NEW MESUREMENT METHOD OF TEXTILE BENDING CHARACTERISTICS

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Abstract: *In the focus of examination of the drapability of textiles or properties of composite sheets with great flexibility is their bending property. There are a lot of ways of measuring as well as Cantilever Test developed by Peirce or the known KES-F system. There is an optical bending test equipment developed at the Department of Polymer Engineering, Budapest University of Technology and Economics. It has advantages opposite to traditional ones namely the optical image processing based analysis works without mechanical contact and defining bending parameters based on knowledge bases built by mechanical simulation. Shape of the bended material is defined by the picture of three projected laser lines. Material properties come from comparison the deflection curves or surface of specimen evaluated by picture processing and defined by the FEM simulation. Paper presents the instrument, the way of measurement, evaluation methods and results.*

Keywords: *bending properties, flexible composite sheet, modeling, image processing, FEM analysis*

1. Introduction

Simulating the drapability behaviour of textiles basically needs the knowledge of their bending properties. The bending behaviour of textiles is mainly characterized by the bending length measured by Cantilever Test developed by Peirce [1]. Other characteristic is the bending stiffness measured by the special bending tester instrument of KES-F system [2].
We present a measurement method working in a new optical way – similar to our formerly developed system for measuring fabric drape [3] – which make possible to determine the bending characteristic of textiles with application of image processing.
During the measurement the fabric sample is griped on its two ends and three laser lights are projected onto sample deflecting freely between the two grips. The curves of laser curves on the bended sample are recorded by a camera and the shape of them is determined by image processing making possible to create a virtual surface of the bent sample. The bending characteristics and the data such as the bending stiffness needed to simulate drape behaviour are determined by mathematical methods from the determined shape.
In this paper the instrument developed for measuring bending characteristics, and the way of measurement and evaluation are presented.

2. Measuring Instrument

The test table of the equipment consists of several element pairs of same dimensions of upper and lower sections. Upper sections can be turned up separately and the lowers can be turned down separately as well. During measurement a 100 mm by 600 mm sized specimen is laid on the turned down lower elements strainlessly that is fixed by turning down the upper elements. There is an unslipping coat on fixing elements. Thanks for the construction the bending effect can be measured with different length. In case of measuring the upper fixed parts of suitable number are turned up and the lowers opposite them are turned down. Specimen will deflect down because of the gravity. There is a bijection between the mechanical parameters and the shape of specimen. There are three laser projectors above the table and a camera. The camera takes the image of the projected laser lines (Figure 1.).

