Sylvie® 3D Drape Tester – New system for measuring fabric drape

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Newly developed measuring system Sylvie® 3D Drape Tester, used to determine static fabric drape, is presented. As opposed to the conventional Cusick drapameter, the measuring system described is based on storing the 3D geometrical properties of the draped sample form, using photographs in the process. The photos and their processing are employed to reconstruct mathematically the geometrical shape, while the drape coefficient evaluation is based on the geometrical model, using two methods.

1. Introduction

The aims of modelling textile materials and woven structures, for the purposes of garment industry and computer graphics, are quite different. If you, for example come to a real or virtual tailor, select the fabric you wish and, prior to making the final decision, wish to see how the suit or skirt would fit, it is preferable that you could see the precisely modelled article of clothing on the computer screen. When such applications are concerned, the aim is to create the simplest model to offer a real result or one acceptable to an average observer [1].

The purpose of creating a physically precise and predictable model is minimal, if any. The main aim is to create computer-generated pictures and animations for the so-called proper appearance of the clothing. Garment constructor should be able not only to measure the body (take the measures) and create a personal virtual model, but to define some characteristics of the real fabrics necessary for the 3D visualisation as well.

In practice, fabrics are exposed to numerous complex deformations, such as draping, folding or bending. In order for the designer to be able to reach the optimal level of a rational engineering design, it is necessary to know and understand complex fabric deformations.

It is much more convenient, in some cases, to determine the parameters of the simulation system by using the conventional equipment, such as a photo/video equipment used for data acquisition and storage. This is why the new measuring system Sylvie® 3D Drape Tester has been developed. The system used conventional equipment and offers computer-generated simulation of the draped fabric geometry. The parameters of the fabric simulation model, based on the so called parameterised system of particle elements, have been adapted so as to match the geometry of the real fabric in a static state, draped over a round surface (Drapemeter), evaluating the parameters according to the photograph of the fabric.

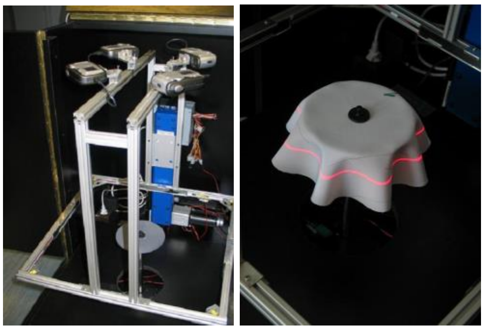
2. Sylvie® 3D Drape Tester – system for measuring textile fabric drape

A round fabric sample, with the diameter of 30 cm is used with the Sylvie® 3D Drape Tester measuring system, the same as with the conventional Cusick Drapemetre. The diameter of the round table in the equipment is 18 cm. The sample draped exhibits conventional mechanical deformations.

To determine the sample geometry, defined using for laser beams used to illuminate the sample through mirrors, special 3D scanner is used. Laser beam lines on the draped sample, which determine the cross-sections of the curve, are recorded as digital photographs. Based on the recordings of the cross-section curves of the draped samples, an analytical characterisation of the curve cross-section geometry is done, employing the regression Fourier series. The interpolation of the positioned draped sample cross-section curve is done using a special type of the cube B-spline method [2]. The surface interpolated is used to reconstruct the original 3D-sample geometry.

2.1 Equipment used

The computer-controlled equipment is mounted in a black box, Fig. 1a. The computer moves the centrally positioned round table, ensuring thus a natural fabric folding and drape, necessary for the testing. The central part of the equipment is a computer-controlled frame, with laser beams used to illuminate the sample through the mirrors and four cameras used to record the laser beams, i.e. the cross-sections of the curves at the various levels of the draped sample, Fig. 1b.



a) *b)*

Fig. 1. Sylvie 3D Drape Tester: a) Computer-controlled equipment mounted in a black box, b) Laser beams lines on a draped sample

2.2 Measuring procedure

The new system offers storing and recording the sample form at various levels of the draped sample, enabled by the computer-controlled frame, with the lasers and the system of 4 digital cameras on it. Although this procedure yields numerous curves to determine the drape coefficient, only the curve of the lower edge of the draped sample is used, the lower edge being the last point of the outer fold, Fig. 1b.

Prior to determining the curves recorded by the four cameras, it is necessary to calibrate the measuring system. This is done by interpolating the curves based on the calibration pictures. Calibration is done in order to define the dimensions of the curves of the sample draped form ground-plan cross-section. Based on the recordings of the etalone, recorded by the equipment described, the computer software calculates and stores the distortion and the necessary rotation of the four fourths. One fourth of calibration etalon can be seen in Fig. 2.

