Predicting deformation and failure of plastics

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Predicting Deformation and Failure of Plastics

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Introduction

Constitutive modeling can be used to design plastic products without the need of costly experiments. An in-house developed model [1] is recently modified to describe thermo-rheological complex behavior [2]. This study explores its performance using amorphous polystyrene (PS) and polymethylmethacrylate (PMMA) and semi-crystalline polypropylene (PP).

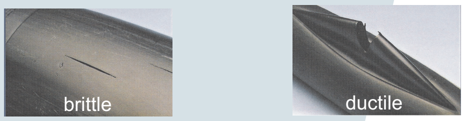

Figure 1 *An example: numerical life-time predictions can reduce costs in the design of plastic gaspipes.*

Theoretical Background

In thermo-rheological simple materials (PC above roomtemperature) only the primary glass-transition (α) is present, whereas for thermo-rheological complex materials (PMMA) also a secondary glass-transition (β) is present, see figure 2a. The β-process typically causes strain rate dependent yield stress and yield drop behavior as displayed in figure 2b. Therefore, the model is modified in a way described elsewhere [2].

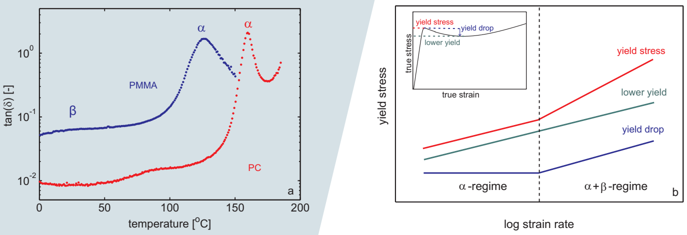

Figure 2 a) *Glass-transitions in PC and PMMA.*
b) *Strain rate dependence of yield behavior.*

Materials and Methods

Figure 3 shows how the parameter set is obtained. First compression tests on PMMA, PS and PP are performed at various strain rates. For validation, tensile and creep tests are performed on tensile bars of two grades of PMMA with a different thermal history. However, only one parameter S_a is changed and is determined by a tensile test, see reference point in figure 4a.

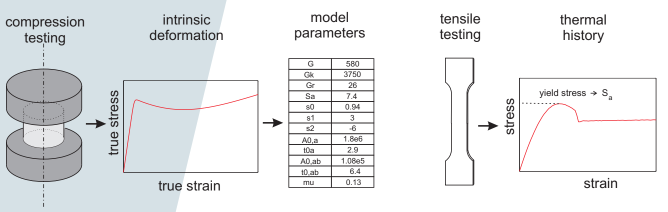

Figure 3 *Characterization of intrinsic deformation behavior.*

Characterization of Intrinsic Deformation

Figure 4a shows the experimental intrinsic deformation (symbols) and its numerical description (lines). The blue curves exhibit α-behavior, but also the β-process is captured, as the black curves show. Moreover, figure 4b shows that the yield stress is described in both regions. The modified model als captures the intrinsic deformation of PS and PP, see figures 4c and 4d.

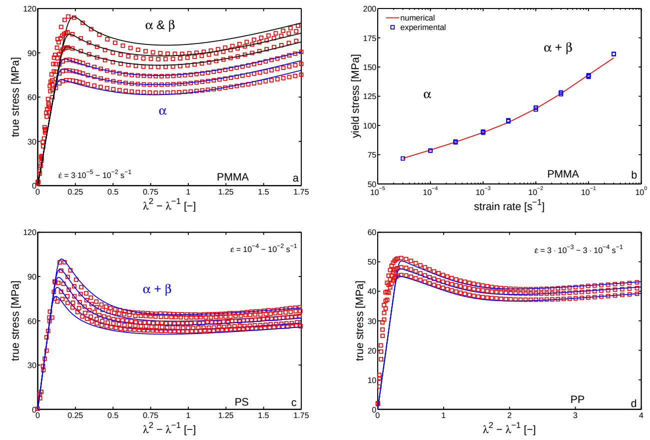

Figure 4 *The model captures* a) *PMMA, α and β,* b) *PMMA, yield stress,* c) *PS, α and β-region,* d) *semi-crystalline PP.*

Validation: Predictions for PMMA

Figure 5 shows that the model predicts (lines) accurate the tensile yield stress and creep life-time (symbols) of two PMMA-grades based on the S_a determined at the reference point using the same parameter set.

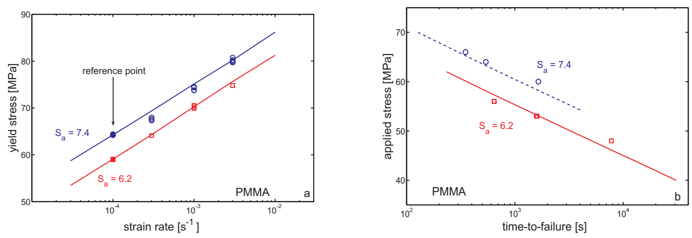

Figure 5 *Predictions for PMMA of* a) *the tensile yield stress,* b) *the creep life-time.*

Conclusions

- ☐ The modified model successfully describes thermo-rheological complex deformation behavior.
- ☐ The model predicts yield and failure behavior of multiple PMMA-grades using the same parameter set.

References:

[1] E.T.J. Klompen, PhD-thesis, 2005

[2] L.C.A. van Breemen et al., Mate Poster Contest 2005

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