

DRAPE EVALUATION BY THE 3D DRAPE SCANNER

3 BOYUTLU DÖKÜMLÜLÜK TARAYICI İLE DÖKÜMLÜLÜĞÜN DEĞERLENDİRİLMESİ

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ABSTRACT

This paper presents an objective drape evaluation by means of a 3D Drape Scanner to capture complex drape information and increase the accuracy of drape fabric measurement, especially for high-drape fabrics. The new 3D Drape Scanner provides a true three-dimensional image of a drape sample and automatically evaluates chosen drape characteristics such as: the drape coefficient (DC), the number of waves, their area, perimeter and location (angle and depth of waves) by means of the software 3Dscan. 3Dscan offers the full range of procedures for drape measure, including the ability to cover the sample surface with the same texture as the actual scanned fabric. The 3D Drape Scanner presented works fully automatically and secures defined conditions for putting the fabrics into their draped state.

Key Words: Drapability, Scanner, Drape coefficient.

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1. INTRODUCTION

Drape is a very important fabric property for the aesthetic appearance and appeal of garments, and also plays a decisive role in garment comfort and fit. Drape is defined as the “deformation of fabrics produced by gravity when only part of the fabric is directly supported” (1). Fabrics may drape in dramatically different ways, depending on the fibre content, type of yarn, fabric structure and type of finish. Many instruments for drape measuring have been developed up to the present time. Pierce (2) developed a device – called a Cantilever bending tester or Shirley stiffness tester – to measure two-dimensional drape on the basis of the measurement of fabric bending length. However this tester could not capture the complex three-dimensional double curvature of fabric drape. Therefore various objective methods have been designed to imitate subjective drape evaluation methods (e.g. hanging the fabric over a rectangular or circular pedestal and allowing the fabric to fall naturally into folds, and so on). The circular disk method, called a “drapemeter”, has become one of the most widespread devices for 3D drape measurement. Cusick’s drapemeter (3), see figure 1, and the F.R.L Drapemeter (Chu (4)) are the best known drapemeters. Cusick’s drapemeter works according to the following principle: a circular specimen is placed between two smaller horizontally mounted discs, and is deformed when permitted to hang under its own weight. The lid of the instrument is raised to

insert a test piece between the horizontal plates. In this position a perspex ring supports the fabric being tested. When the lid is closed the support is removed and the fabric drapes. By means of a light source and a parabolic mirror, a shadow of the draped specimen is cast onto a circular paper placed centrally on the lid of the instrument. The outline of the shadow is traced onto the paper.

Drape coefficient can also be expressed in different ways from above. According to Chu, Cusick and ISO 9073-9 (5), drape coefficient (DC) is expressed as the percentage of the total area to the annular ring of fabric obtained by vertically projecting the shadow of the draped specimen, see equation 1.

$$DC = \frac{A_S - A_D}{A_O - A_D} \cdot 100 \% \quad (1)$$

where A_O is the area of the original undraped specimen, A_D is the area of the supporting plate and A_S is a projected shadow area of the specimen after draping.

A low drape coefficient indicates easy deformation of a fabric and a high DC indicates less deformation.

Cusick (3) simplified the procedure of measuring DC, which involved weighting a paper tracing of draped (W_1) and undraped images (W_2). The drape coefficient is calculated by expressing W_2 as a percentage of W_1 .

$$DC = \frac{W_2}{W_1} * 100 \quad \% \quad (2)$$

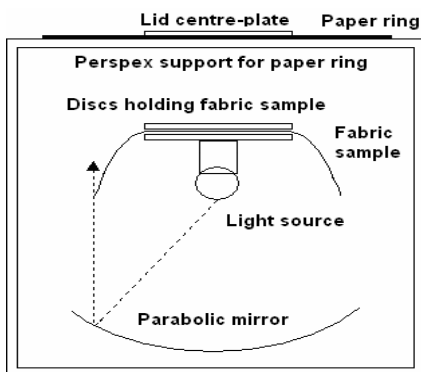


Figure 1. Scheme of Cusick's drapemeter.

