurities like oil, wax and fatty substances present in the fabric. It improves fabric absorbency.

Bleaching: This process removes natural colorings matter present in the material and it improves the whiteness of the material.

Cold wash: To reduce the alkali concentration on the fabric by washing it in cold water.

Neutralization: This process neutralises the alkali content present in the fabric by treating with acids. Then the fabric is processed with hot & cold wash treatments.

Calendaring: To remove creases present in the fabric by passing it over several cylinders. Here the calendaring process is carried in the absence of stiffening, softening and other kinds of finishing agents.

Cutting & stitching

Circular specimens of 0.3m diameter were prepared with and presented in ***Figure 3*** six types of seams, named S1 to S6.

Seam. A seam is a joint consisting of a sequence of stitches uniting two or more pieces of material. Six most common types of seams are used to make samples from two groups, i.e. superimposed and lapped seams.

The combination of stitch type & direction was employed on each type of seam, which is shown in ***Figure 4***. Stitch type –single and double(sgl,dbl), directions - warp way-D1, weft way-D2 & bias direction-D3).

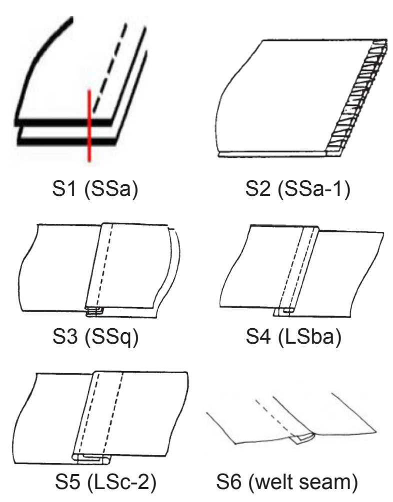

Figure 3. *Seam type.*

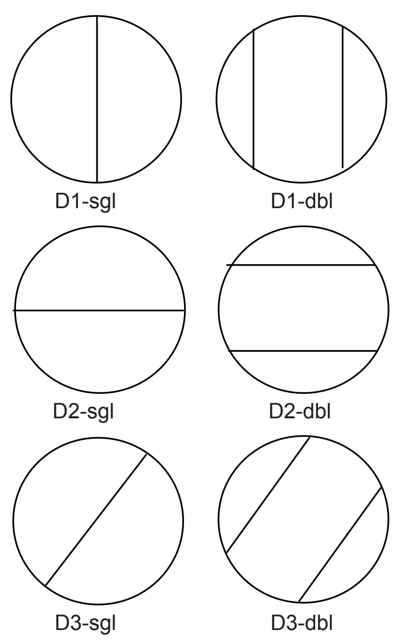

Figure 4. *Stitch direction (D1 to D3) and types (sgl, dbl); D1-sgl: single row of stitch parallel to warp, D1-dbl: double row of stitches parallel to warp, D2-sgl: single row of stitch parallel to weft, D2-dbl: double row of stitches parallel to weft, D3-sgl: single row of stitch in bias direction, and D3-dbl: double row of stitches in bias direction.*

A total 72 samples were prepared with a combination six types of seams and six types of patterns with two trails.

Test method

Image processing method

In this method, a thin sheet of paper is placed on the top surface of the drape meter. A shadow image is formed in the paper, which was captured using a digital camera. The coding written in the MATlab software converts the coloured image into a grey scale one and it counts the number of black pixels of the shadow drape profile and computes the area of the drape profile. The reference point starts where it finds the first white pixel, and counting starts where it finds the first black pixel after the white pixel (x_n,y_n). The counting ends where it finds the first white pixel after the black pixel. In between the white pixel the numbers of black pixels were counted with reference to x_n,y_n. It computes the proportional area based on the outer radius which was given as the input to the program (see ***Figure 5***).

