Simulation Of Thermomechanical Couplings Of Viscoelastic Materials

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Introduction: Elastomers are used for several technical applications, e.g. for bearings. Large dynamic loads cause finite strains and self-heating of the elastomer. As material properties change with the temperature, modelling an application isothermal is not sufficient. Therefore, a thermomechanical coupled model is suggested.

Computational Methods: The model for viscoelastic material behaviour is built by the 2nd Piola-Kirchhoff (1) tensor and N evolution equations (2).

$$\bar{\mathbf{T}} = -pJ\mathbf{C}^{-1} + 2J^{-\frac{2}{3}}c_{10}\left(\mathbf{I} - \frac{1}{3}\mathrm{tr}(\hat{\mathbf{C}})\hat{\mathbf{C}}^{-1}\right) + 2J^{-\frac{2}{3}}\sum_{n=1}^{N} c^{e}_{10;n}\left(\hat{\mathbf{C}}^{-1}_{i;n} - \frac{1}{3}\mathrm{tr}\left(\hat{\mathbf{C}}^{-1}_{i;n}\cdot\hat{\mathbf{C}}\right)\mathbf{I}\right) \quad (1)$$

$$\dot{\hat{\mathbf{C}}}_{i;n} = \frac{4}{r(\theta)}\left(\hat{\mathbf{C}} - \frac{1}{3}\mathrm{tr}\left(\hat{\mathbf{C}}\cdot\hat{\mathbf{C}}^{-1}_{i;n}\right)\mathbf{I}\right) \quad (2)$$

The temperature development is modeled by the energy-balance (3).

$$0 = \rho_0(A + B\theta)\dot{\theta} + K\alpha\theta\dot{J} - \lambda_\theta Div\left(Grad(\theta)\right) - \sum_{n=1}^{N} c^{e}_{10;n}\,\hat{\mathbf{C}}^{-1}_{i;n}\cdot\hat{\mathbf{C}}\cdot\hat{\mathbf{C}}^{-1}_{i;n} : \dot{\hat{\mathbf{C}}}_{i;n} \quad (3)$$

Due to the temperature dependent material parameters in (1) and (2) the model is fully thermo-viscoelastic coupled.