Cusick's method of drape evaluation is often used for drape measuring as the basis of an image analysis technique. The image analysis enables many measurements to be made in a relatively short time. A digital camera captures the image of the draped specimen from the drapemeter and a computer carries out analysis of the captured image and translates it into appropriate output. Vangheluwe and Kiekens (6) put a camera linked to a computer directly above the drapemeter. Natarajan and Vikaran (7) developed the so-called Web-camera drapemeter that captures an image of a draped sample from two directions (vertically and horizontally) with a simple and affordable camera. Yang and Matsudaira (8) developed a dynamic drape tester to measure the static and dynamic drape coefficient that reflects dynamic fabric behaviour in response to human body movement. They also used image analysis for their drape evaluation. Among other researchers who integrated Cusick's drapemeter principle with image analysis for drape measurement are NonHyun Dong and KangNam Ku (9) – system D&M, Ruckman et al.(10) who developed a dynamic drape measuring system, *Robson and Long*(11) – system SDDAMS and so on.

Chu (4), Cusick (1,3) and the other researches refer to the disadvantages of drape measurement by means of the classical drapemeter.

- The evaluation of the dimensionless drape coefficient DC (%) is carried out only on the basis of the projected area of draped fabric. The shape of the draped fabric can be different even though the drape coefficient is the same or very similar. The draped fabric image also contains other important features such as the number and location of waves. Using more parameters can better specify the degree of fabric drape.
- The inability to identify the inner drape waves (that are formed under the outer border of the circular disc holding the fabric sample) is a significant problem of the drape measurement for high-drape fabrics. The inner waves are not identifiable from a two-dimensional projection of a draped sample with the classical drapemeter.

The 3D Drape Scanner presented in this paper eliminates the above-mentioned disadvantages. The 3D Drape Scanner is able to capture a true three-dimensional image of the draped fabric (that corresponds to the shape and

dimensions of the drape sample) and thus improves the accuracy of drape measurement (12,13). The principles behind the 3D Drape Scanner will be described in the next part of this paper.

2. DRAPE MEASUREMENT BY THE 3D DRAPE SCANNER

2.1. Principles of the 3D Drape Scanner

The 3D Drape Scanner integrates the classical drapemeter with the basic principle of triangular scanning in order to capture a true 3D image of fabric drape. Capturing the 3D image of fabric drape is obtained by scanning the draped fabric's shape, rotating the scanning head around the testing sample, see figure 2,3. The scanning head consists of two CCD cameras (using the rotating arm as the vertical axis, the angle of the CCD cameras is 30°) and a line laser. The images the laser light traces (on the testing sample) are used for the automatic calculation and display of the 3D drape image by means of the special software *3Dscan*. Drape measurement of one fabric by the 3D Drape Scanner takes approximately 1 minute. The 3D Drape Scanner is controlled (i.e., the motion of the scanning head, the motion of the add disc, starting and stopping of measurement, etc.) by the software. Furthermore, *3Dscan* enables automatic calculations of drape parameters such as: the number of waves/nodes, their area and perimeter, characterization of their location (angle and depth/length of waves), see figure 7, and enables the scanned surface to be covered with a texture corresponding to the texture of the real scanned fabric, see figure 6. The wire frame model of the 3-D drape circle sample is covered by the image of the true texture, see figure 4.

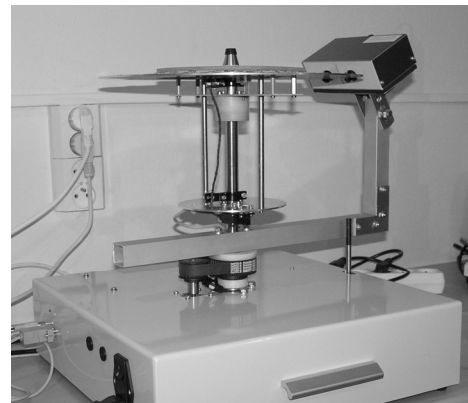


Figure 2. 3D Drape Scanner before drape measurement (moving table at top in dead centre).

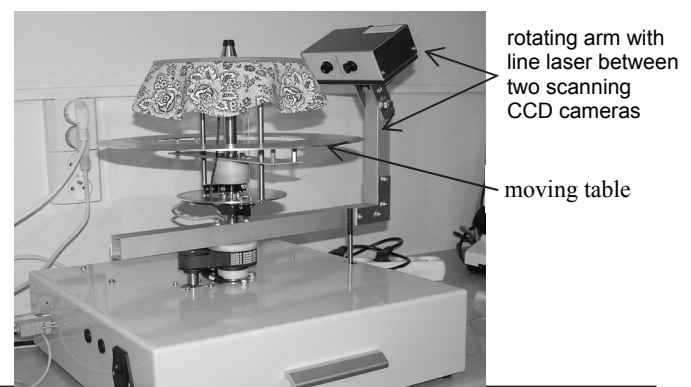


Figure 4. Image of the true texture of scanned fabric B (actual size of fabric – 30x30 cm).

