Punch test of breast implant

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Abstract: The treatment of breast cancer is one of the most significant medical problem. The patient undergoes ablation after diagnosing breast cancer. Another procedure of treatment consists of radiotherapy and chemotherapy. These procedures are very hard to patient psychological state of mind. But the most psychological problem is loss of the breast. The surgeon wants to return the breast for the patient as soon as possible. The field of reconstructive surgery is still open for new approaches from different branches. Tension in resulted scar can be found out by numerical model before the surgery and the surgeon can find better approach for the surgery. The essential task for the customized virtual surgery, the material model of the breast implant is needed. There is no established model for this implant. The aim of this contribution is to perform a punch test in application of the breast implant.

Keywords: silicone gel, FEM, material model, breast implant.

1 Introduction

Virtual customized surgery is one of the trends in the field of clinical biomechanics. This approach enables to predict the surgery result, so that many problems can be avoided before real surgery. The reconstruction of a breast after ablation is one of the clinical applications. The essential task for this virtual surgery is to find out the material model of the breast implant. This contribution is focused on a punch test done on the standardized breast implant.

This work has two parts. The first one is an experiment in the laboratory. Second part is about finding suitable material model and its material constants.

2 Materials and methods

The experimental sample was the round breast implant *McGhan* TSLP235g (textured shell surface, soft touch, low profile plus, size range 235 g).The implant was put on the plane desk and compressed by hemispherical punch with a diameter 25 mm. The velocity movement of the punch was 30 mm/min with total displacement 25 mm. All processes of measurement were captured by an optical system ARAMIS (GOM) for taking true strain on the sample. The frame rate was set on three images per second. The experiment was repeated five times after material relaxation. This measurement is seen on Fig. 1.

The MSC.Marc software (*MSC.Software Ltd., the Czech Republic*) was used for numerical analyses of the breast implant. The material identification was done by material data fitting function. The most suitable material model was chosen Yeoh one. The strain energy function is written in terms of the principal stretches as

$$W = \sum_{i=1}^{3} C_i (I_1 - 3)^i \tag{1}$$

where C_i are material constants, K is the initial bulk modulus. The original model proposed by Yeoh had a cubic form with only I_1 dependence and is applicable to purely incompressible materials. The initial constants from the material data fitting function are seen in Tab. 1.

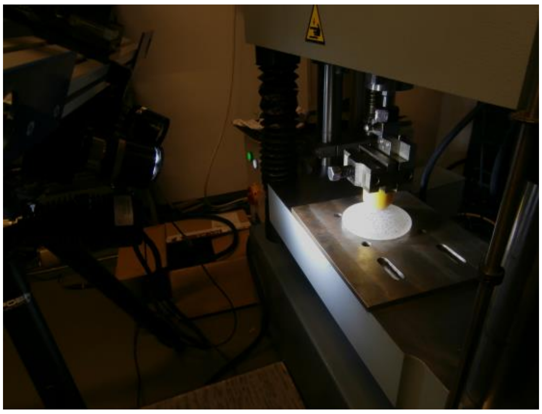

Fig. 1: Experiment measurement.

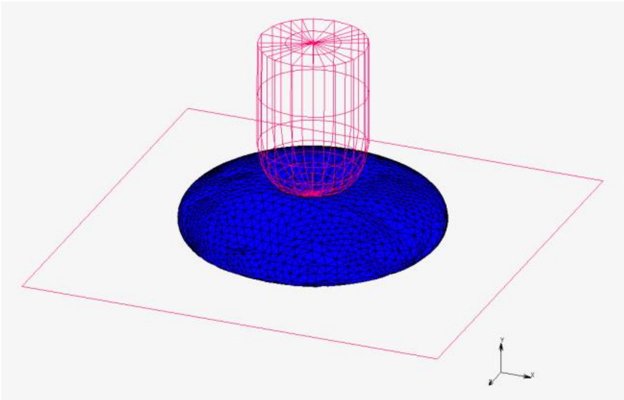

Fig. 2: FEM model.

Tab. 1: Initial material [MPa]

C10	C20	C30
0.00157439	0.000117081	4.3026×10^{-7}

The real geometry of the breast implant was taken by 3D scanner NextEngine before measurement. This scanner based on a laser beam technology. The geometry from 3D scanning is not complete due to light reflexing during scanning. The scanned surface was repaired in Geomagic software. The volume model of the implant was imported into FEMAP preprocessor software. The meshing of the model was done by 96 887 tetrahedral elements. The preprocessing of the model was done in MSC.MARC too, Fig. 2. The material model was defined as above. The contact between the punch and the breast was defined as with friction Coulomb bilinear friction model. The friction coefficient was set to 0.5 values. The punch and plane desk are defined as a rigid body.

3 Results

The comparison of force displacement curve from FEM analysis and the experimental one can be seen on figure 3.