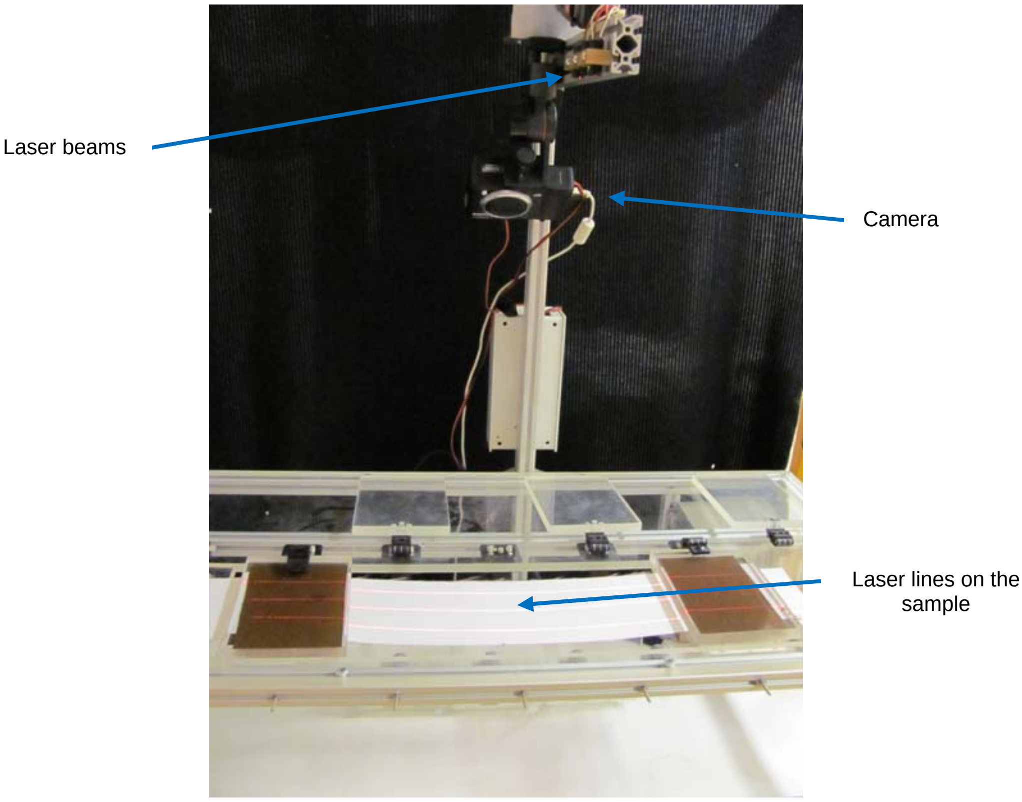

Figure 1. Instrument for measuring bending properties of textiles

3. Calibration and Picture Processing

In order to develop suitable measuring methods and achieve necessary accuracy, we had to calibrate the cross-sections on the photo as well as to analyze errors.
Light-beams forms planar curves in three positions. Points of curve are determined by processing of pictures. For 3D scanning the plane to plane perspective transformation is a bijection. Perspective transformation by homogenous coordinates is a linear transformation [4] that projects quadrangle to quadrangle. The matrix of transformation (1) has eight independent coordinates.

$$\underline{\underline{P}} = \begin{bmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & 1 \end{bmatrix} \tag{1}$$

Corners of a rectangular calibration element are appropriate to define of matrix coordinates (Figure 2). Corners of calibration equipment are $\left(t_x^i, t_y^i\right)$, and corners of its picture are $\left(v_x^i, v_y^i\right)$ (*i*=0, 1, 2, 3) and the transformation is shown in Equation (2).

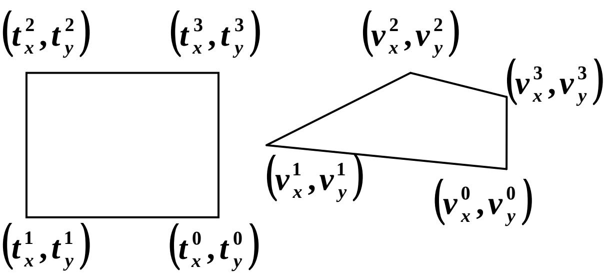

Figure 2. Planar perspective projection

$$\begin{bmatrix} v_x^i \\ v_y^i \\ 1 \end{bmatrix} = \begin{bmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & 1 \end{bmatrix} \cdot \begin{bmatrix} t_x^i \\ t_y^i \\ 1 \end{bmatrix} \tag{2}$$

There are eight unknown coordinates and eight equations represented by formulas (3) in every plane [5].

$$\begin{aligned} v_x^i &= \frac{p_0 \cdot t_x^i + p_1 \cdot t_y^i + p_2}{p_6 \cdot t_x^i + p_7 \cdot t_y^i + 1} \\ v_y^i &= \frac{p_3 \cdot t_x^i + p_4 \cdot t_y^i + p_5}{p_6 \cdot t_x^i + p_7 \cdot t_y^i + 1} \end{aligned} \qquad \mathrm{i} = 0, 1, 2, 3 \tag{3}$$

Determination of corner coordinates can be defined from calibration photo (Figure 3).