Figure 3. 3D Drape Scanner during the drape measurement (moving table at bottom in dead centre).

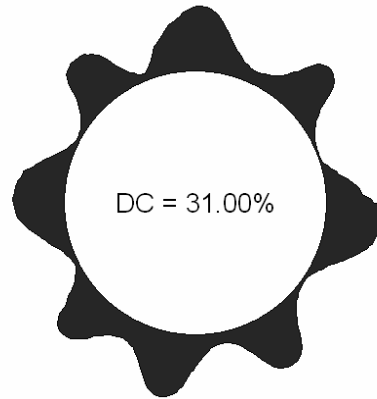
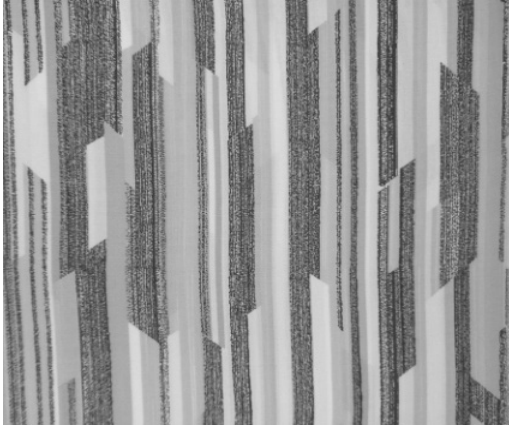


Figure 5. Image of 2D projection of drape sample B, with drape coefficient.

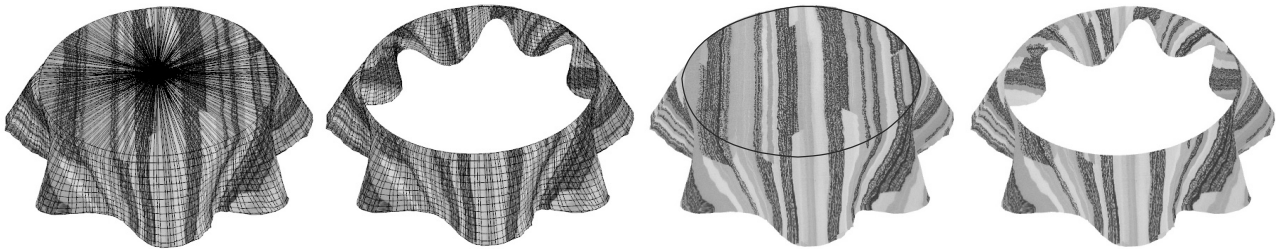


Figure 6. Examples of 3D representation of drape sample B after 3DScan covered it with the true texture.