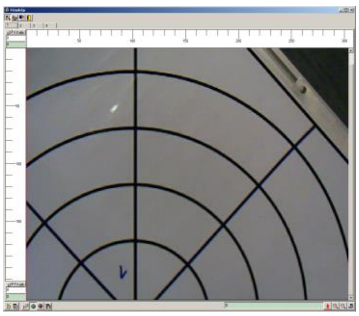


Fig. 2. A fourth of calibration etalon

2.2.1 Processing the images

The four images, making the cross-section curves, are stored by the newly developed computer software, Fig. 3. The curve points are defined using the methods of image processing. Taking into account the distortion and rotation of the individual curve segments, they are positioned into a single image, Fig. 4.

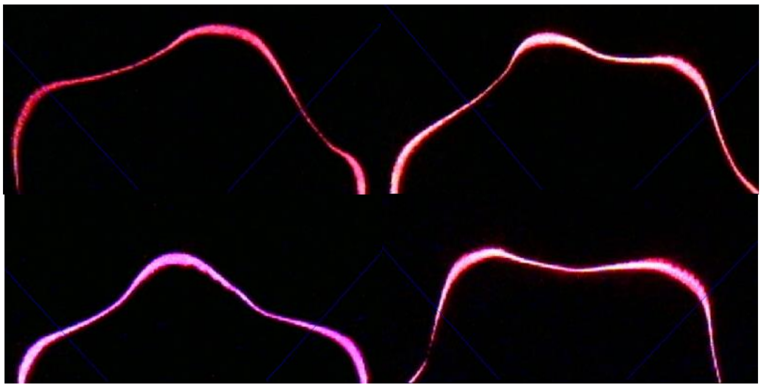


Fig. 3. Four images of curve cross section

Fig. 4. Reconstructed curve cross section

The cross-section curves are approximated by the members of the Fourier series, in a polar co-ordinate system (1). Most of the members (*n*) can be defined by the computer software in question.

$$R(\varphi) = \frac{1}{2} a_0 + \sum_{i=1}^{n} a_i \cos(i\varphi) + \sum_{i=1}^{n} b_i \sin(i\varphi) \qquad (1)$$

The Fourier's coefficients are defined by the minimal square method. If the N number of the cross-section points measured are at the actual level (R_k, φ_k), then the a_i, b_i are the coefficients defined by the minimum of the function (2).

$$\sum_{k=1}^{N}\left\{R_k-\left[\frac{1}{2}a_0+\sum_{i=1}^{n}a_i\cos(i\varphi_k)+\sum_{i=1}^{n}b_i\sin(i\varphi_k)\right]\right\}^2=minimum \qquad (2)$$

2.2.2 3D reconstruction

The geometry of the sample draped form is modelled by the Bezier's surface patches. The shape of the surface patches is defined by the $P_{i,j}$ vertices, Fig. 5.

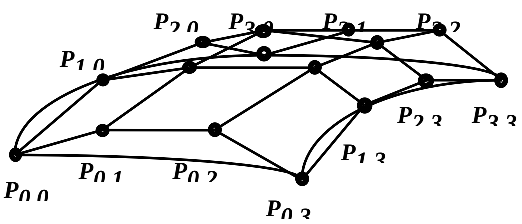


Fig. 5. Bezier's surface patches

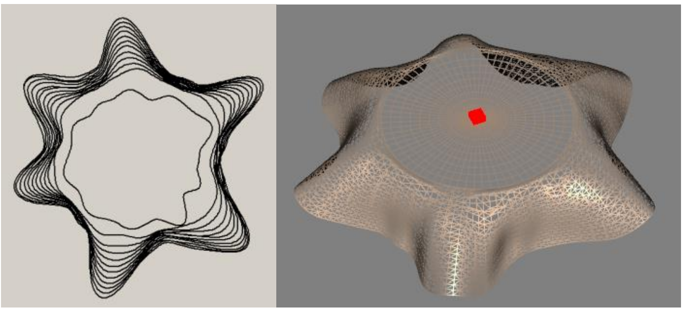
The surfaces patches are continually linked with each other, based on the interpolation by the Catmull-Romm spline method. The slopes of the edges of the surfaces patches are also defined by the vertices of the actual element.