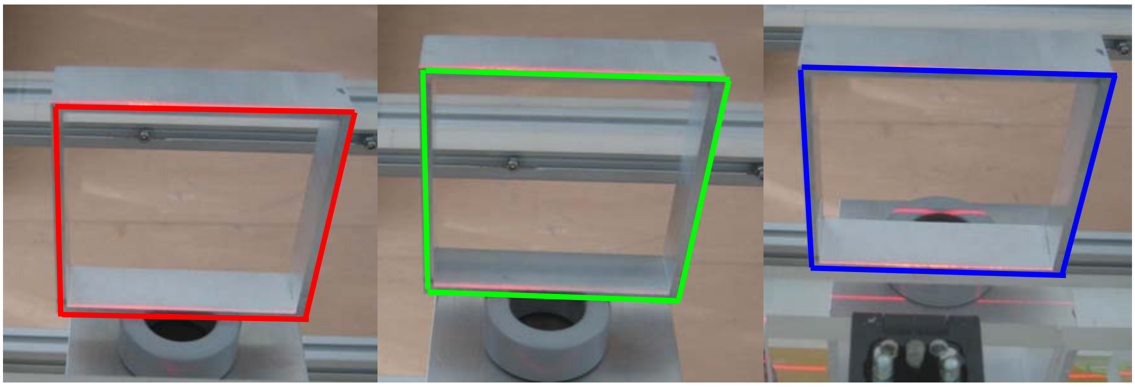

Figure 3. Calibrating rectangles

We are able to process different curves of the beams from the picture (Figure 4). Upon the filtered points and calibrating rectangles 3D coordinates of the surface points are defined.

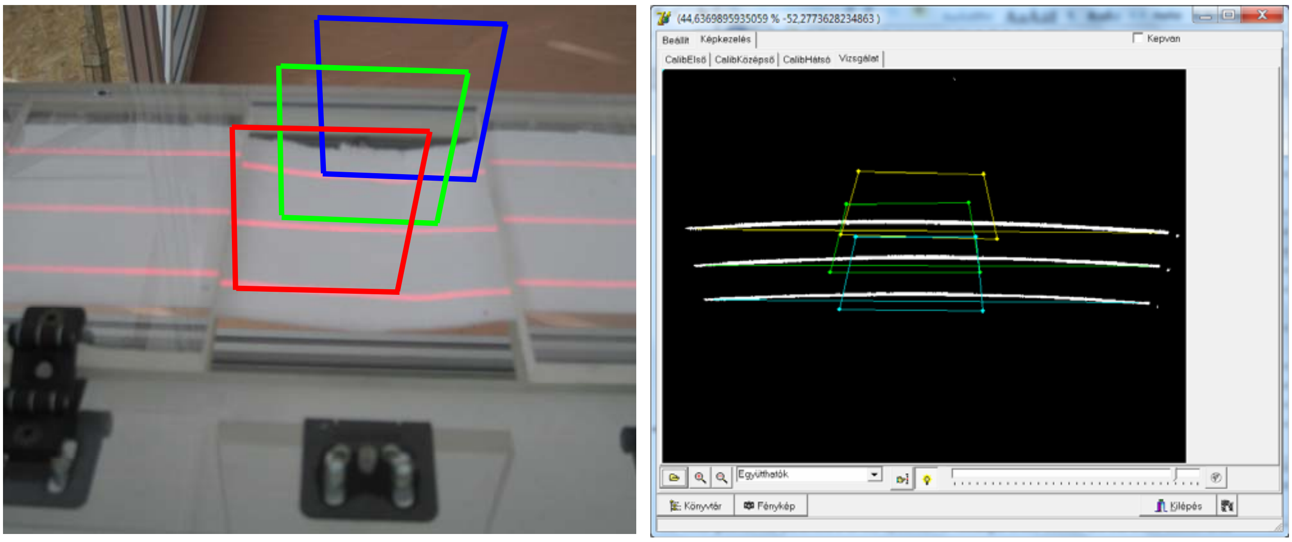

Figure 4. Measuring process

The surface curves of the specimen are defined by polynomial regression (Figure 5) [6].