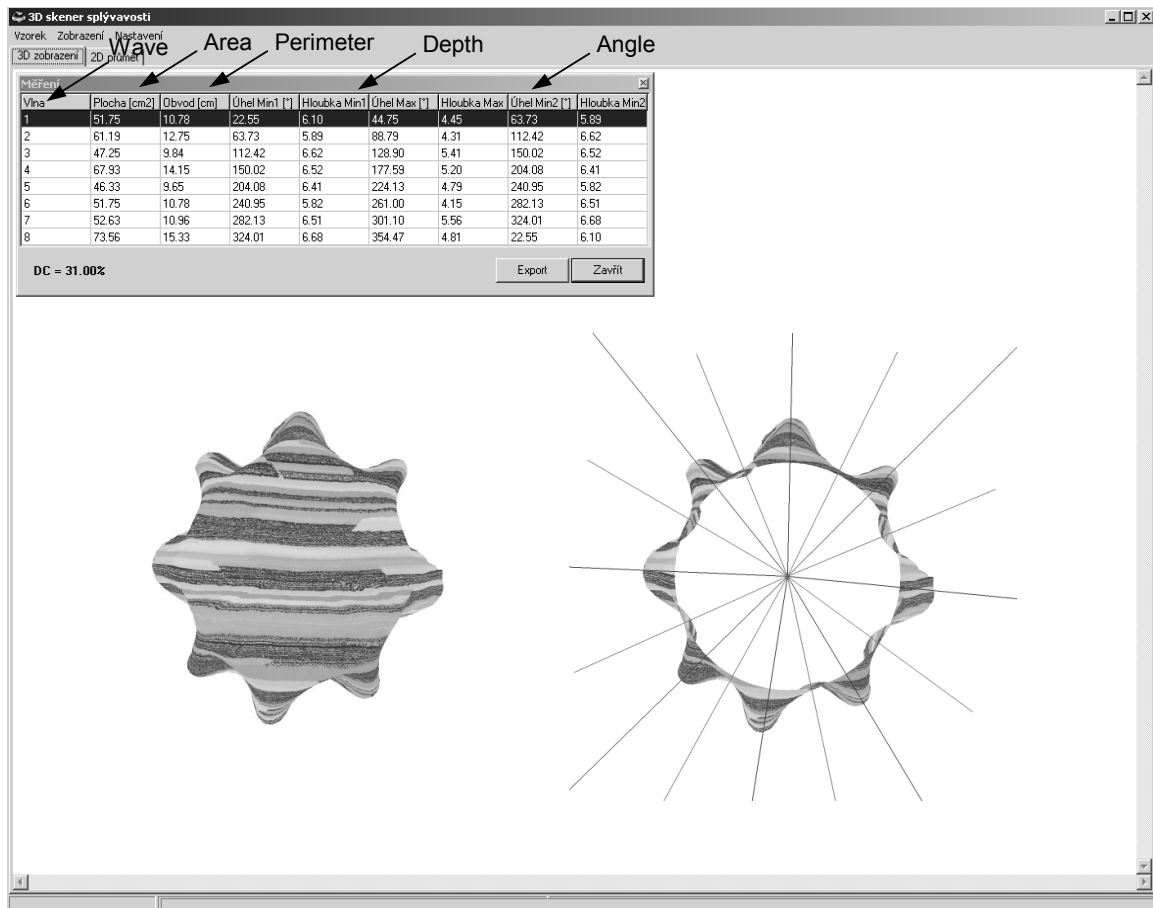


Figure 7. Main window of 3DScan, displaying a table of evaluated drape parameters including number of nodes, area of waves, etc.

2.2. 3D Drape Scanner in comparison with classical drapemeter

The main advantages of the 3D drape scanner are:

- the display of the true three-dimensional image of the draped fabric
- the possibility of covering the tested drape sample with the true texture, thus improving the accuracy of the measurement
- automatic measurement and evaluation of chosen drape characteristics (DC (%), number of waves, angle, depth, etc.) using the 3Dscan software

A further advantage of the 3D Drape Scanner consists in its ability to increase the reproducibility of drape measurement, in comparison with the Shirley Drape Tester (which uses Cusick's classical method of drape measurement), in particular because it uses defined conditions for putting the fabrics into their draped state (12). The Shirley Drape Tester uses the principle of adding a circular table to put the test sample into its draped state. The motion of the circular table (in the direction of axis z) is derived from the free fall of the frame construction (where table is fixed). The vibration of the table (due to the accelerated, constrained motion of the table towards the bottom centre) causes random errors in the resulting DC (%) measurement.

The construction of the 3D Drape Scanner ensures that the circular table moves at a constant speed in axis z. The improvement of drape measurement reproducibility is evident from the decrease in shape variability of the tested drape samples (namely in the distribution and shape of particular drape waves). Twenty samples which were cut out of the same fabric (fabric B - Table 1), were measured both by Cusick's method – using the Shirley Drape Tester – and by the 3D Drape Scanner. The unfolded outer outlines of the twenty samples after draping are displayed in the following graphs, see Figures 8, 9. Twenty projected shadow areas of the specimens after draping were transferred to polar coordinates. The pole (0,0) of the polar coordinate system is identical with the centre of the tested sample, d (cm) is the radius (d is set as the distance between the pole and the outer outline of the draped sample) and γ ($^\circ$) is the angle that the radius d forms with a weft direction.

Moreover, the structural design of the 3D Drape Scanner (using a constant speed for the added circular table movement) eliminates the data variance of the drape coefficient DC (%). Therefore, a group of six fabrics (drape range 20-75 DC (%)) was measured by both the classical Shirley Drape Tester and by the 3-D Drape Scanner, see Table 2. The physical fabric property measurements shown in Table 1 were determined according to the European Committee for Standardization (CEN).