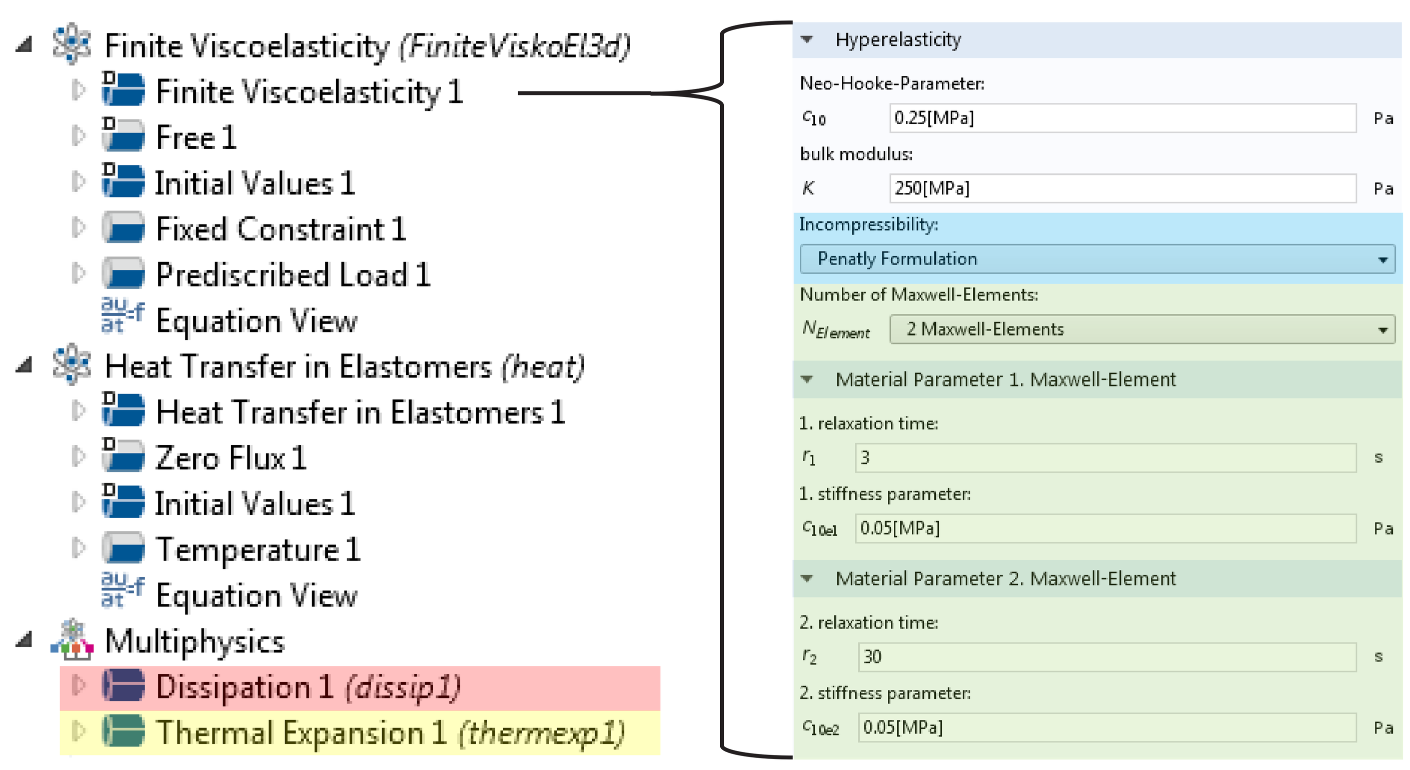

Figure 1. Model-Tree and viscoelastic domain feature

Results: Under dynamic displacements and fixed temperature boundary conditions, the temperature of inner points increases due to dissipation. Increasing temperature reduces the relaxation time with respect to the WLF-equation.

