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MODELING HIGH FLEXIBLE UNDERCLOTHES BASED ON BURSTING TEST RESULTS

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Abstract:

If someone wants to model common behavior of human body and underclothes he or she will face some difficulties. In case of soft tissue of human body and knitted underclothes of high elasticity exhibit time-dependent and nonlinear mechanical and rheological properties that are to be considered in simulations. We use the bursting test to study the high deformation of the underclothes subjected to two axis loads. This makes it possible to survey the fabric behaviors from little deformations until failure in a way independent of direction. We analyze the connection between the bursting test and one direction tension test by means of finite element method.

The presentation is about the measurements with the bursting tester and the determination of fabric parameters using finite element technology for searching for best agreeing simulation to the bursting measurements.

Key words: *bursting test, high elastic underclothes, rheological properties, material modeling, material parameter*

1. INTRODUCTION

This research is about the bursting test of underclothes fabrics and its FEM simulation, which makes the connection between the uniaxial tension test and the bursting test. The advantage of the bursting test is its relative quickness. There is no need for fabric sample preparation, it is not necessary to cut an exact size sample for the test, because the frame of the tool determines the testing geometry.

2. EXPERIMENTAL

2.1. Presentation of the bursting test's method

Figure 1: The process of bursting test

The process of the test: after fixing the sample on the frame of the tool, a polished ball whose diameter is smaller than the inner diameter of the frame, moves at a constant speed and pressure on the sample. The vertical displacement of the sample depending on the reaction force is recorded.

The examination is the same in each direction of the fabric, it determines the load-bearing and deformation capacity of the fabric as a 3D stress. The table 1 contains the parameters of the tool used for the tests.

Table 1: The parameters of the tool

The diameter of the ball	19 mm
The inner diameter of the frame	25 mm
The maximum of the vertical displacement of the ball	45 mm
The moving speed of the ball	100 mm/min

2.2. Presentation of the test fabrics

In this study we analyzed 31 different fabrics used for making underwear. We can divide this fabrics for 5 groups, according to the field of application. These groups are the followings:

- Lining fabrics (7 each)
- Girdle fabrics (5 each)
- Sponge materials (2 each)
- Cup materials (11 each)
- Lace fabrics (6 each)

3. RESULTS

We present the results of the bursting test by material types. We examined the maximal strain and the force load at the maximal strain.

3.1. Lining fabrics

The behaviour of the different types of lining fabrics were similar, but the maximal strain and the force load at the maximal strain were different. There was fabric that does not split by the maximal displacement of the tool. Typically, the large displacements were established at low loads, but then the curve began to increase exponentially until the splitting of the sample has begun. The splitting has occurred either one or several steps.

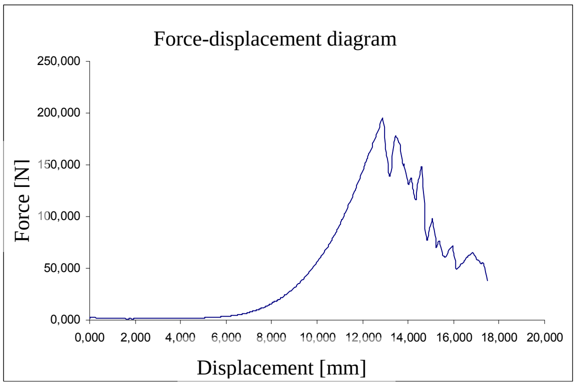

Figure 2: Typical curve of several step splitting

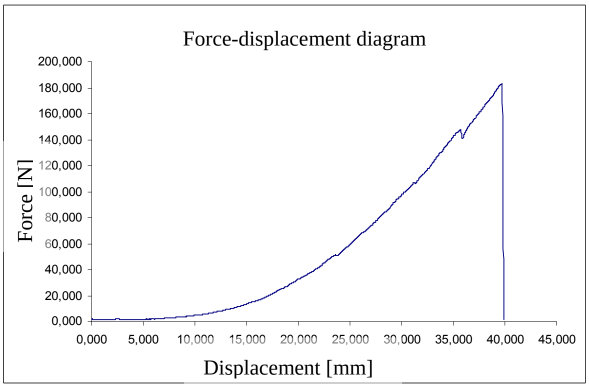

Figure 3: Typical curve of one step splitting

3.2. Girdle fabrics

The most of the girdle fabrics were not split during the test. Those are capable of large deformation. Shown in the figure 4 and 5 two typical curve, which are representative this group of fabric.