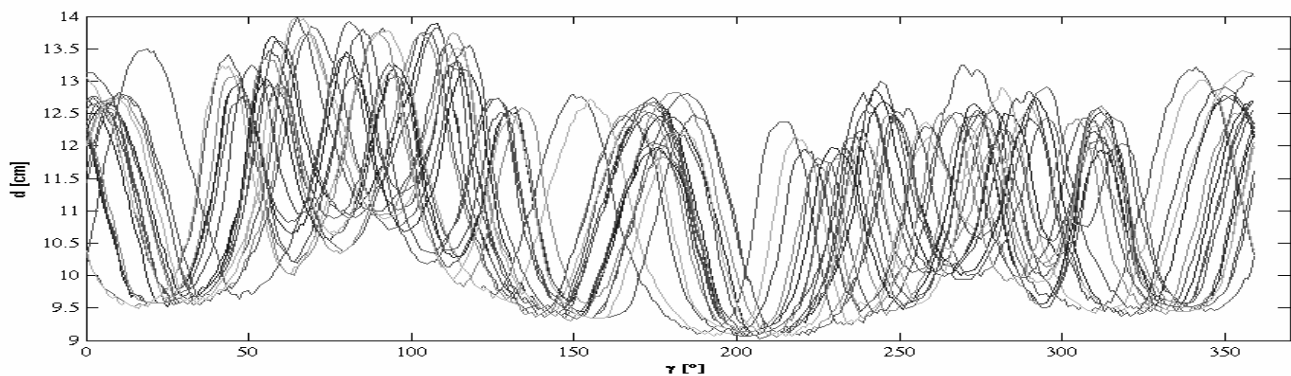


Figure 8. The unfolded outer outline of twenty samples of fabric B after draping onto the polar coordinate system; drape measurement carried out by the Shirley Drape Tester

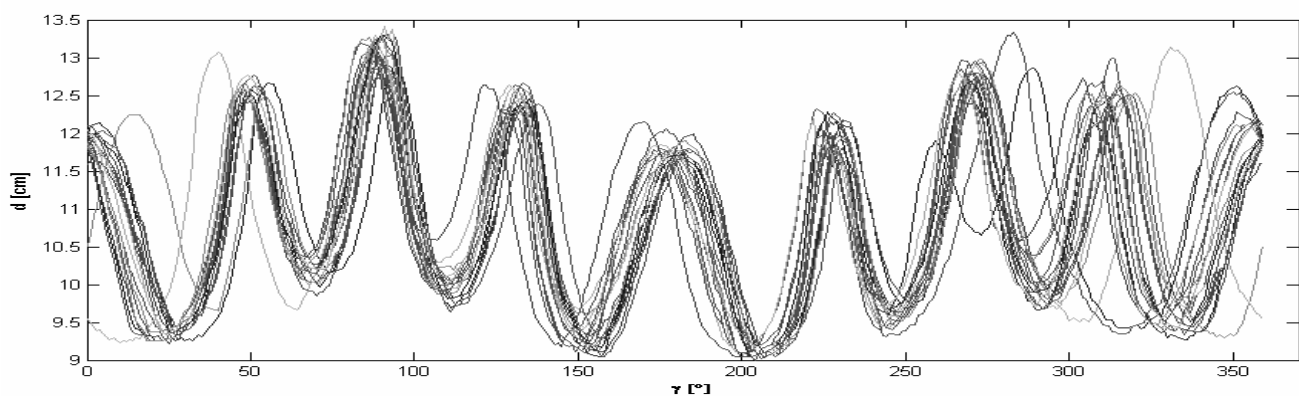


Figure 9. The unfolded outer outline of twenty samples of fabric B after draping onto the polar coordinate system; drape measurement carried out by the 3D Drape Scanner.

Table 1. Fabric properties.

| Fabric | Weave | Count (W x F/100 mm) | Weight (g/m ²) | Thickness (mm) | |
|--------|-------------------|----------------------|----------------------------|----------------|-------|
| A | viscose | plain | 160 x 140 | 80 | 0,357 |
| B | viscose | plain | 400 x 220 | 115 | 0,407 |
| C | polyester | satin | 360 x 290 | 148 | 0,690 |
| D | viscose/acetate | plain | 430 x 330 | 55 | 0,130 |
| E | polyester/viscose | satin | 96 x 230 | 101 | 0,313 |
| F | cotton | twill | 490 x 250 | 190 | 0,667 |

Table 2. Results of the drape measurement by the 3D drape scanner in comparison with the drape measurement by the Shirley Drape Tester.

