

How strong is your product?

Citation for published version (APA):

Engels, T. Á. P., Govaert, L. E., Peters, G. W. M., & Meijer, H. E. H. (2004). How strong is your product?. Poster session presented at Mate Poster Award 2004 : 9th Annual Poster Contest.

Document status and date: Published: 01/01/2004

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.

• The final author version and the galley proof are versions of the publication after peer review.

 The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- · Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
 You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

How strong is your product?

T.A.P.Engels, L.E.Govaert, G.W.M.Peters and H.E.H.Meijer

Introduction

An attempt has been made to predict the development of mechanical properties during processing. As a starting point the temperature dependence of the evolution of the yield stress during annealing treatments on polycarbonate below T_g , as derived by Klompen et al. [1], is used. In combination with the process-related thermal history, which can be derived from numerical simulations of the injection molding process, an estimate of the yield strength distribution throughout the product can be obtained.

Model

From yield data obtained by annealing at different temperatures a master curve can be constructed using (annealing) time-temperature superposition, see figure 1.

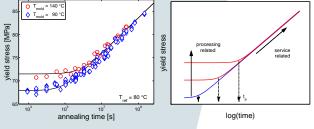


Figure 1 Annealing kinetics

The kinetics of the yield stress are captured by the following set of equations:

$$a_T(T) = exp\left(\frac{\Delta U_a}{R} \cdot \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right) \tag{1}$$

$$\sigma_y(t) = c_0 + c_1 \cdot \log(t_{eff} + t_a) \tag{2}$$

$$t_{eff} = \int_0^t a_T^{-1}(T(\xi)) d\xi$$
 (3)

The evolution of the yield stress is assumed to begin when the glass transition temperature, T_g , is passed.

Experimental

From a commercial grade of polycarbonate, Lexan 141R, injection molded samples were made. Mold temperatures were varied from 30° C to 130° C. Subsequently tensile bars were machined from the injection molded samples to determine the resulting yield stress, see figure 2 below.

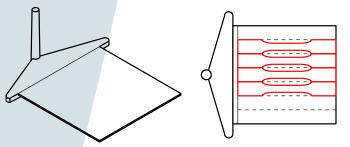


Figure 2 Injection molded part and tensile bars / department of mechanical engineering

Results

Evaluation of the thermal history of the injection molded samples as obtained by Moldflow; see figure 3 (left), leads to the predicted yield stresses as shown in figure 3 (right).

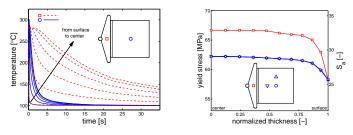


Figure 3 Temperature (left) and yield stress distributions (right)

For different mold temperatures the resulting experimental verus numerical yield stresses are presented below.

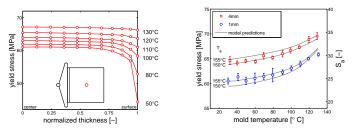


Figure 4 Numerical versus experimental results

Conclusions

A new simulation tool has been developed which enables the analysis of the development of yield stress during processing of glassy polymers. With the current state of the art in constitutive modeling, the knowledge of the yield stress distribution is sufficient to perform life-time predictions in static and dynamic loadings [2]. In combination this opens a route to true product optimization without ever performing a single mechanical test.

Future work

- □ Incorporate equilibrium kinetics; in this approach the glass transition temperature is treated as a parameter rather then a result of kinetic vitrification.
- □ Investigate the influence of pressure on the evolution kinetics.

References:

- [1] KLOMPEN, E.T.J., ENGELS, T.A.P., GOVAERT, L.E., MEIJER, H.E.H.: *Elastoviscoplastic modeling of the large strain deformation of glassy polymers: influence of thermo-mechanical history.* (J.Rheol., submitted.)
- [2] KLOMPEN, E.T.J., ENGELS, T.A.P., VAN BREEMEN, L.C.A., SCHREURS, P.J.G., GOVAERT, L.E., MEIJER, H.E.H.: A 3-D plasticity approach to time-dependent failure of polycarbonate. (J.Rheol., submitted.)
- [3] GOVAERT, L.E., ENGELS, T.A.P., KLOMPEN, E.T.J., PETERS, G.W.M., MEIJER, H.E.H.: Processing induced properties of glassy polymers: Devolopment of the yield stress in polycarbonate. (IPP, submitted.)