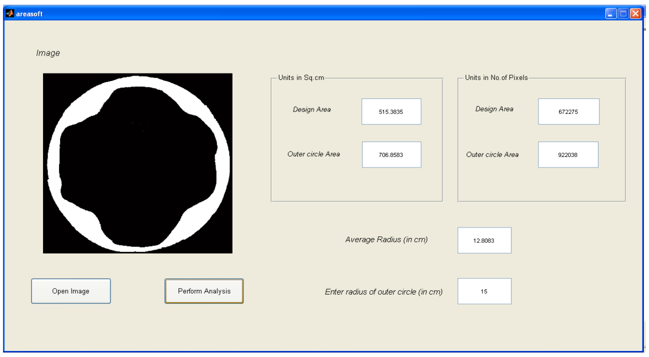

Figure 5. *Area of drape profile computed.*

Surfer method

Surfer is a grid based mapping software that interpolates irregularly spaced XYZ data into a regularly spaced grid. The grid is used to produce different types of maps including contour, vector, image, shaded relief, 3D surface, and 3D wireframe maps. The grid files themselves can be edited, combined, filtered, sliced, queried, and mathematically transformed. The software requires the X, Y, Z values as input (in the excel sheet form) to generate the grid file.

To find X, Y, Z values, a perforated circular disc of 0.32 meters was used, which consists of concentric circles of diameters such as 0.19, 0.21, 0.23, 0.25, 0.27 and 0.29 m. The disc is divided into 36 intervals, each making 10 degrees, which is further divided into 5 degrees when the diameter exceeds 0.23 m. The intersecting points are drilled to a diameter of 0.002 m to measure the values in the Z direction, which is shown in the presented in ***Figures 8 - 10*** (see page 140 and 142).

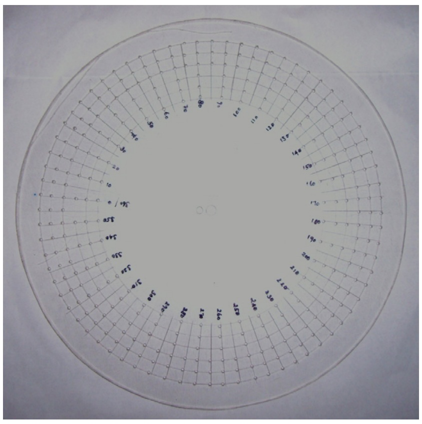

Figure 6. *Circular perforated disc to measure values in the 'Z' direction.*

The X, Y, Z values are measured and analysed using surfer software.

The flow chart (***Figure 8***, see page 140) illustrates the relationship between XYZ data files, grid files, contour maps, 3D surface maps, volume and the drape profile area. This flow chart can be applied to any grid based map type. This example displays only two of the grid based maps (i.e. contour and 3D surface).

The XYZ values taken for sample number 15 are shown in ***Table 4***.

Table 4 shows the X, Y, Z values of sample number 15, at each 5 degree with various concentric circle diameters (0.095 m to 0.145 m). The X, Y, Z values for remaining 72 were measured like sample number 15. These values are used as inputs to surfer software, which generates the contour and other maps, as mentioned below (***Figure 9***, see page 140).

Gridding overview

A grid is a rectangular region comprised of evenly spaced rows and columns. The intersection of a row and column is called a grid node. Rows contain grid nodes with the same Y coordinate, and columns contain grid nodes with the same X coordinate. Gridding generates a Z value at each grid node by interpolating or extrapolating the data values.

Of the various gridding options, we have used the Natural Neighbor method. The Natural Neighbor generates good contours from data sets containing dense data in some areas and sparse data in other areas. It does not generate data in areas without data. The Natural Neighbor does not extrapolate Z grid values beyond the range of data.

Map types

1. Contour maps: A contour map is a two-dimensional representation of three-dimensional data. Contours define lines of equal Z values across the extent of the map. The shape of the surface is shown by the contour lines. Contour maps can display the contour lines and they can also display colours and patterns between the contour lines.