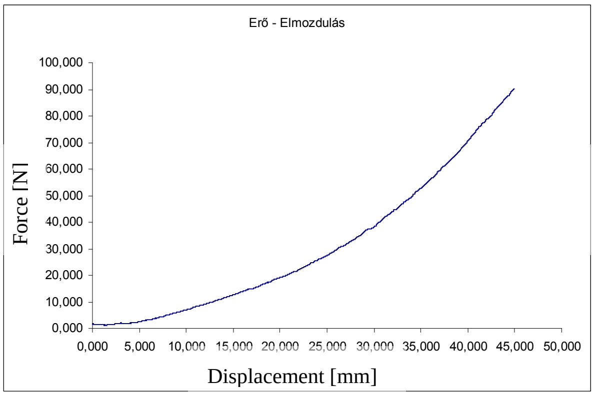

Figure 4: Typical curve without split

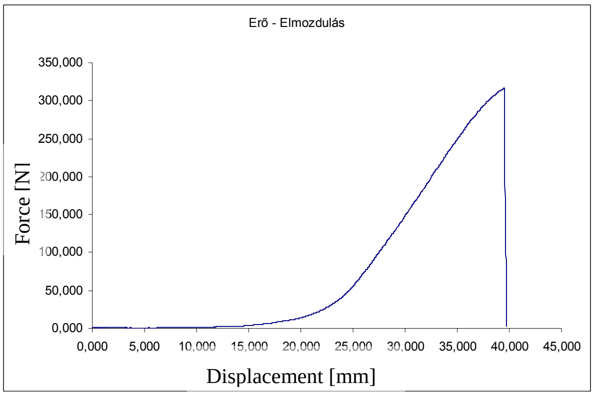

Figure 5: Typical curve with split

3.3. Foam material

The behaviour of the two types of foam material was similar, both of them split during the test and the splitting force was relatively large. The way the splitting occurred was determined by the structure of the fabric.

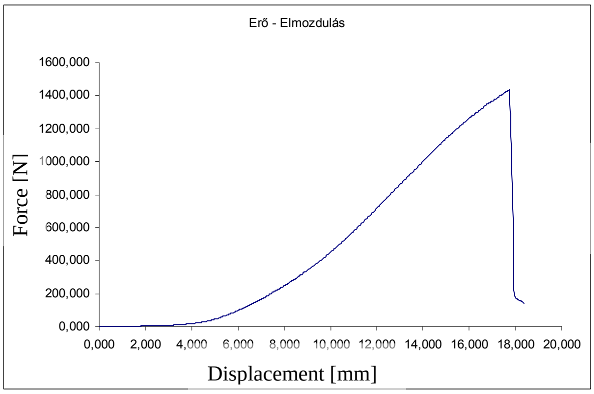

Figure 6: Several steps split curve

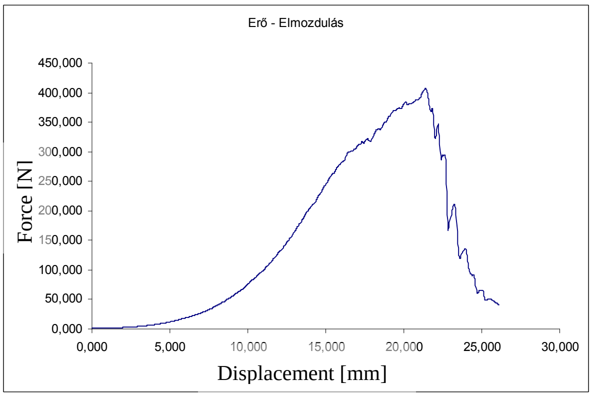

Figure 7: One step split curve

3.4. Cup materials

The curves of the bursting test were quite diverse, because of the huge variety of patterns and structures of the cup materials. Materials with the same structure but different colour had the same type of curve, but the maximal strain and the splitting force was slightly different. Figure 8 and 9 show two atypical curve, which belong to two cup material, which had different structure than the others. In addition other types of material characteristic curves have also occurred.

