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Identification of Hyperelastic Parameters of Porous Polyurethane Sponges

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INTRODUCTION: Porous polyurethane sponges have recently been used as a scaffold for cartilage tissue engineering [1]. A poroviscoelastic overlay model [2] can be used to describe the constitutive behavior of this material. In this study a method to evaluate elastic material parameters of the solid phase of the scaffold is described.

METHODS: Displacement controlled compression tests were performed on a cylindrical sample of 4 mm in height and 8 mm in diameter. To eliminate friction effects, radial displacements were inhibited at the top and the bottom surface of the sample (*Fig. 1a*). The displacement was applied in five steps with a relaxation time of 15 minutes after each step (*Fig. 1b*). At the end of this relaxation phases, where an equilibrium state of the sample was assumed, images of the sample were taken and crosshead displacement as well as force response was recorded. The radial displacements at the edge of the sample were determined from the images using grey scale correlation software (VEDDAC, Chemnitzer Werkstoffmechanik GmbH).

The hyperelastic model

$$\boldsymbol{T} = 2\cdot\partial\psi/\partial\boldsymbol{C} \qquad (1)$$

establishes a relation between the 2nd PIOLA-KIRCHHOFF stress tensor $\boldsymbol{T}$ and the right CAUCHY-GREEN tensor $\boldsymbol{C}$. The polyconvex energy density function

$$\psi = (C_1/\alpha)\cdot[e^{\alpha(I - \ln III - 3)} - 1] + D_2\,(\ln III)^2 \qquad (2)$$

defined in terms of the first and third invariant of $\boldsymbol{C}$ (I and III) and containing the parameters C_1, D_2 and α characterizes the actual material behavior. A semianalytical algorithm assuming a homogeneous state of strain in a cylindrical layer in the middle of the sample was employed to obtain a first estimation for suitable material parameters.

The finite element code SPC-PM2AdNl (SFB 393, TU Chemnitz) was then utilized to identify the values of C_1 and D_2 which lead to the best possible fit of the hyperelastic model to the measured data. The parameter α was kept constant at $\alpha = -9.0$. The commercial finite element code MSC MARC with a custom made material subroutine was used to simulate the measured data with the obtained material parameters.

RESULTS: Parameter identification with a fixed $\alpha = -9.0$ led to $C_1 = 1.51\cdot10^{-2}$ and $D_2 = 4.46\cdot10^{-4}$ (equivalent to $E = 0.063MPa$ and $\nu = 0.053$ at small deformation) as best fit. In *Fig. 2* the curves computed with these parameters are shown in comparison to the measured ones.

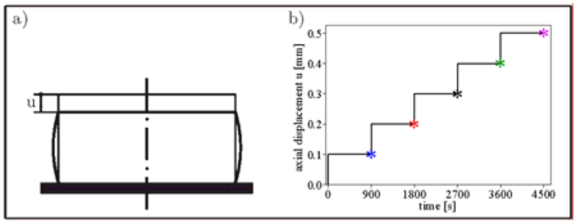

Fig. 1: a) diagram of the undeformed and the deformed state of the sample. b) applied displacement (marks points of equilibrium)*

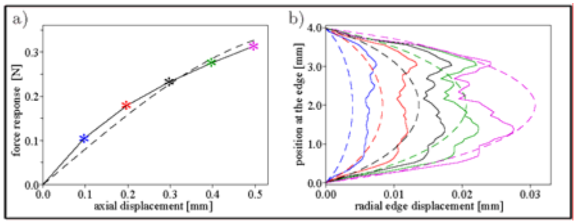

*Fig. 2: measured (solid) & computed (dashed) force-displacement-curve (a) and radial edge displacements (b) in the points of equilibrium (marked by *)*

DISCUSSION & CONCLUSIONS: The force-displacement-curve observed in the experiment could be fit quite well with the hyperelastic model. However, the less good curve fit for the radial edge displacements suggests that the model does not represent too well the porous structure of the scaffold.

REFERENCES: [1] S. Grad, L. Kupcsik, K. Gorna, et al (2003) *Biomaterials* **24**:5163-71 [2] U.-J. Görke, H. Günther, and M. A. Wimmer (2006) accepted for publication

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