2. Base map: Base maps display boundaries. Boundaries can include roads, buildings, streams, lakes, etc. Base maps can be produced from several file formats. Empty Base Maps allow you to create a base map with no objects. Objects can be manually added and removed as needed.

3. Post maps: Post maps and classed post maps show data locations . Post symbols and the individual post label positions can be customised.

4. Image maps and shaded relief maps: Image maps and shaded relief maps are raster images based on grid files. Image maps assign colours based on Z values from a grid file. Shaded relief maps assign colours based on the slope orientation relative to a light source.

5. Vector maps: 1-grid and 2-grid vector maps display direction and magnitude

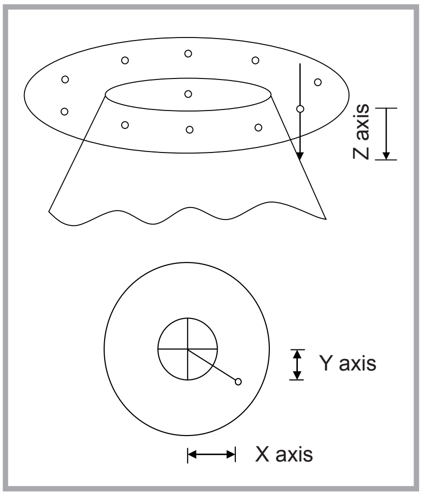

Figure 7. *Drape measurement directions.*

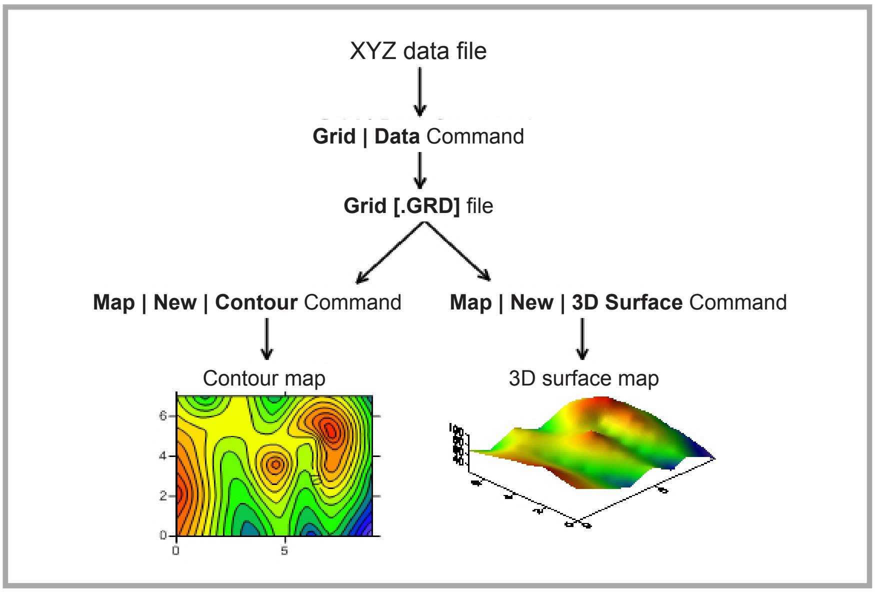

Figure 8. *Procedural flow chart.*

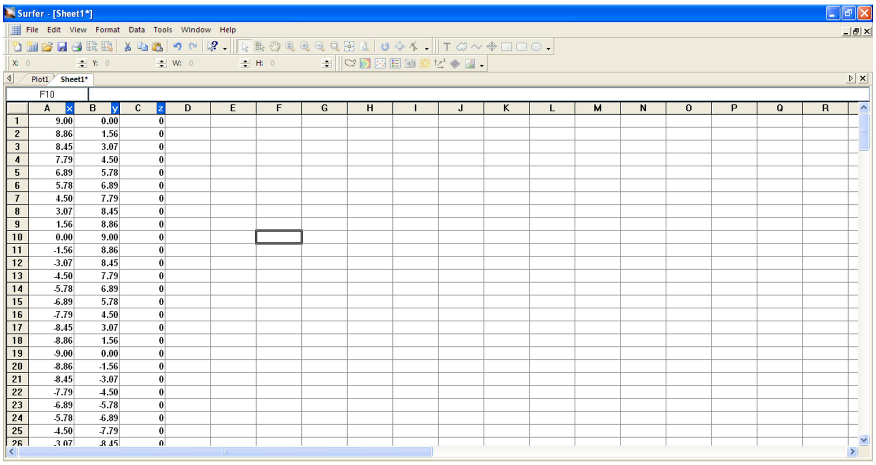

Figure 9. *XYZ data copied to Surfer (sheet) to generate a contour (Sample No 15).*

Table 4. *XYZ values of sample number 15 (S2 P2 Trail1).*

S. No	Degree θ	Radius, cm	X, cm	Y, cm	Z, cm
001	0	9	9.00	0.00	0
002	10	9	8.86	1.56	0
003	20	9	8.45	3.07	0
004	30	9	7.79	4.50	0
005	40	9	6.89	5.78	0
006	50	9	5.78	6.89	0
007	60	9	4.50	7.79	0
...	...	...	...	...	...
...	...	...	...	...	...
216	340	13.5	12.69	-4.62	-3
217	345	12.5	12.07	-3.24	-2.4
218	345	13.5	13.04	-3.49	-2.7
219	350	9.5	9.36	-1.65	-0.4
220	350	10.5	10.34	-1.82	-1.9
221	350	11.5	11.33	-2	-3.1
222	350	12.5	12.31	-2.17	-3.7

data using individually oriented arrows. For example, at any grid node on the map, the arrow points in the direction of the steepest descent („downhill") and the arrow length is proportional to the slope magnitude. In Surfer, vector maps can be created using the information in one grid file (i.e. a numerically computed gradient) or two different grid files (i.e. each grid giving a component of the vectors).

6. 3D surfaces: Surfaces are colour three-dimensional representations of a grid file. The colours, lighting, overlays, and mesh can be altered on a 3D surface.