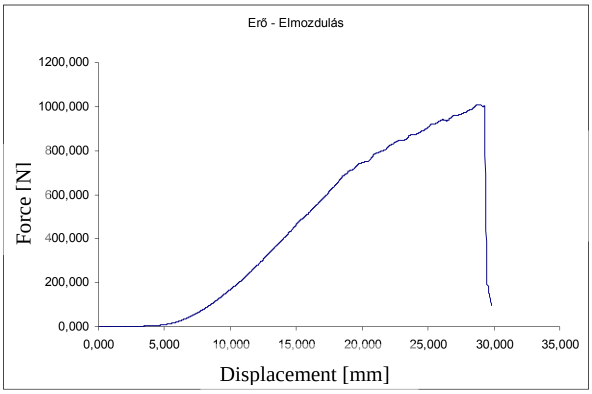

Figure 8: Atypical one step split curve

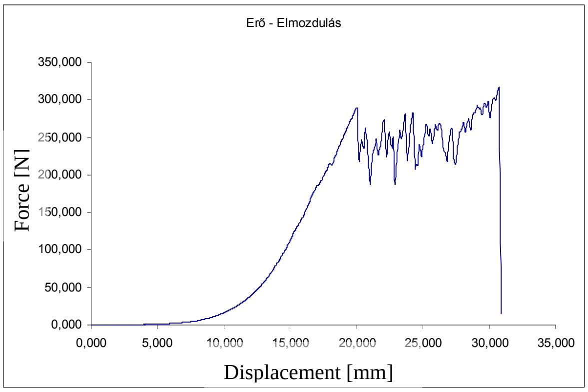

Figure 9: Multiple steps split curve

3.5. Lace fabrics

All of the lace fabrics were split during the tests at relatively low force. While preparing the test care was taken to avoid any embroidery design in the measuring area. The curve characteristics were similar to the curve shown in figure 10 except one sample, which split in multiple steps, shown figure 11.

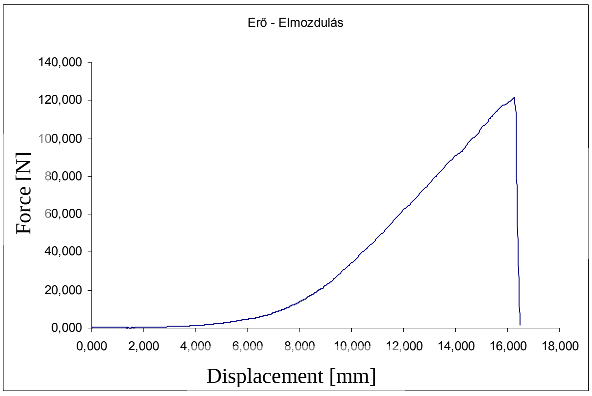

Figure 10: Typical one step split curve

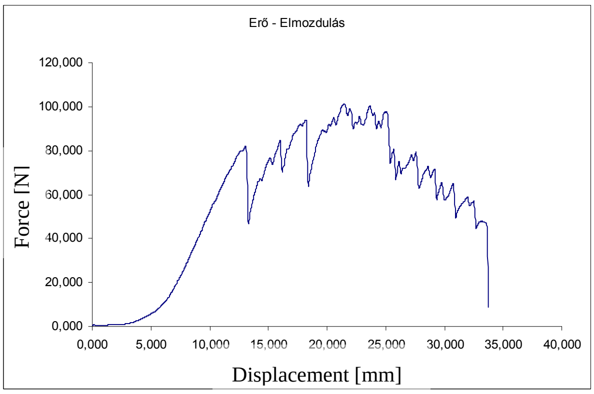

Figure 11: Multiple steps split curve

The types of splits

After the test two kinds of split holes appeared, round shaped and slot like shape. The type of the holes depended on the structure of the fabric and the method of the split. Figure 12 shows a typical round shaped hole, and figure 13 shows some slot like holes.