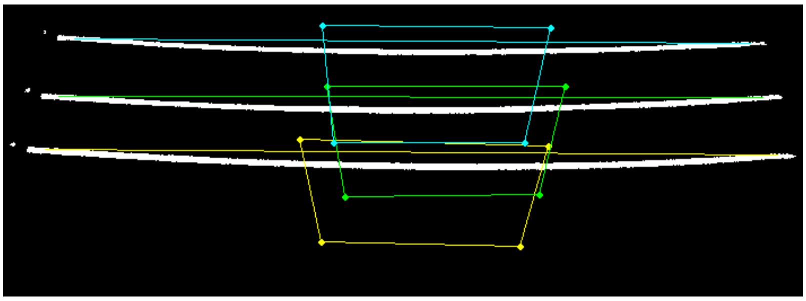

Figure 5. The processed curves

4. Estimation of the bending parameters

The strip-like specimen cut out of fabrics, fibrous mats, or flexible fiber reinforced composites is laid on a horizontal plate and gripped at both ends with a span length *Lo*. After removing the supporting plate from between the grips the specimen stretches under its weight and takes up a curved shape that is represented by the middle line in Figure 6. This middle line can be determined as a *y(x)* function from the image of the laser beams projected on the specimen using suitable image processing methods developed.
Before loading the initial geometrical parameters of the specimen of rectangle cross section are the cross section area ($A_o=b_oh_o$), the inertial moment ($I_o=h_o3b_o/12$), and the linear density ($q_o=\rho A_o$) where b_o and h_o are the width and the thickness respectively, and ρ is the volume density. Supposing that the material of the specimen is elastic with finite tensile (A_oE) and bending (I_oE') stiffnesses – E and E' are the tensile and bending modulus respectively – we can simulate the problem with different material parameters [7] by using Ansys Finite element System.
Selecting the simulation closest to the measured deflection function, z(x,y), the sought parameters can be estimated by those used for simulation.

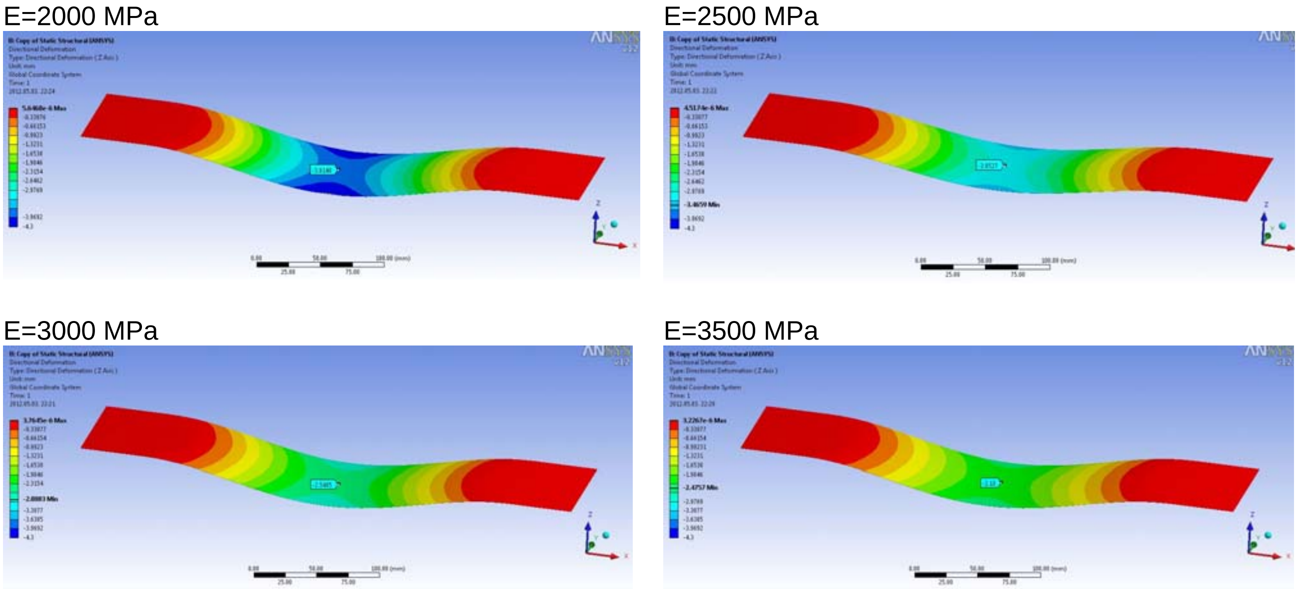

Figure 6. Results of different simulations

A plain woven fabric specimen made of polyester yarns cut out in warp direction was used for testing the measuring principle. The surface density, width, length, and thickness of that were 80 g/m^2, 50 mm, 300 mm, and 0.183 mm, respectively.
Figure 6 shows the different results of deformation direction z with different tensile moduli. The simulation with a tensile modulus of 2500 MPa (upper right-hand side image in Figure 6) provided the closest deflection measured at the middle of the fabric specimen that was assessed about 2.5 mm consequently the tensile modulus of the specimen in warp direction may be about 2500 MPa.

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