7. 3D wire frames: Wire frames are three-dimensional representations of a grid file. A wire frame is created by connecting Z values along lines of constants X and Y. At each XY intersection (grid node), the height of the wire frame is proportional to the Z value assigned to that node. The number of columns and rows in the grid file determines the number of X and Y lines drawn on the wire frame.

Results and discussion

The results are pooled and the average of trails 1 & 2 recorded. Anova was performed on the test results using the factorial design. Discussion on the results follow the ***Tables 5, 6***.

Sample code:

- S1: Seam type 1
- S2: Seam type 2
- S3: Seam type 3
- S4: Seam type 4
- S5: Seam type 5
- S6: Seam type 6
- D1: Stitch direction 1 (direction parallel to warp)
- D2: Stitch direction 2 (direction parallel to weft)
- D3: Stitch direction 3 (bias direction)
- Sgl: Single stitch
- Dbl: Double stitch
- Control: Control sample (without any seam).

The drape coefficient found by image analysis is compared with the new method (Surfer method), which generates the fall of fabric, and the projected area and lateral area from that drape coefficient is calculated (***Table*** *7*).

The single factor analysis has shown that there is no significant difference in the drape value given by the two methods. Thus the new method is acceptable.

The measurement of depth on the draped cloth using Surfer generated a lot of other information.

Results of the factorial design given in ***Tables 8*** & ***9*** clearly indicate that no significant difference exists between the replications. The main factors associated with stitch, direction and seam and their interaction has no significant effect on the drape.

The drape co-efficient % determined by image analysis is insensitive_in showing the difference due to the seam factor. The effect due to the seam is clearly seen in the results obtained for the drape co-efficient %; the volume obtained on Surfer also clearly indicated the difference. This again proves the advantage of measuring one more dimension and characterising the drape.