The values in the vertices of the 3D geometry are defined by the approximating curves (1) at various levels [3].

3D reconstruction, Fig. 6, is appropriate to calculate the drape coefficient K_D, defined according to the following equation:

$$K_D=\frac{A-\pi R_1^2}{\pi\left(R_2^2-R_1^2\right)}\cdot 100 \qquad (3)$$

where R_1 is the radius of the fabric supporting disc, R_2 is the radius of the fabric sample, and A is the projected shadow of the draped fabric.



a) *b)*

Fig. 6. 3D Reconstruction of the sample draped shape: a) Approximating curves of the 3D draped sample geometry, b) Simulation of the draped sample appearance

2.3. Measuring the drape coefficient

The measuring system described offers two ways of determining drape coefficients. The first is based on the four original photographs of the curve cross sections, Fig. 3. The software determines the curves of covering the outer points of the laser beams on the draped sample. The surface enclosed by the points can easily be measured. The drape coefficient K_D is determined numerically, using integers according to the equation (3). This method of determining drape coefficient is analogous to the conventional method of the Cusick drapemeter.

Although numerical integration is used with the other method of determining drape coefficients as well, the surface used in the calculation is a horizontal projection of the 3D draped samples created by the simulation [4].

3. Experimental

Based on the *Sylvie® 3D Drape Tester* measuring system presented and the methods of determining drape coefficients described, we have compared the results of determining drape coefficient obtained by the measuring system presented and the ones obtained by the conventional Cusick drapemeter.

15 fabrics have been used in the experiments, differing by the raw material content, surface area mass, construction, thickness and mechanical properties. Some properties of the fabrics used can be seen in Tab. 1.

Table 1 Characteristics of the fabrics tested

Desig-nation	Raw material content	Weave	Surface mass W/gm^{-2}	Fabric* thickness h/mm	Elongation** ε_{-1} / %	Deformation work WT_{-1}/cN cm	Bending rigidity B_{-1}/cN cm^2	Shear rigidity $G_{-1}/cN(st)^{-1}$
01	100% Cotton	Plain	191.06	0.61	7.05	13.23	0.1059	2.84
02	100% Cotton	Plain	191.47	0.61	7.69	14.11	0.0933	2.84
03	100% Cotton	Plain	188.55	0.62	6.51	12.15	0.1117	3.07
04	100% Cotton	Twill	197.07	0.77	10.00	16.17	0.1212	1.52
05	100% Cotton	Twill	191.65	0.92	8.17	11.56	0.0964	0.64
06	100% Cotton	Satin	194.03	0.81	6.54	9.90	0.0854	0.60
07	100% Cotton	Panama	187.70	0.86	8.81	12.45	0.0789	0.53
08	100% Cotton	Rips	186.90	0.85	8.00	11.66	0.0839	0.43
09	67% CV; 33% flax	Plain	206.89	0.61	6.86	12.54	0.1021	3.03
10	50% PES; 50% Cotton	Plain	204.09	0.62	7.42	14.50	0.1241	4.05
11	100% PES	Plain	202.03	0.59	7.76	14.31	0.1263	3.55
12	100% Cotton	Plain	167.12	0.57	6.98	12.64	0.0899	2.16
13	100% Cotton	Plain	148.08	0.56	6.22	10.98	0.0760	1.43
14	100% Cotton	Plain	185.37	0.68	8.91	15.09	0.0923	1.91
15	100% Cotton	Plain	169.62	0.69	8.42	13.13	0.0727	0.71

