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Introduction

For the past years a constitutive model to describe glassy polymer deformation has been developed [1,2]. In this model the viscosity approach is thermorheologically simple, unfortunately few polymers show this type of deformation. The approach presented here extends the model to be used for thermorheologically complex deformation. For thermorheological simple deformation , like Polycarbonate (PC), the rate dependence of the yield drop remains constant, however for thermorheological complex materials, such as polymethylmethacrylate (PMMA), there is a pronounced difference in yield drop depending on strain rate [3]. An extensive validation of this new approach can be found in [4].

Model

The model is employed as two parallel parts, i.e. the part describing the yield and strain softening σ_s and the other describing the strain hardening σ_r.

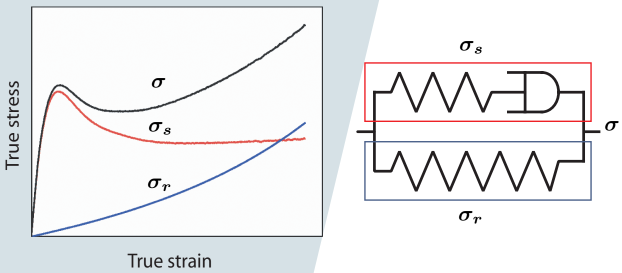

Figure 1 ***Left***: *True stress-strain curve* ***Right***: *Mechanical analog.*

$$\boldsymbol{\sigma} = \kappa(J-1)\boldsymbol{I} + G\tilde{\boldsymbol{B}}_e^d + G_r\tilde{\boldsymbol{B}}^d$$

The plastic deformation rate tensor $\boldsymbol{D}_p$ is related to the effective deviatoric stress tensor $\boldsymbol{\sigma}_s^d$ by a non-Newtonian flow rule with an Eyring viscosity η:

$$\boldsymbol{D}_p = \frac{\boldsymbol{\sigma}_s^d}{2\eta(\overline{\boldsymbol{\sigma}}, p, T, S)} = \frac{G}{2\eta}\tilde{\boldsymbol{B}}_e^d.$$

Rheological complex viscosity

Where the old approach incorporates only the α process this approach uses both the α and β processes, see left hand side of figure 2.

$$\eta = \eta_{0_\alpha}\left[a_{\sigma_\alpha} + \frac{\eta_{0_{\alpha+\beta}}(S_a)}{\eta_{0_\alpha}\exp[S_a]}a_{\sigma_{\alpha+\beta}}\right]\exp\left[\frac{\mu p}{\tau_{0_\alpha}}\right]\exp\left[S_a R(\overline{\gamma}_p)\right]$$

where

$$a_{\sigma_\alpha} = \frac{\frac{\overline{\tau}}{\tau_{0_\alpha}}}{\sinh\left[\frac{\overline{\tau}}{\tau_{0_\alpha}}\right]} \quad \text{and} \quad a_{\sigma_{\alpha+\beta}} = \frac{\frac{\overline{\tau}}{\tau_{0_{\alpha+\beta}}}}{\sinh\left[\frac{\overline{\tau}}{\tau_{0_{\alpha+\beta}}}\right]}.$$

The summation of the two viscosity functions, as shown here, is only allowed if the zero-viscosity η_{0_α} of the α process is much larger then the zero-viscosity $\eta_{0_{\alpha+\beta}}$ of the $\alpha+\beta$. This summation of the two viscosity functions for PMMA is shown in the right hand side of figure 2.

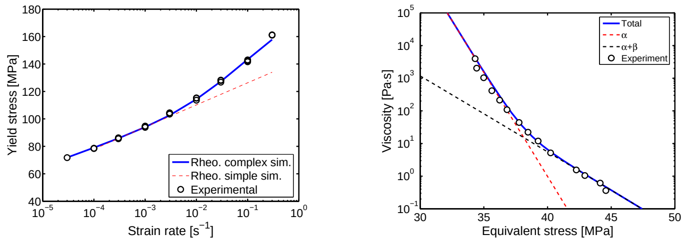

Figure 2 ***Left***: *Yield stress versus strain rate* ***Right***: *Viscosity versus equivalent yield stress.*

Characterization

The input parameters for the model are derived from uniaxial compression tests. However for uniaxial compression simulations with different pressure dependence parameter (μ) values, identical simulation results will be obtained. To determine the pressure dependence parameter (μ) micro indentation experiments were performed. A best fit is obtained for 0.13. The current thermal state (S_a) is obtained by fitting the true yield stress of the simulation to the experiment.

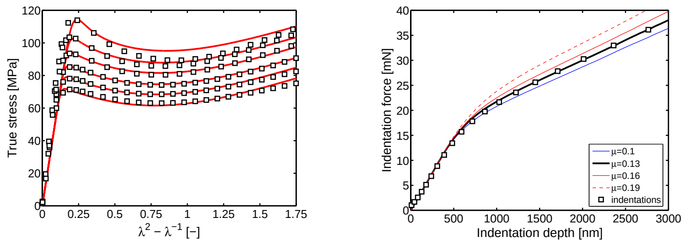

Figure 3 ***Left***: *Uniaxial compression simulations show identical results for different μ values* ***Right***: *Pressure dependence parameter μ determined via micro indentation.*

Conclusions

- With this new approach yield stresses for all strain rates can be predicted.
- The pressure dependence can be determined using micro indentation.

Future work

- Extend the model for friction and wear simulations.

References:

[1] Klompen, E.T.J., Engels, T.A.P., Govaert, L.E. and Meijer, H.E.H.: *Elastoviscoplastic modeling of the large strain deformation of glassy polymers: influence of thermo-mechanical history.* (Macromolecules.)

[2] Klompen, E.T.J., Engels, T.A.P., van Breemen, L.C.A., Schreurs, P.J.G., Govaert, L.E. and Meijer, H.E.H.: *A 3-D plasticity approach to time-dependent failure of polycarbonate.* (Macromolecules.)

[3] Klompen, E.T.J.: *Mechanical properties of solid polymers.* (PhD Thesis.)

[4] Janssen, R.P.M. et al. : *Mate poster contest 2005*

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