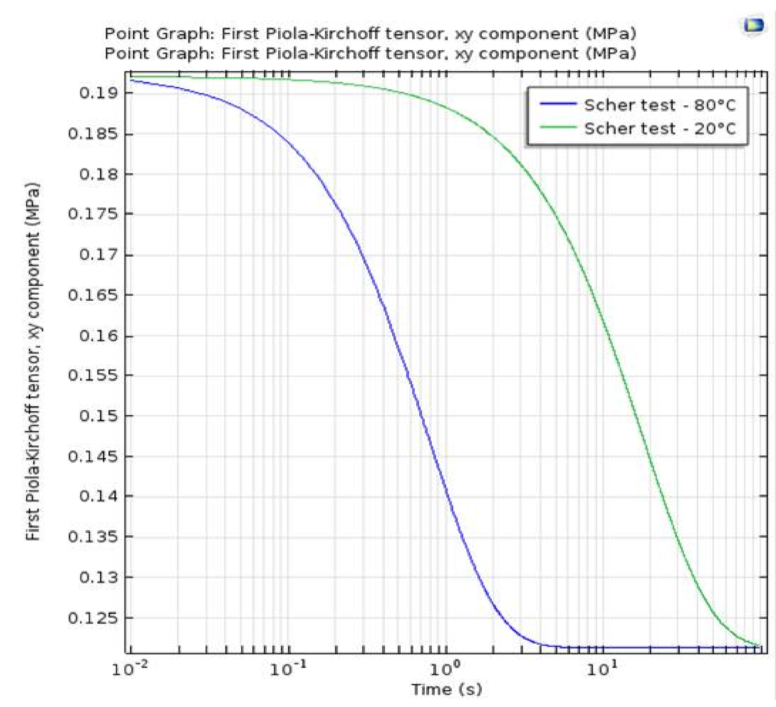

Figure 2. Relaxation

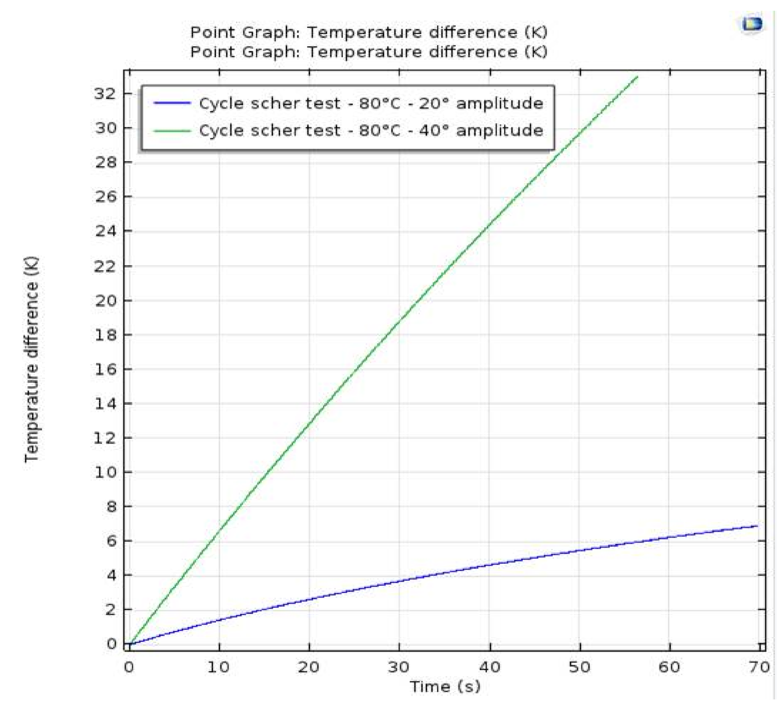

Figure 3. Self-heating

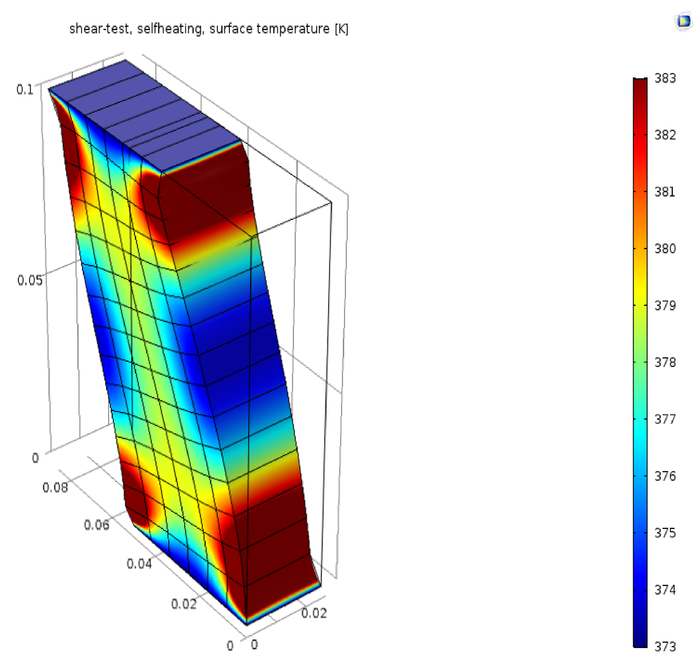

Figure 4. 3d shear sample

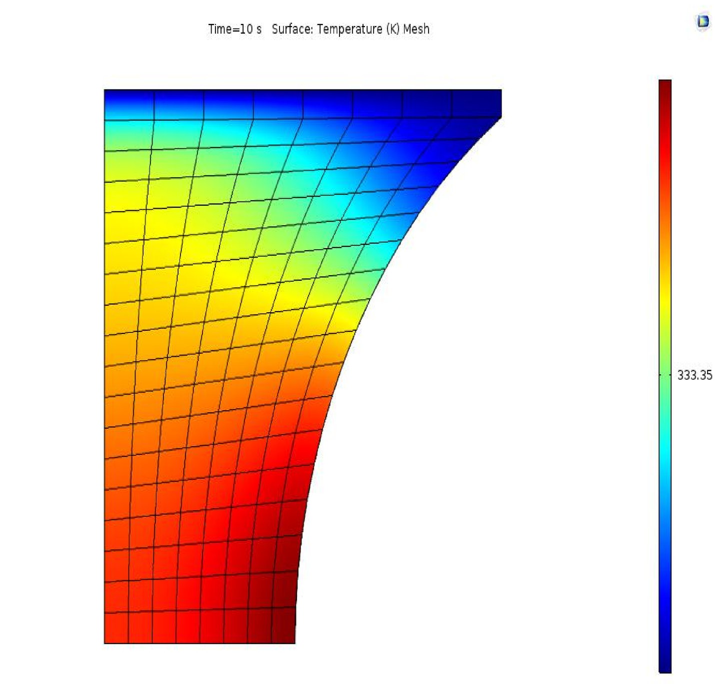

Figure 5. Hourglas sample

Conclusion: The modular setup provides flexibility for executing a simulation. On the one hand, it is possible to add couplings with respect to an increase of computational time. On the other hand, couplings could be neglected if the necessity to simulate a phenomenon is absent.

References:

1. B. Dippel et al., Thermo-mechanical couplings in elastomers – experiments and modelling, ZAMM, Vol. 95, pp. 1117-1128 (2015)
2. M. Johlitz, Zum Alterungsverhalten von Polymeren: Experimentell gestützte, thermo-chemische Modellbildung und numerische Simulation, habilitation thesis, Universität der Bundeswehr München (2015)
3. E.H. Lee, Elastic-plastic deformation at finite strain, J. Appl. Mech., Vol. 36, pp. 1-6 (1969)