| Number of measure / Fabric | DC (%) by the 3D drape scanner | | | | | | DC (%) by the Shirley drape tester | | | | | |
|--|--------------------------------|-------------|-------------|-------------|-------------|-------------|------------------------------------|-------------|-------------|-------------|-------------|-------------|
| | A | B | C | D | E | F | A | B | C | D | E | F |
| 1. | 23,0 | 31,0 | 43,1 | 54,7 | 58,8 | 74,0 | 25,3 | 31,8 | 50,1 | 55,1 | 61,8 | 72,8 |
| 2. | 23,9 | 30,0 | 46,5 | 54,2 | 58,4 | 72,5 | 21,1 | 24,2 | 47,2 | 51,9 | 62,5 | 70,8 |
| 3. | 21,1 | 30,8 | 44,7 | 55,4 | 60,8 | 73,2 | 17,0 | 26,8 | 41,1 | 53,8 | 58,9 | 71,9 |
| 4. | 22,5 | 28,3 | 44,4 | 53,8 | 58,0 | 74,7 | 22,6 | 28,1 | 47,8 | 53,7 | 58,4 | 72,3 |
| 5. | 22,4 | 29,1 | 43,5 | 52,1 | 59,2 | 72,7 | 20,6 | 25,6 | 45,7 | 52,4 | 59,6 | 74,0 |
| 6. | 24,5 | 28,6 | 45,6 | 52,5 | 58,9 | 74,1 | 19,2 | 26,2 | 46,8 | 55,7 | 59,9 | 74,2 |
| 7. | 20,3 | 31,5 | 44,8 | 51,8 | 59,1 | 72,9 | 18,5 | 29,5 | 50,2 | 53,8 | 60,4 | 71,6 |
| 8. | 22,0 | 32,2 | 45,2 | 54,0 | 58,6 | 73,8 | 22,4 | 30,5 | 46,5 | 54,6 | 62,0 | 73,5 |
| 9. | 21,5 | 32,0 | 42,8 | 52,0 | 60,1 | 72,6 | 23,1 | 23,7 | 42,5 | 54,3 | 58,6 | 75,0 |
| 10. | 24,6 | 31,8 | 43,5 | 54,7 | 58,9 | 74,8 | 24,5 | 30,9 | 45,2 | 55,8 | 62,5 | 72,9 |
| Mean | 22,6 | 30,5 | 44,4 | 53,5 | 59,1 | 73,5 | 21,4 | 27,7 | 46,3 | 54,2 | 60,5 | 72,9 |
| St. deviation | 1,4 | 1,4 | 1,2 | 1,3 | 0,8 | 0,9 | 2,6 | 2,9 | 2,9 | 1,5 | 1,6 | 1,3 |
| Variance | 2,1 | 2,1 | 1,4 | 1,7 | 0,7 | 0,8 | 7,0 | 8,2 | 8,5 | 2,3 | 2,6 | 1,7 |
| DC_{min} | 20,3 | 28,3 | 42,8 | 51,8 | 58,0 | 72,5 | 17,0 | 23,7 | 41,1 | 51,5 | 58,4 | 70,8 |
| DC_{max} | 24,6 | 3,932,2 | 46,5 | 55,4 | 60,8 | 74,8 | 25,3 | 31,8 | 50,2 | 56,6 | 62,5 | 75,0 |
| DC_{max} - DC_{min} | 4,3 | 3,9 | 3,7 | 3,6 | 2,8 | 2,3 | 8,3 | 8,1 | 9,1 | 5,1 | 4,1 | 4,2 |

A comparison of the DC results between the standardized drape evaluation (Shirley Drape Tester - SDT) and the suggested 3D Drape Scanner, was performed using statistical analysis such as: a paired samples comparison, and a variance equivalence test (Fisher Snedecor test – F test). The arithmetic means of the DC of the given fabrics A-F were compared.

The paired sample comparison revealed that differences (at a significance level of 0.05) between the drape

measurement by 3Dscan and by SDT are not significantly different from zero. The Bland Altman plot and the graph of confidence ellipse affirm this hypothesis, see figure 10.

A high degree of correlation (the R value is 0.993) has been shown to exist between the DC results of the above-mentioned drape testers (see figure 11). To summarize, the standard drape meter can be fully replaced by the 3D Drape Scanner.