The more powerful option is the variogram, by which it is possible to characterise the smoothness or roughness of the surface, having various models to fit the data. ***Figure 10*** (see page 142) illustrates the flat surface when the drape goes into a 3D surface; hence one can conceive of volume generation. Surfer has a built-in option to compute volume, which is clearly a novel way of understanding drape.

Furthermore it is evident that this parameter indicates the effects of the seam, which, as stated earlier, the classical method of drape calculation was insensitive to.

Other advantages of using Surfer

It generates the 3D drape profile along with contour lines using the XYZ data, which is illustrated by taking one example (***Figure 10***).

The contour map shows lines of equal elevation (ie, depth in this case) of the draped fabric. The lines spaced closely indicate a steeper bending, while the spaced line indicates a flatter region. From the same map a 3D surface can be generated which gives the visual appearance of the draped sample.

The vector map shows the direction and magnitude of flow i.e. curvatures. Also various maps can be superimposed.

We can rotate the generated profile using the track ball option, by which we can visualise both the top and front view and any other perspective.

The more powerful option is the variogram, by which it is possible to characterise the smoothness or roughness of the surface. The option has various models to fit the data. ***Figure 11*** illustrates the same.

The model computes the anisotropy ratio and anisotropy angle. The initial slope indicates the surface roughness, and if the slope is steep the surface is rougher. This analysis further helps in characterising the surface more clearly.

The real advantage of this method of taking the drape profile is that one can randomly take few measurements and still get a contour map which is almost similar to the original one.

Conclusions

No significant difference was found in DC % between the image processing and surfer method.

Table 5. *Consolidated results: a) image processing method and b) surfer method.*

S. No	Sample code	a) Drape coefficient % (DC%)			b) Drape coefficient % (DC%)		
		Trial 1	Trial 2	Average DC% (Trial1 + Trial2)/2	Trial 1	Trial 2	Average DC% (Trial1 + Trial2)/2
01	S1 D1 sgl	58.62	65.25	61.96	61.62	57.86	59.74
02	S1 D1 dbl	73.33	73.88	73.63	66.93	64.28	65.52
03	S1 D2 sgl	53.98	56.41	55.21	54.33	55.65	54.99
04	S1 D2 dbl	61.49	57.85	59.69	59.85	62.07	60.96
05	S1 D3 sgl	59.73	57.73	58.75	56.09	56.76	56.43
06	S1 D3 dbl	55.97	59.50	57.76	56.54	58.09	57.31
07	S2 D1 sgl	59.28	59.84	59.58	58.97	57.20	58.09
08	S2 D1 dbl	58.18	63.60	60.91	59.19	64.28	61.73
09	S2 D2 sgl	57.96	53.09	55.55	63.17	57.64	60.41
10	S2 D2 dbl	55.86	54.53	55.21	60.96	58.97	59.96
11	S2 D3 sgl	59.50	61.16	60.36	62.07	60.74	61.40
12	S2 D3 dbl	60.06	58.84	59.47	63.84	58.31	61.07
13	S3 D1 sgl	59.39	63.82	61.63	63.39	67.37	65.38
14	S3 D1 dbl	62.05	74.54	68.32	67.59	74.45	71.02
15	S3 D2 sgl	61.16	62.05	61.63	59.63	62.07	60.85
16	S3 D2 dbl	66.36	68.57	67.49	64.50	62.95	63.72
17	S3 D3 sgl	61.60	58.07	59.86	66.93	64.94	65.94
18	S3 D3 dbl	56.63	61.05	58.86	64.28	66.71	65.49
19	S4 D1 sgl	62.82	56.85	59.86	61.40	56.32	58.86
20	S4 D1 dbl	57.40	62.38	59.91	59.19	64.28	61.73
21	S4 D2 sgl	55.52	59.84	57.70	61.40	60.52	60.96
22	S4 D2 dbl	62.82	66.58	64.72	64.94	68.48	66.71
23	S4 D3 sgl	63.60	54.75	59.20	62.51	60.52	61.51
24	S4 D3 dbl	67.69	65.36	66.55	66.49	62.07	64.28
25	S5 D1 sgl	53.31	57.29	55.33	52.78	56.09	54.44
26	S5 D1 dbl	58.73	51.65	55.21	58.53	60.08	59.30
27	S5 D2 sgl	56.19	50.44	53.34	58.97	53.66	56.32
28	55 D2 dbl	66.69	59.95	63.34	65.38	58.53	61.96
29	S5 D3 sgl	63.37	56.74	60.08	60.52	64.06	62.29
30	S5 D3 dbl	65.47	61.38	63.45	62.95	58.09	60.52
31	S6 D1 sgl	58.40	51.87	55.16	63.61	60.52	62.07
32	S6 D1 dbl	65.36	61.83	63.62	66.71	63.61	65.16
33	S6 D2 sgl	60.06	62.38	61.24	60.08	61.84	60.96
34	S6 D2 dbl	69.23	51.32	60.30	66.93	55.87	61.40
35	S6 D3 sgl	62.3	61.49	61.96	64.94	62.07	63.50
36	S6 D3 dbl	58.18	56.08	57.15	60.30	59.63	59.96
37	**Control**	**54.99**	**56.19**	**55.59**	62.29	60.30	**61.29**

