SHEAR IN PLANAR BIAXIAL TESTS USING RAKES: NON-INTUITIVE RESULTS

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Introduction
A planar biaxial tensile test is frequently used for material characterization and constitutive modelling of soft biological tissues. Different gripping mechanisms, such as clamps, rakes and sutures are available, each resulting in different boundary conditions and different stress states. Clamps on one hand do not allow contralateral movement, introducing a large amount of shear stresses. Sutures on the other hand allow contralateral movement and sample rotation, using a pulley system which assures zero shear stresses. Finally, rakes allow limited contralateral movement introducing small shear forces. Nonetheless, shear deformations and forces in rake-based planar biaxial testing are often neglected in subsequent analysis (e.g. [1]). While it was recently shown that neglecting shear in a rake-based set-up does not influence the parameter fitting when the sample material is mounted symmetrically w.r.t. the test axes [2], the effect of neglecting shear in the case of an asymmetric mounting is less clear. This abstract investigates the effect of including and neglecting shear on the parameter fitting of a rake-based planar biaxial test when a sample is mounted asymmetrically by means of finite element (FE) simulations.

Methods
A FE model is created in Abaqus/Standard 6.12-2 of a planar biaxial test using rakes as described in [2]. The GOH-model [3] is used to define the sample material with only 1 fiber family to obtain a sample material that is asymmetric w.r.t. the test axes. In an actual planar biaxial experiment markers’ displacements are tracked optically and normal forces are measured. Shear forces can typically not be measured; however the shear displacement of the rakes can be tracked optically as well. Therefore, the following data is exported from the simulation: marker displacements, normal forces at the rakes’ outer end and rakes’ displacements at the rakes’ inner end. Three cases are considered in the data analysis. In I shear is neglected; in II shear is taken into account in the deformation gradient (calculated based on the markers’ displacements), but external shear forces are assumed to be zero; in III external shear forces are calculated from the rakes’ displacements and shear is also taken into account in the deformation gradient. Based on the exported data, experimental and model stresses are calculated and a classical parameter fitting is performed on the GOH-model for each of the cases using the methodology described in [2]. This simulation and analysis is repeated for different parameter sets.

Results
GOH-parameters were obtained with high goodness of fit values (results not shown). However, depending on the ground truth parameters inserted in the FE simulation, a different case resulted in approximating the ground truth parameters the best. This is reflected in Figure 1 in which the experimental and the ground truth model stress curves of the three cases are shown for one specific simulation. It can be noticed that for this simulation the model stress of I lies the closest to the experimental stresses.

Discussion
Intuitively it is to be expected that when shear is not neglected, this would result in improved parameter fitting. However, from our results it is clear that this is not always true. The cause is twofold. On one hand, the experimental stress in a planar biaxial test slightly over- or underestimates the ground truth model stress due to inhomogeneities in the stress-strain field. These inhomogeneities are a.o. dependent on the material that is been tested [2]. On the other hand, taking shear into account results in an increased model stress, while the experimental stress remains approximately the same. Hence, when the experimental stress underestimates the model stress, including shear will result in a model stress curve further from the experimental stress curve and consequently in an impaired parameter fitting. Preliminary results show that the IEC-method [2] can overcome this problem.

References

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