Finite Element-Based Characterization of Viscoelastic Materials

X. Song[1], S. Dircks[1], D. Mirosnikov[1], B. Lassen[2]

[1]Mads Clausen Institute, SDU, Sønderborg, Denmark
[2]DONG Energy, Fredericia, Denmark

Abstract

The objective of this study is to acquire a full characterization of a hyper-elastic material. The process is realized by performing a Dynamic Mechanical Analysis (DMA) with a viscoelastic material (illustrated in Figure 1), which is extended by image processing algorithms in order to measure the changing distance of two dots in the direction of contraction (it can be seen in Figure 2). Due to the non-linear behavior of the material, the model cannot be expressed by Neo-Hookean model precisely, so in order to overcome this problem, hyper-elastic material models are introduced. Hyper-elasticity provides a means of modelling the stress- strain behavior of such materials [1]. Using the Weak Form PDE interface of COMSOL Multiphysics® software, three mathematical models are developed, where the strain- energy density function depends on different hyper-elastic constitutive equations, including the painted dots which are placed by using domain point probes (which can refer Figure 3). The chosen constitutive equations are Mooney-Rivlin [2], Yeoh [3] and Arruda-Boyce [4]. The results of DMA portrait the non-linear behavior of the material, while the results of the numerical study demonstrate that the all three models exhibit the correct trend of the non-linear behavior of the material, further the Arruda-Boyce model shows the best fitting performance (demonstrated in Figure 4).

Reference

[1] A. H. Muhr, Modeling the Stress-Strain Behavior of Rubber, Rubber Chemistry and Technology, Vol. 78, pp. 391-425 (2005)
[2] M. Mooney, A Theory of Large Elastic Deformation, Journal of Applied Physics, Vol. 11, pp. 582-592 (1940)
[3] O. H. Yeoh, Some Forms of the Strain Energy Function for Rubber, Rubber Chemistry and Technology, Vol. 66, pp. 754-771 (1993)
[4] E. M. Arruda and M. C. Boyce, A Three-Dimensional Model for the Large Stretch Behavior of Rubber Elastic Materials, J. Mech. Phys. Solids, Vol. 41, pp. 389-412 (1993)

Figures used in the abstract

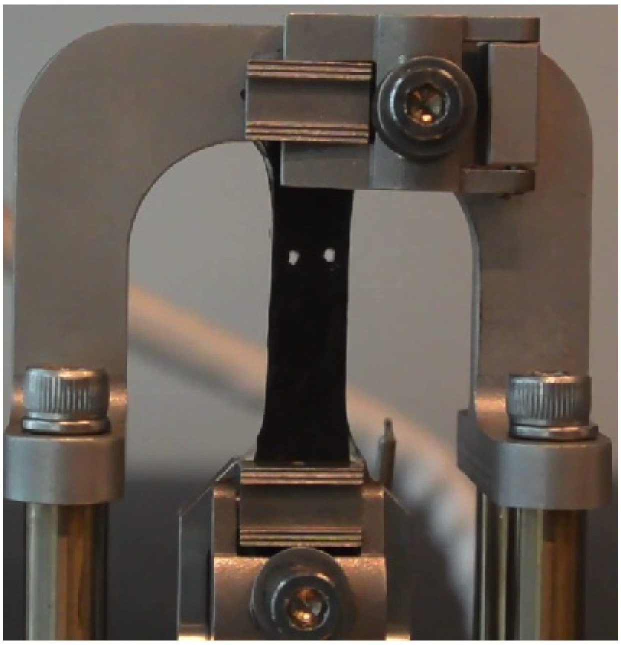

Figure 1: The stretched material sample.