Table 6. *Consolidated results – Surfer method (volume, exponential ratio & angle).*

S. No	Sample code	Exponential angle & ratio		Volume		
		Trial 1 (ratio)	Trial 2 (angle)	Trial 1	Trial 2	Average DC% (Trial1 + Trial2)/2
01	S1 D1 sgl	1.71	107.95	645	638	642
02	S1 D1 dbl	1.50	136.80	654	648	651
03	S1 D2 sgl	2.00	29.19	653	665	659
04	S1 D2 dbl	1.84	165.80	708	671	690
05	S1 D3 sgl	1.49	84.78	642	607	625
06	S1 D3 dbl	1.73	20.37	633	635	634
07	S2 D1 sgl	1.39	111.05	628	616	622
08	S2 D1 dbl	1.20	131.15	631	603	617
09	S2 D2 sgl	1.76	101.10	618	532	575
10	S2 D2 dbl	1.66	64.87	657	638	648
11	S2 D3 sgl	2.00	170.90	564	562	563
12	S2 D3 dbl	2.00	86.42	632	548	590
13	S3 D1 sgl	1.15	110.95	648	592	620
14	S3 D1 dbl	1.89	109.45	614	609	612
15	S3 D2 sgl	1.75	100.25	641	642	642
16	S3 D2 dbl	1.35	86.63	545	565	555
17	S3 D3 sgl	1.27	120.60	653	663	658
18	S3 D3 dbl	1.65	98.94	571	616	594
19	S4 D1 sgl	1.59	111.30	585	649	617
20	S4 D1 dbl	1.54	113.95	644	533	589
21	S4 D2 sgl	1.68	37.17	522	674	598
22	S4 D2 dbl	1.41	92.04	632	604	618
23	S4 D3 sgl	1.94	129.60	637	639	638
24	S4 D3 dbl	1.53	163.30	560	547	554
25	S5 D1 sgl	1.76	116.00	562	636	599
26	S5 D1 dbl	1.46	45.95	539	567	553
27	S5 D2 sgl	2.00	97.83	616	564	590
28	55 D2 dbl	1.77	83.12	615	583	599
29	S5 D3 sgl	1.97	117.99	570	615	593
30	S5 D3 dbl	1.68	108.86	529	557	543
31	S6 D1 sgl	1.62	84.20	640	629	635
32	S6 D1 dbl	1.50	32.50	538	564	551
33	S6 D2 sgl	1.63	98.65	535	581	558
34	S6 D2 dbl	1.35	151.55	522	565	544
35	S6 D3 sgl	1.24	150.85	548	556	552
36	S6 D3 dbl	1.83	87.42	496	609	553
37	**Control**	**1.06**	**96.40**	**534**	**516**	**525**

Table 7. ANOVA for average drape co-efficient % by image analysis and Surfer.