Figure 12: Round shaped hole

Figure 13: Slot shaped holes

FEM ANALYSIS OF A FOAM FABRIC

We searched the connection between the bursting test and uniaxial tension test with the help of FEM modelling the bursting test. The simulation does not cover the splitting process. Modelling the geometry only the fabric and the ball were needed to model, because the fixed geometry made by the frame of the tool was defined by the division of fabric surface. With this simplified geometrical model the simulation time were greatly reduced. This is particularly important in case of a hyper-elastic non linear material model.

3.6. Geometrical and mesh model

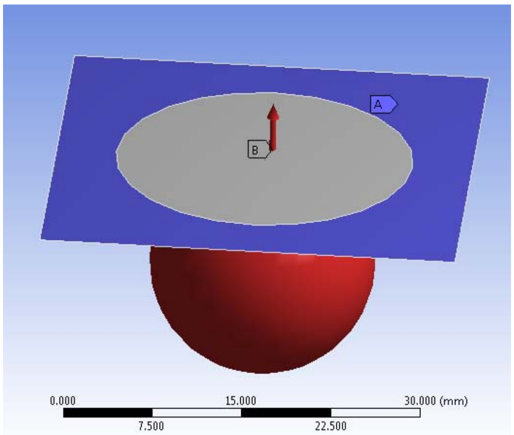

Figure 14: Geometrical model and loads

The geometrical model and the FEM simulation were made in Ansys Workbench 12.0 software. The fabric was modelled as a surface. The dimensions of the model geometry were entirely equal to the dimensions of the testing tool. Figure 14 shows the geometrical model and the loads. The blue area on the plane representing the fabric surface is the fixed geometry. The displacement of the ball was 20 mm, normal direction of the fabric sample. (The direction of the displacement is shown as a red arrow on figure 14.)

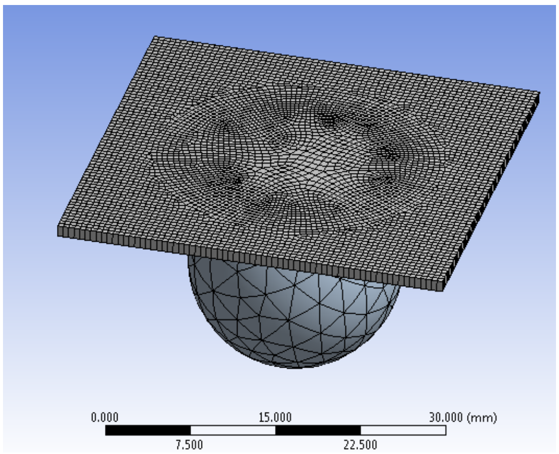

Figure 15: The mesh of the model

While creating the mesh the main effort was taken on the fabric material. The size of the elements of the fabric were 0.5 mm. The mesh model consisted of a total of nearly 6000 elements. The mesh is shown on figure 15. The boundary of the surface consist no surface crossing elements.

3.7. Curve fit to the data received uniaxial tensile test data

We were making both bursting tests and uniaxial tensile tests on the given fabric. The uniaxial tensile test were made on the two typical directions of the fabric, but only one of the data were noted. We used only the first part of the data of the original tensile test while the splitting has not occured yet.

The points of the stress-strain diagram were imported into the Ansys software in a table format, where the curve fit can be done directly for the main material models. In this foam fabric the 5-parameters Mooney Rivlin formulation was sufficiently fit to the measured data.

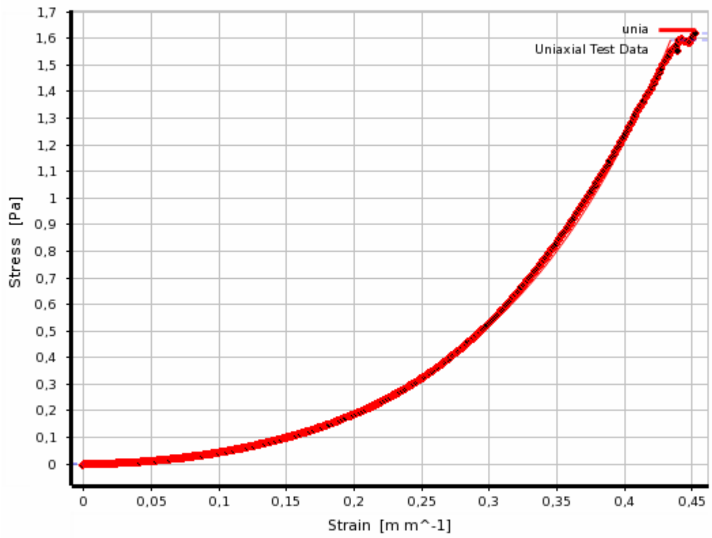

Figure 16: Curve fit to measured data

As shown on the figure 16, only at the end of curve is a minimal differences between the measured and the fitted curve. (The thin red line is the fitted curve.) Table 2 contains the parameters of the material model. In the table "C" values are the material constants "D1" is the incompressibility parameter.

