Assignment 6

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Finite Element Analysis I

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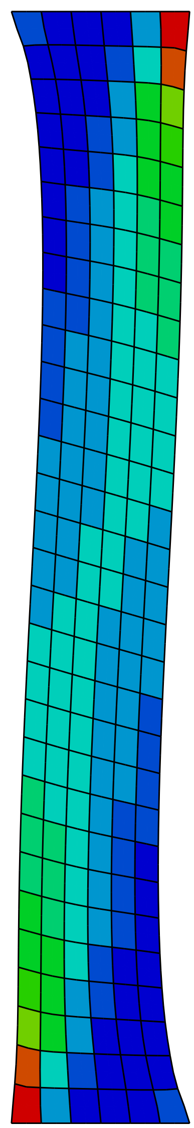

Abstract

The objective of this assignment is to determine the material parameters. The data is gathered via an anatomical sample during experimental measurements. However, the material parameters cannot be so easily determined by the experimental data. So further analysis is necessary to get a better numerical model that later can be used for further analyzing. This assignment analyzes the material from the cornea, a part of the eye. The numerical model should give a better understanding of the fibers in the cornea and how they are reacting due to exposes of stresses.

Contents

1 Introduction

In this assignment, we will create a model that should mimic a part of the cornea. The material of the model in Abaqus should have anisotropic and hyperelastic properties. A good fit for describing this behavior can be made with the Holzapfel-Gasser-Ogden function, which describes very well the strain energy potential with collagen fibers. What we are doing is gathering control data from actual experiments in the lab. Therefore a part of the cornea is exposed to force, which generates stresses on the sample of tissue. we are measuring the displacement which happens on a specific force. with that data, a model can be created in Abaqus with the Holzapfel-Gasser-Ogden function. However, the function is based on parameters which we don't know yet, but can only guess.

$$W = C_{10}(\bar{I}_1 - 3) + \frac{1}{D}\Big(\frac{J^2 - 1}{2} - \ln J\Big) + \frac{k_1}{2k_2}\sum_{\alpha=1}^{N}(\exp[k_2 < E_\alpha >^2] - 1) \tag{1}$$

$$E_\alpha = \kappa(I_3 - 3) + (1 - 3\kappa)(I_{4(\alpha)}) \tag{2}$$

W = strain energy per unit of reference volume
C_{10}, D, k_1, k_1, k = are temperature-dependent material parameters
N = is the number of families of fibers ($N \leqslant 3$)
$\bar{I}_1$ = is the first invariant of $\bar{C}$ [1]
J = is the elastic volume ratio
$I_{4(\alpha)}$ = are pseudo-invariants of $\bar{C}$

Giving this information from the Abaqus documentation [1] and knowing that is a good fit for the modeling of collagen fibers, a sample can now be created. In Figure 1 in (b) we

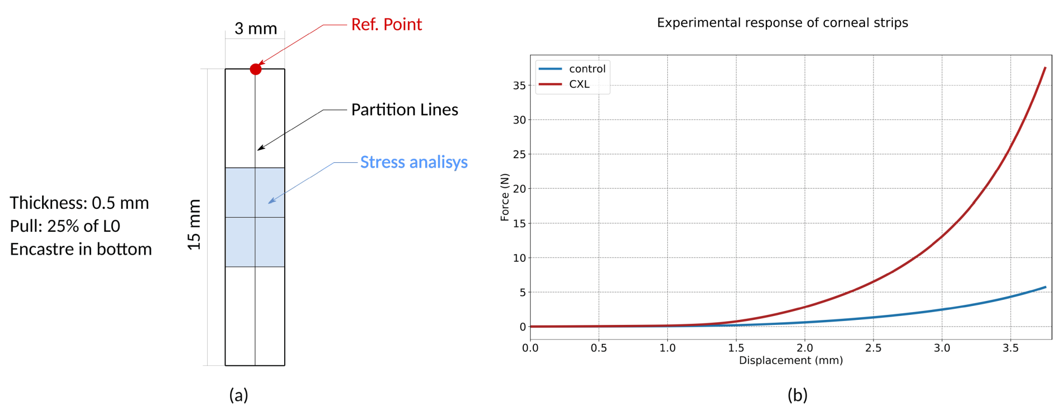

Figure 1: Shema of the sample in abaqus (a) and result of the experiment (b)

have two curves. One (control) shows the results form the experiment of a healthy person and the Other (clx) shows the result from a sample after chemical cross-linking (clx). The chemical cross-linking process should simulate the cornea of an elderly person. So with that data, we can model either a cornea of a healthy or an elderly person.

2 Methods

2.1 Sample and experimental data

We created a model in Abaqus based on the requirements of the assignment as can be seen in Figure 1 in (a). We don't know the parameters of the sample jet. so we are estimating it and try if our sample is running. Therefore we used these parameters C10 = 5.5e-2, D = 1e-2, k1 = 65, k2 = 85, k = 0.2. Also, we rotate the sample as we want the force to be evenly distributed between the collagen strains. These strains are modeled within the formula. With the change of orientation in the 30° direction the force are even on the strains. Here with these parameters and the rotation, the even distribution is good across the sample.

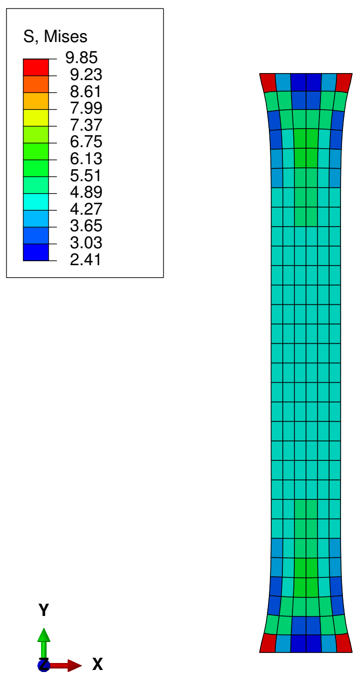

Figure 2: Shema of the sample in abaqus (a) and result of the experiment (b)

Later we will see the sample again with optimized parameters and what impact it has on the stresses of the model.

2.2 Optimization of the formula with C_{10}

3 Results and Discussion

The analytical and the experimental results are similar. Logically the experiment with introduced friction (friciton coefficien 0.2) results in a higher stress/strain ration, as energy of the compression gets lost in friction. during modelling, we ran into troubles with the simulation due to the sharp corner of the press. Thus we introduced a small 1mm fillet to smoothen the process. This worked out fine and the results got better and were calculated more quickly.

The stress/strain ratio calculations which allowed for small sliding show a higher stress per strain ratio.

References

[1] https://www.sharcnet.ca/Software/Abaqus610/Documentation/docs/v6.10/books/stm/default.htm?st
mat-anisohyperelastic-holzapfel