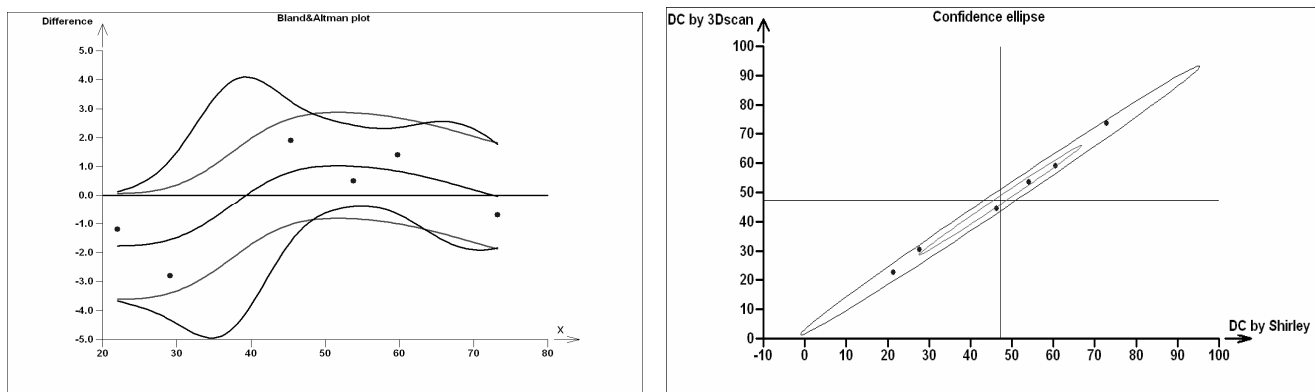


Figure 10. Bland Altman and Confidence Ellipse from the analyse of the paired sample comparison.

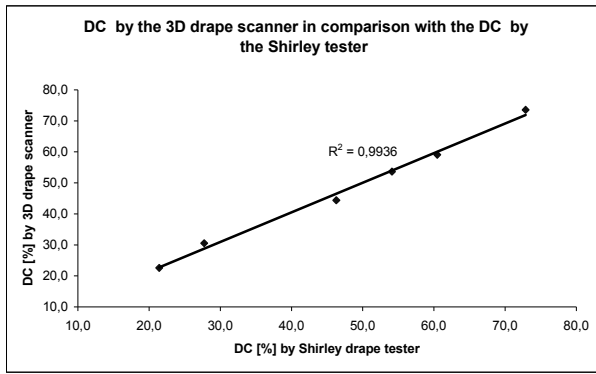


Figure 11. Comparison of the DC measurement by the 3D Drape Scanner with the DC measurement by the Shirley Drape Tester.

The measurement should be as accurate as possible. Wide variance of DC measurements by the SDT is a problem. The fabrics with medium and lower drapability (DC less than 60%) show more variance in the measured DC, see fabrics A, B, C in Table 2. It depends on the measurement conditions, especially on the afore-mentioned vibration of the circular moving table (caused by the accelerated constrained motion of the moving table towards the bottom centre), which puts the fabrics into their draped state. The DC variance of fabric C was investigated. The variance equivalence F test for fabric C does not allow the null hypothesis $H_0: \sigma_{DC_{Shirley}}^2 = \sigma_{DC_{3Dscanner}}^2$ as opposed to the alternative hypothesis $H_A: \sigma_{DC_{Shirley}}^2 \neq \sigma_{DC_{3Dscanner}}^2$. The variances ratio 6.01 and the P value was 0.0066. That means the variances are different. The Box plot and graph of the Kernel density also affirmed this hypothesis, see Figure 12. From the point of view of variance, the 3D Drape Scanner is more appropriate and gives a more accurate drape evaluation. In addition the DC variance of the 3D Drape Scanner is lower than that of the Shirley Drape Tester.

