11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

FINITE ELEMENT MODELLING OF BIAXIAL TENSION TESTS OF SOFT TISSUES WITH CLAMPS AND HOOKS

Martin Slazansky[1], Jiri Bursa[2*] and Stanislav Polzer[3]

[1]Institute of Solid Mechanics, Mechatronics and Biomechanics, Brno University of Technology, Technicka 2896/2, 61669 Brno, Czech Republic. E-mail: slazanskym@seznam.cz
[2] ISMMB, BUT, Technicka 2, 61669 Brno, Czech Republic. E-mail: bursa@fme.vutbr.cz
[3] ISMMB, BUT, Technicka 2, 61669 Brno, Czech Republic. E-mail: polzer@seznam.cz

Key Words: *Soft Tissue, Finite Element Model, Mechanical Testing, Biaxial Test.*

Introduction: In biaxial testing of soft tissues, e.g. arterial wall, clamps or hooks are used to introduce the load to the specimen (see fig. 1) and no relevant information on advantages or drawbacks of both of them can be found in literature. Not only the way of load transmission itself but the number of loading elements, their dimensions and accuracy of their positioning may influence the experimental results substantially. Therefore a number of variants of biaxial tests have been compared using finite element (FE) simulations.

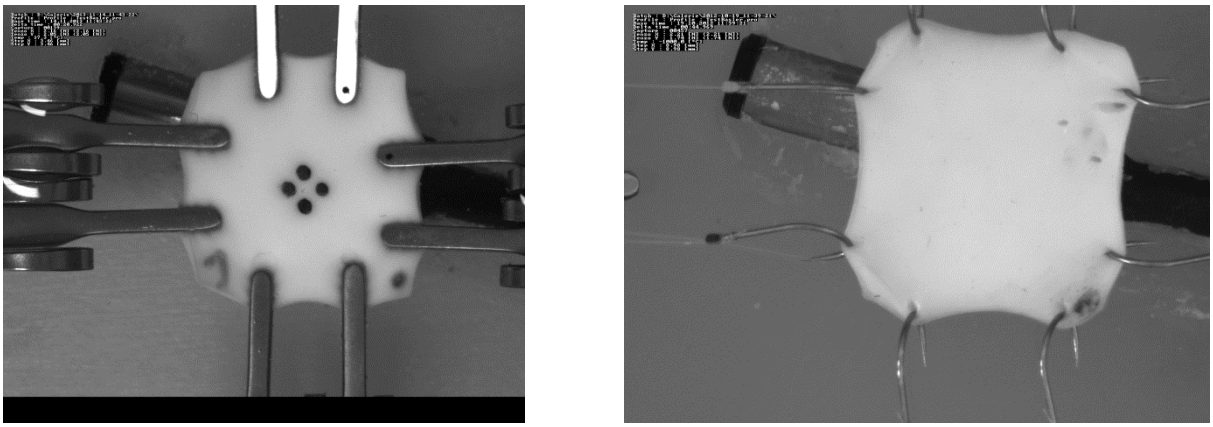

Fig. 1: Biaxial testing of soft tissues with clamps (left) and hooks (right).

Methods: FE models of a specimen of aortic tissue with dimensions of 18 x 18 x 1,8 mm were created (see fig. 2). Isotropic hyperelastic 3-parameter Yeoh material model was applied, based on stress-strain curves from different types of tests. The deformation of the specimen was induced in two different ways, either by means of clamps with different width (in the range of 1÷6 mm) or using hooks with different diameter (0,4 ÷ 1,0 mm). While for the clamps a rough contact in the length of 2 mm was prescribed and they were pushed into the specimen by prescribing displacements of 0,5 mm perpendicular to the surface of the specimen (i.e. compression by more than a half of the specimen thickness totally), the hooks were placed into prepared holes with a frictionless contact. The number of clamps/hooks was changed in the range 1÷3 per specimen edge. In addition to equibiaxial tests, proportional tests with u_x/u_y displament ratio 2 and 4 were simulated as well. In all simulations engineering

stress was calculated from the total reaction force in the clamps/hooks and specimen undeformed dimensions, while engineering strain was evaluated from displacements of four nodes located similarly to the markers in real experiments.