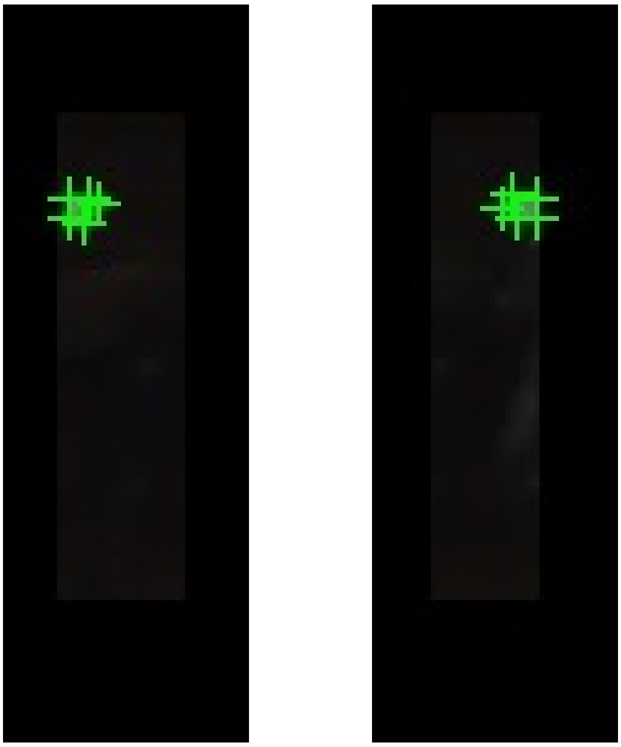

Figure 2: On this figure the detection aims the left and the right dot, respectively.

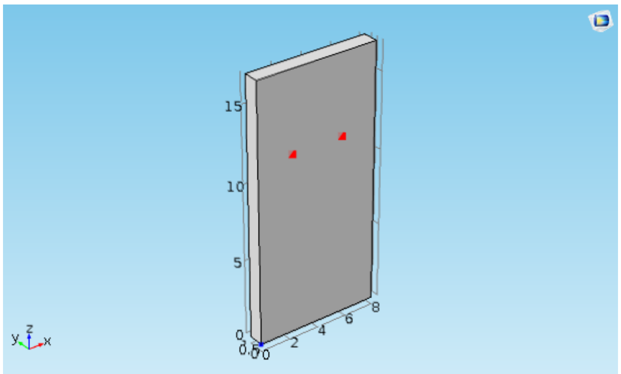

Figure 3: Geometry model including two probes. The probes placements corresponds to the position of the painted dots of the real sample.

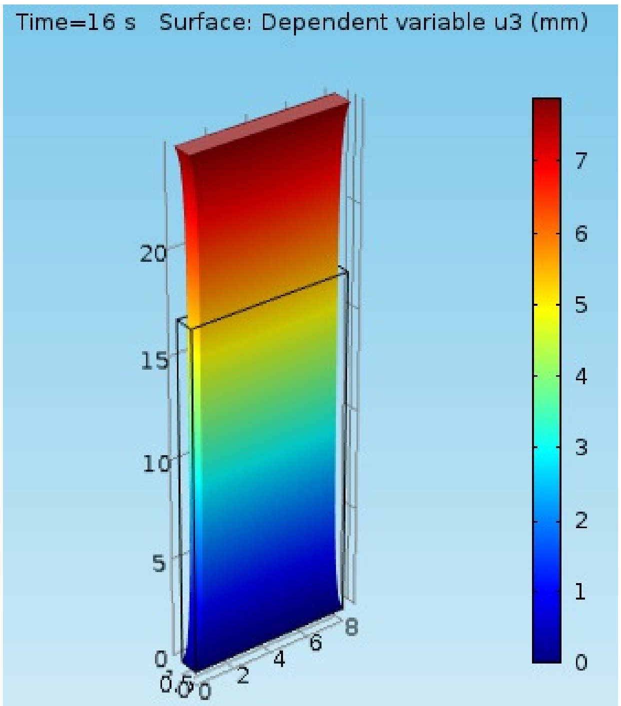

Figure 4: The resultant deformation shown in COMSOL.