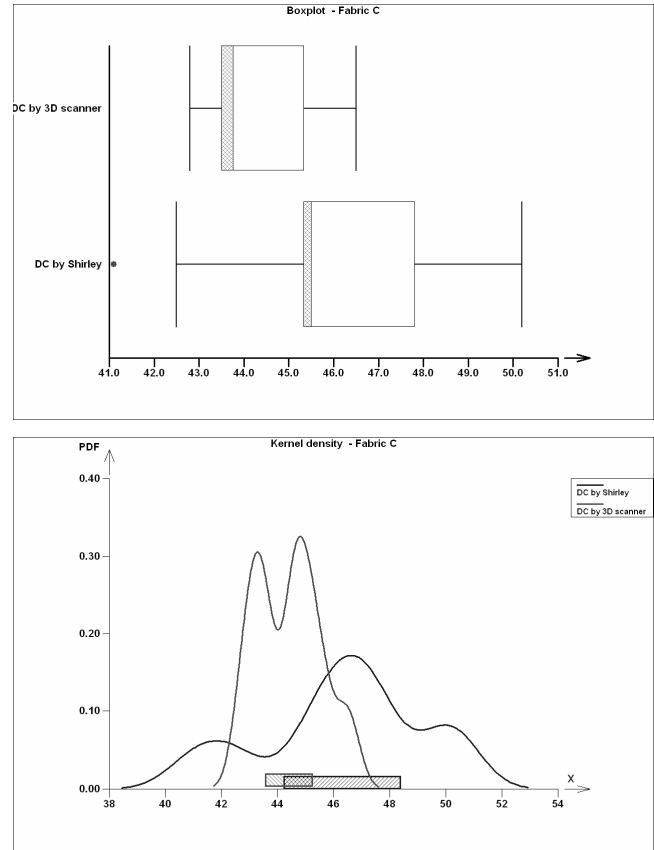


Figure 12. Kernel density and Boxplot for fabric C.

The inability to identify the inner drape waves, which are formed under the outer border of the circular clamping discs, is a significant problem, especially in the case of fabrics with high drape. The arrow, see Figure 13b, denotes the above-mentioned problematic inner waves that are not captured by the standardized measurement of DC. Up to the present time there has been no possibility of solving the problem with the classical drapemeter. The 3D Drape Scanner enables it.

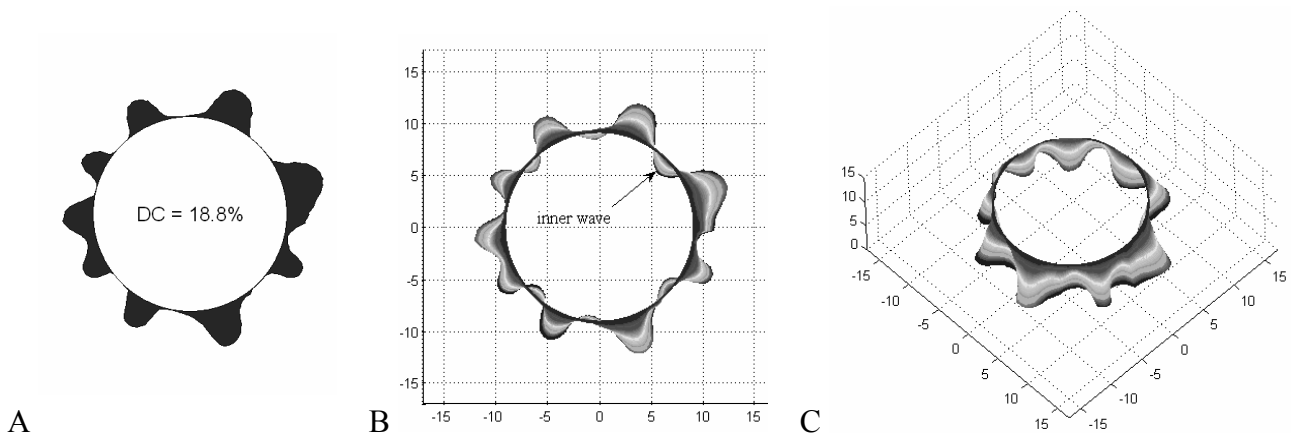


Figure 13. A: Image of 2D projected shadow area of the fabric after draping. B: Corresponding 3D image of draped fabric A. C: Corresponding 3D image of draped fabric A.

A modification of the DC calculation (equation 1) was recommended, to increase drape evaluation accuracy for highly draped fabrics. The new equation (3) contains the areas of the inner waves in comparison with equation 1

$$DC = \frac{(A_S - A_{IW}) - A_D}{A_O - A_D} \cdot 100 \quad \% \quad (3)$$

where A_{IW} represents the area of the inner waves.

The DC value decreases after recalculation by means of the new equation 3 (for fabric displayed on figure 14 from 18,8 % to 18 % DC). The accuracy of the DC determination for high draped fabrics can be increased about 5 % from the initial DC value.

3. CONCLUSION

In this research, an innovative measurement device for fabric drape evaluation is presented, called the 3D Drape

Scanner. The new 3D Drape Scanner provides a true three-dimensional image of draped samples. The drape measurement and evaluation of representative drape parameters (DC, number of nodes, area, perimeter and depth of wave, etc.) has been performed, fully automatically, under defined measurement conditions using the 3Dscan software.

A comparison of the results between the standardised drape evaluation (by the Shirley Drape Tester) and the suggested 3D Drape Scanner was carried out. The high correlation of the DC results has been shown. The next research will be focused on the application of the 3D drape scanner in order to verify the results of 3D fit simulation systems such as VStitcher – Gerber Technology.

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