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	26.038	1	26.03	1.76	0.187671	3.97
Within groups	1059.616	72	14.71			
Total	1085.654	73				

*Table 8. Factorial analysis; ** significant at α = 0.05, * significant at α = 0.01.*

Source	By image processing	By Surfer	
	Drape co-eff. % (Image proc)	Drape co-eff. % (Surfer)	Volume
Trails			
Seam types		**	**
Stitch direction			
Stitch type (Single & double)	**	**	*
Seam/direction	**	*	
Stitch type/seam			
Direction/stitch type		*	
Stitch type/direction/seam			

Table 9. ANOVA factorial analysis.

Source	DF	Sum of Sq.	Mean Sq.	F-ratio	Sig
Trails	1	262.59	262.59	0.8205	
Seam types	5	3825.45	765.09	2.3906	
Stitch direction	2	667.65	333.82	1.0430	
Stitch type (single & double)	1	3719.53	3719.53	11.6217	
Seam/direction	10	9738.56	973.86	3.04287	
Stitch type/seam	5	1423.86	284.77	0.8898	
Direction/stitch type	2	1320.81	660.41	2.0634	
Stitch type/direction/seam	10	4788.723	478.87	1.4962	
Error	35	11201.79	320.05		
Total		36948.97			

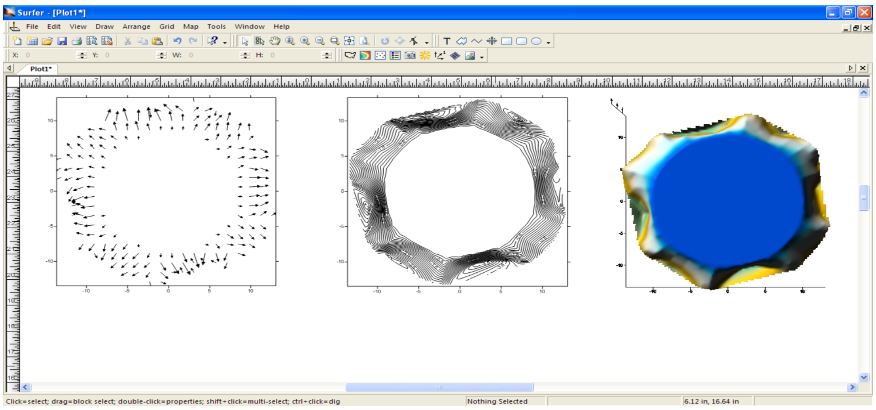

***Figure 10.** Vector, contour and 3D surface of sample number 15 – S2 P2 (Trail 1).*

A new way of measuring the depth of the draped sample is devised. Using Surfer for analysis gives a lot of other additional information such as the drape volume, variogram, vector maps, drape contour lines and a 3D surface with 360° rotation etc.

The drape co-efficient % determined by image analysis is insensitive in showing the difference due to the seam factor, with Surfer showing the same. In addition to the seam, the direction and stitch on the drape differs significantly. Hence measuring the depth and analysing with Surfer is one of the most powerful tools to characterise the drape of fabrics in a better way, as it offers the advantage of using random measures and is still able to generate a close contour including all values.

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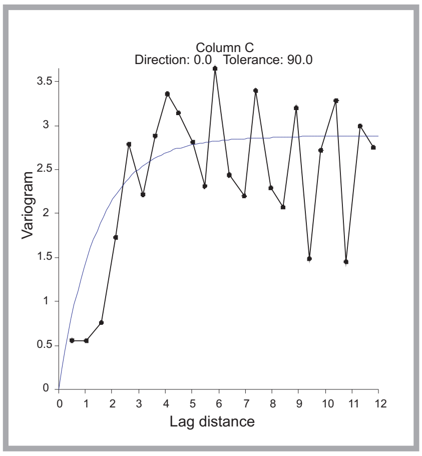

***Figure 11.** Variogram (exponential fit).*

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