Quantitative fatigue life predictions of glassy polymers

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Quantitative Fatigue Life Predictions of Glassy Polymers

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Introduction

Lifetime estimation is imperative for reliable design of polymer components. Recent research shows that quantitative creep life prediction is possible, taking the thermal history into account, using an elasto-viscoplastic model [1]. Samples subjected to cyclic fatigue loading show similar failure behavior. Therefore in this study we

- ☐ follow the same modeling approach to predict the cyclic fatigue life of PC under isothermal conditions.
- ☐ investigate its applicability for non-isothermal conditions.

Materials and Methods

Two PC grades are injection molded into tensile bars.

	Lexan141R (3mm)		Lexan101R (1mm)	
thermal history	Q	A	Q	A
age S_a	29.5	33.8	27.3	43.6

Table 1 *Thermal history of the samples. Q:Quenched, A:Annealed.*

The applied stress signal can be seen in figure 1. To approach isothermal conditions, 1 mm thick samples are loaded in a watertank. In the non-isothermal case, samples are loaded in air and heating is measured using infrared thermography.

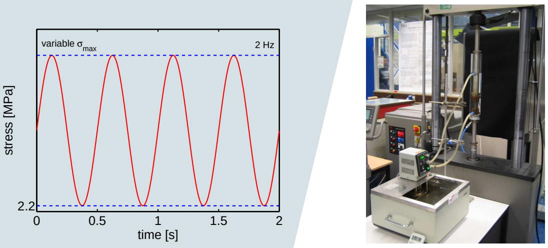

Figure 1 *a) The applied stress signal. b) The isothermal set-up.*

Isothermal Fatigue

Figure 2 shows that the model accurately predicts fatigue life of samples with different thermal histories. Also the effect of physical aging is accounted for, which can be observed from the increase in yield stress. Similar results are obtained for fatigue loading in compression.

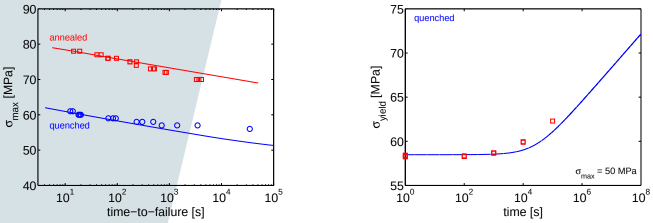

Figure 2 *a) Fatigue life predictions (lines) compare well to experiments (symbols). b) The model includes the effect of physical aging.*

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Non-Isothermal Fatigue

Figure 3 shows the fatigue life and heating in the sample under non-isothermal conditions. At high stress failure is thermally dominated, caused by the high internal damping of the polymer. This can be recognized in hysteresis loops.

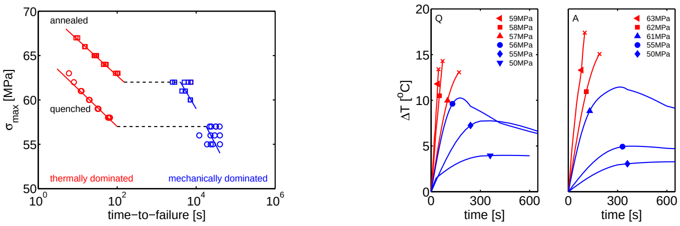

Figure 3 *a) Time-to-failure vs. stress of Lexan141R. b) Heating of Lexan141R during fatigue loading.*

Figure 4 shows that the hysteresis for the current single-mode model is nihil, whereas a visco-elastic multi-mode model [2] predicts large energy dissipation. These loops are used to determine the dissipated energy and heating rate.

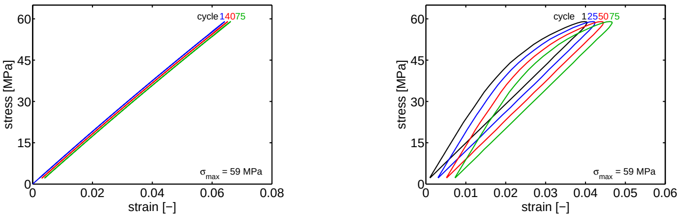

Figure 4 *a) Small hysteresis loops predicted by the current single-mode model. b) Hysteresis described by a multi-mode model [2].*

Comparing the results to experimental values, see figure 5, shows that the multi-mode description adequately describes hysteretic heating during cyclic loading for two PC grades.

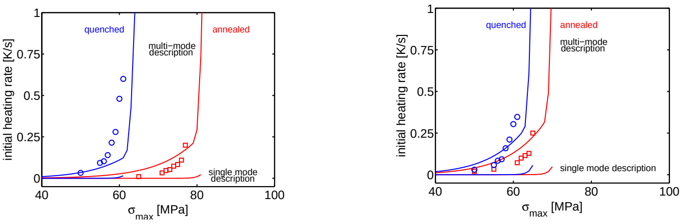

Figure 5 *The multi-mode approach gives a good estimation of the heating rate in a) Lexan101R and b) Lexan141R.*

Conclusions

- ☐ Provided isothermal conditions, the model yields quantitative accurate fatigue life predictions.
- ☐ In the non-isothermal case, a multi-mode approach is required to account for hysteretic heating.

References:

[1] KLOMPEN, E.T.J., ENGELS, T.A.P., GOVAERT, L.E., MEIJER, H.E.H., *Macromolecules*, 2005, *38*,

[2] TERVOORT, T.A., KLOMPEN, E.T.J., GOVAERT, L.E., *J. Rheol.*, 1996, *40*

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