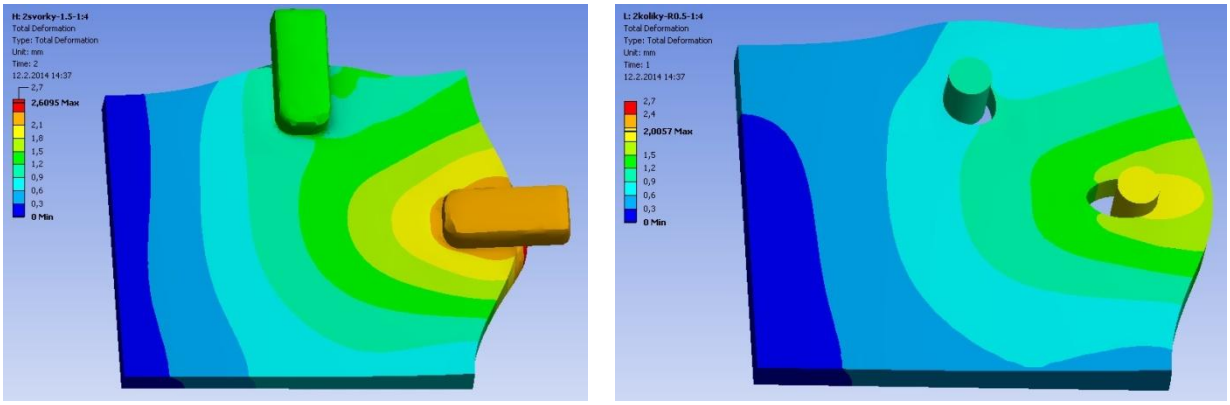

Fig. 2: Simulation of proportional (u_x/u_y = 4/1) biaxial tests with clamps (left) and hooks (right). Displacements [mm] are shown in a quarter of the specimen.

Results: The resulting stress-strain curves have been tested for correlation with the corresponding input curves of the material model. For 1 clamp (or hook) the results are not acceptable even if the clamp width is 6 mm. For 2 or 3 clamps per edge the results of FE simulations have shown a very good correlation of all the simulated tests with the input data (coefficient of determination R^2 = 0.92÷0,99); for the optimal configuration of the clamps even R^2 = 0.999 was achieved. In simulations of equibiaxial tests with hooks, the correlation was similar and slightly improving with increasing diameter of hooks. However, it became worse for simulations of proportional tests and R^2 decreased with increasing u_x/u_y ratio. Consequently we obtained R^2 = 0.84÷0,91 for all of the simulated tests with 2 or 3 hooks.

The optimal position of 2 clamps per edge was in ¼ of the edge length from the specimen corner. Simulations of inaccurate positioning of clamps (shift of ±1 mm parallel to the specimen edge) have shown that all the 160 tested combinations gave a very good correlation (R^2 > 0.83 in all and R^2 > 0.9 in 97% of cases, see fig. 3). More results of sensitivity analyses will be presented at the conference.

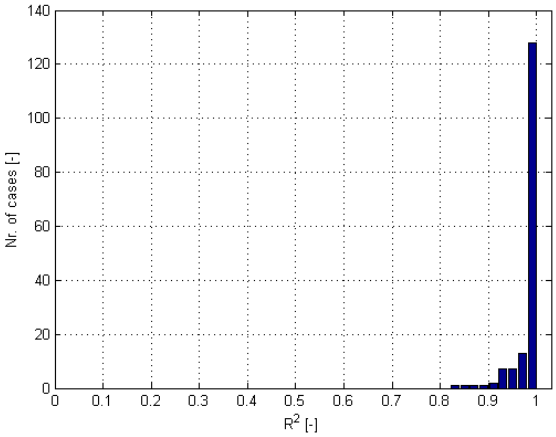

Fig. 3: Coefficients of determination for inaccurate positioning of the clamps.

Conclusion: The FE simulations have shown that clamps rather than hooks can be recommended for proportional biaxial testing while for equibiaxial testing both are comparable. When the inaccuracy of positioning of the clamps is kept in a reasonable range it does not deteriorate the accuracy of the results substantially.

Acknowledgement: This work was supported by Czech Science Foundation project number 13-16304S and by faculty project No. FSI-S-14-2344.