Table 2: Parameters of the material model

Constant	Value
C10	-0,82 [Pa]
C01	0,88 [Pa]
C20	24,19 [Pa]
C11	-58,52 [Pa]
C02	37,17 [Pa]
D1	0 [1/Pa]
Residual	5,87

3.8. Results of the FEM model

The simulation showed the same material behaviour as the bursting test. Only the resulting reaction force values showed small differences. The average maximal reaction force getting by the bursting test was 410.27 N while the simulated result was 366.3 N. The extent of the difference can be explained by the orthotropic behaviour of the tested fabric and the difficulties of modelling the structure of the textile materials. Figure 17 shows the total deformation of the modelled fabric. This figure illustrates the simulated contraction of the material, the fabric behaved the same way during the bursting test.

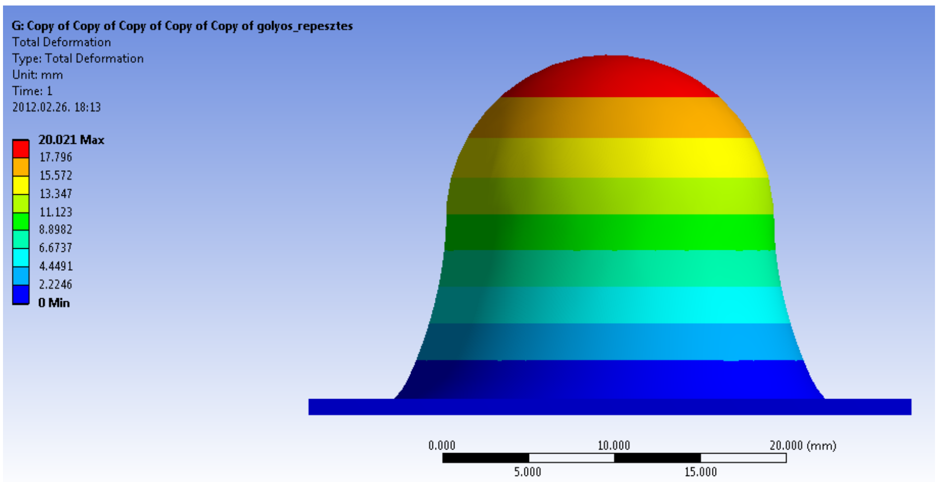

Figure 17: Total deformation of the FEM model

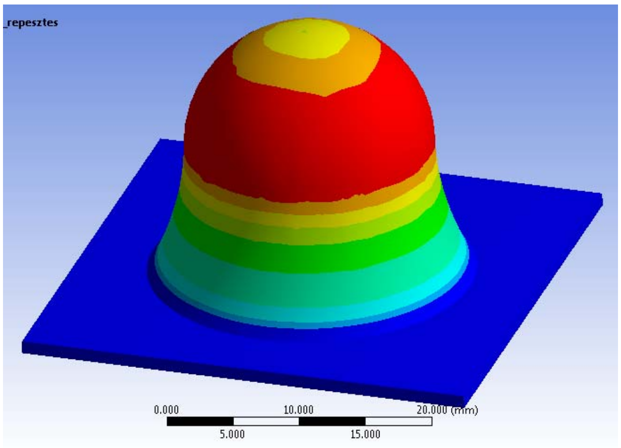

Figure 18: Distribution of the stress

Figure 18 illustrates the stress distribution in the fabric. Clearly visible that the peek of the fabric has lower stress values than the upper (wider) section, as expected.

4. FUTURE PLANS

In the following we plan to refine the finite element model and we take the ortothropic properties of the material into consideration. In addition we planned the cyclic analisys of the fabrics.

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