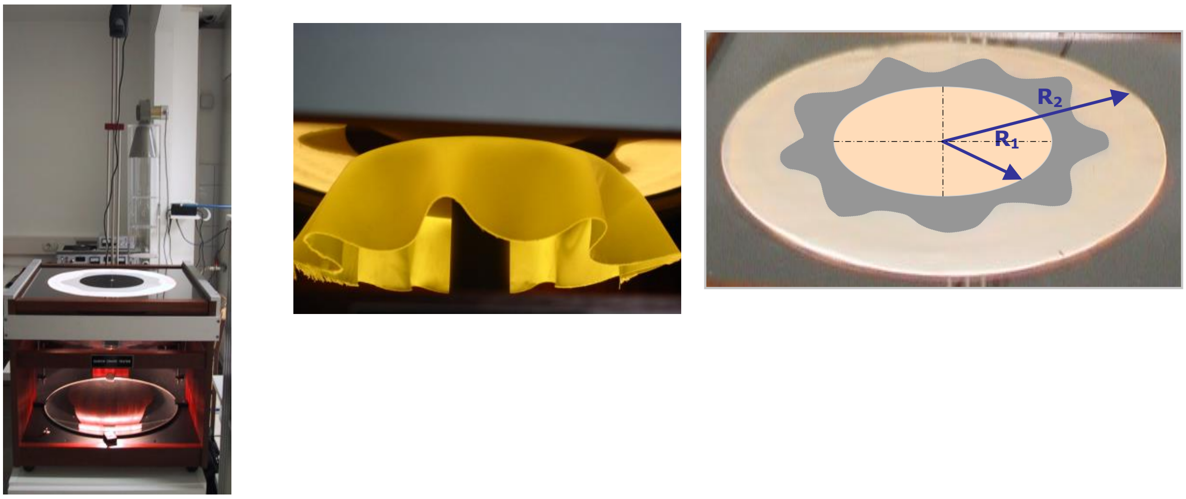
* h – fabric thickness at the load of 0.49 cN cm^{-2}

** ε – elongation at the load of 490.35 cN cm^{-1}

index $_{-1}$ – measuring values warp wise

3.1. Testing methods

Determining drape coefficients using the Sylvie® 3D Drape Tester-a has been done based on the investigations of the 3D geometrical shape of the draped sample surface, employing the described manners of determining the drape coefficients. Contrary to this, the experimental method of measuring drape coefficients using the conventional Cusick drapemeter, equipped with a video camera and a Drape Analyzer software package, is based on the projection (shadow) of the draped surface of the sample, obtained by light reflection (light beam) from a parabolic mirror, Fig. 7. The drape coefficient K_D is defined as a ration of the surface of the rectangular projection of the draped fabric and the surface of the unreformed fabric sample, equation (3) [5-7].



a) *b)* *c)*

Fig. 7: Draping the fabric on the Cusick drapemeter

a) Cusick Drapemeter with a video camera
b) The shape of the draped fabric
c) Projected shadow of the draped fabric

The investigation has been divided into two parts. The first one included the analysis of the draping result reproducibility, while the second involved a comparative analysis of the drape coefficient calculated values, obtained by the Sylvie® 3D Drape Tester presented and the conventional Cusack drapameter respectively.

4. Results and discussion

The results of the reproducibility of measuring drape coefficients, determined by the proposed *Sylvie® 3D Drape Tester-a*, for both methods of determining drape coefficients, are shown in Tab 2. The Tab. 2 shows the average value, standard deviation and variation coefficient of the draping for ten parallel measurements of a single fabric sample.

Analysis of the reproducibility results for the fabrics processed by the Sylvie® 3D Drape Tester shows that the method developed ensures good measuring results reproducibility, since the variation coefficient of the drape coefficient obtained by the first method is 0.135 %, while for the second method it is 0.211 %.

Table 2 Repeatability results for the drape coefficient values calculated for ten parallel measurements on the Sylvie 3D Drape Tester

Number of measurements	**Drape coefficient K_D / %**	
	Manner of evaluating K_D	
	I	**II**
1	60.5	56.1
2	60.9	56.1
3	60.9	56.3
4	60.9	56.3
5	60.9	56.5
6	60.9	56.3
7	60.9	56.3
8	61.0	56.7
9	60.8	56.4
10	60.8	56.7
Average value	60.85	56.37
Standard deviation with	0.135	0.211
Variation coefficient CV / %	0.223	0.375

The values of the drape coefficient obtained by the Sylvie® 3D Drape Tester and the Cusick drapemeter, for 15 different fabric samples (Table 1), are shown in Fig. 8.