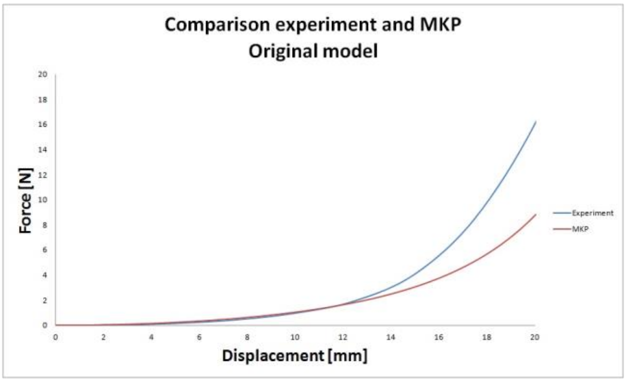

Fig. 3: Initial material data fitting

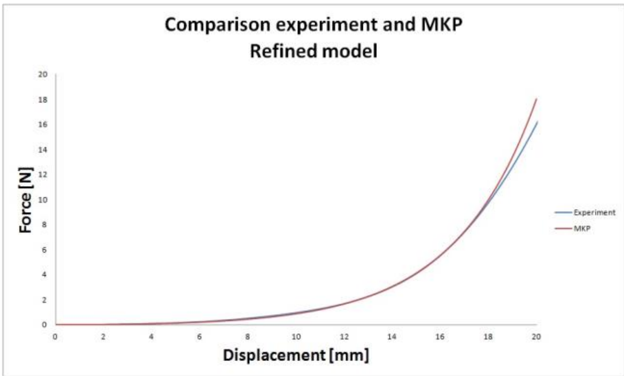

Fig. 4: Updated material data fitting

In case of initial material data fitting the error between experiment and FEM model was very significant. The value of error reached up to 60 %. Updated material constants are in Tab.2. Comparing experiment with FEM model after optimization is on the picture 4. The new value of the error is less than 15 %. This inaccuracy is supposed to be sufficient, because in real operation with silicone breast implants such large deformations are not expected.

Tab. 2: Updated [MPa]

C10	C20	C30
0.000174393	0.000467081	4.3026×10^{-7}

Comparing force displacement curve of the punch is just one part of the task in case of structural large deformation. In this part of the work the frozen deformed FE mesh was compared with data from ARAMIS system. The inspection was done in software Geomagic, Fig. 5. There is only rhomboid part of full screen where the best results are. Geometry accuracy between real model and FEM results are on the picture 6. Length differences are from 0.293 mm to -0.558 mm.

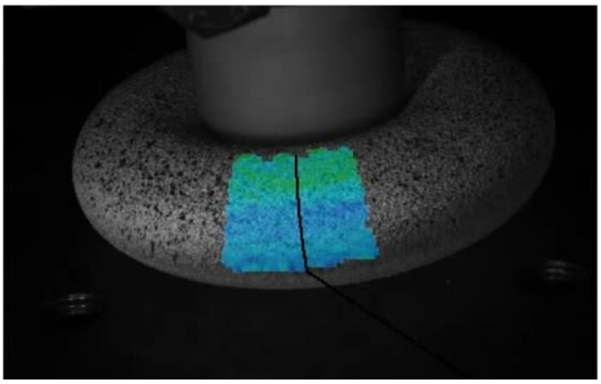

Fig. 5: Showing captures part in experiment.

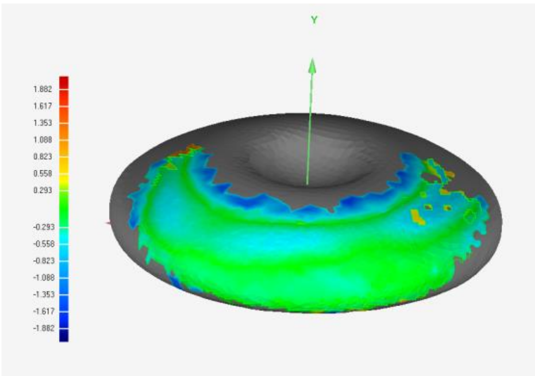

Fig. 6: Comparing geometry from experiment and FEM.

4 Conclusion

Modelling of breast augmentation after ablation due to a tumor is interesting not from the research point of view, but mainly from the social demand of the task. The essential task for this virtual surgery is the material model used for the breast implant. This contribution is focused on a punch test done on the standardized breast implant. It was shown, that punch test can be used as an experimental approach, and nevertheless the standardized material models are not very applicable for the silicon breast implant. The next goal of the work must be development of the more accurate material model, focused on a viscoelastic behavior. Found material model is in a good agreement with only a round implant. If this material model was used in a punch test of the anatomical shape implant, result was not usable. The highest simplification of the task can be seen in creating the FEM model as an one object. In reality, the silicone implant is composed from two parts. One part is a silicone cover and second part is silicone gel infill. In future work will divided breast implant into two parts and create a material model for each part separately. This approach can be supposed to be a more accurate for any type of a breast implant.

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