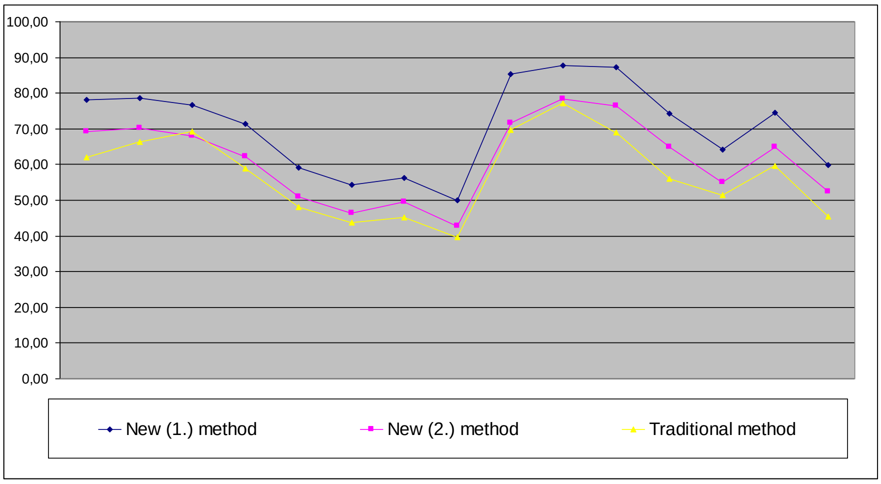


Fig. 8. Comparison of the drape coefficient values (Table 1), obtained by different methods and with different manners of evaluation

Comparing the values of the drape coefficient K_D shows that it is defined by processing the image of the draped sample curve shape, as well as by the projection twisting final curve 3D of the reconstructed fabric sample draped shape, which exhibits higher values than the drape coefficient determined by the conventional method, employing the Cusick drapemeter. The differences in drape coefficient values can be attributed to the differences in defining the draped shape of the sample, both between the two methods (Sylvie® 3D Drape Tester - Cusick drapemeter), and between the two manner of evaluating drape coefficients according to the Sylvie® 3D Drape Tester. Since the first one involves evaluating drape coefficients according to the computer-processed images of the curve cross-sections (curves covering the outer points of the laser beams on the draped sample), while the second determines drape coefficients by projecting the twisting final curve of the 3D reconstructed (simulated) geometry of the draped sample modelled by the Bazier's surfaces, we can rightfully conclude that the surfaces of the draped sample projection obtained thus are bigger than the real rectangular projection of the draped sample. It is also confirmed by the analysis of drape coefficient values, Fig. 8, since drape coefficient values, obtained by projecting the twisted final curve of the 3D simulated geometry of the draped sample, come close to the values of drape coefficients determined by the conventional Cusick drapemeter.

A detailed analysis of the evaluation of drape coefficients leads to an interesting fact that both methods of evaluation, as well as all the three manners of determining drape coefficients have certain disadvantages.

The conventional method with the Cusick drapemeter leads to problems when, due to high deformability of the fabric, the depth of the folds exceeds the width of the area $\Pi(R_2^2 - R_1^2)$, which means that the geometry of the fold is partially below the projection of the horizontal plate surface, with the diameter R_1, and the existing measuring technique cannot recognise it.

When the draping parameters are determined by the measuring system Sylvie® 3D Drape Tester, where the geometrical shape of the draped surface is defined on the basis of processed images of the curve cross-sections, while the software seeks the curves of covering the laser beams on the draped sample, the problem arises of objective recording of the draped sample shape geometry. Because of the folds formed, the lower edge of the outer and inner side of the fold are not in the same plane, and laser beams can recognise only the depth of the fold as a rectangular projection of the lowest position of the fold inner part indentation and not the whole of the fold geometry, i.e. the outer part of the fold.

The measuring system presented offers, besides determining draping properties of static textile fabrics, a representation of the fabric simulation model as well, based on the so called parameterised system of particle elements. Since the parameters of the fabric simulation model are adapted so as to match the real fabric geometry in a static state, the measuring system developed also offers a simulation of the draped fabric related to the visualisation of the fabric incorporated in an article of clothing, as can be seen in Fig. 9 [8-9].

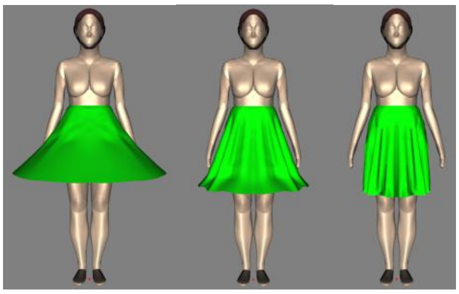


Fig. 9. Virtual Fitting On

5. Conclusions

The measuring system Sylvie® 3D Drape Tester, developed in order to evaluate the characteristics of draped textile fabrics, is a new and original way of evaluating the geometry of a draped shape of a fabric. Apart from the computer-aided simulation of the draped shape geometry, it also offers the possibility of calculating drape coefficients. The results obtained for the drape coefficients calculated exhibit high correlation to the ones obtained by conventional methods.

The method presented is highly acceptable for the purpose of measuring textile fabric draping parameters, as well as for virtual presentation of garment fit.

Acknowledgement

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