EINDHOVEN UNIVERSITY OF TECHNOLOGY

Deformation and failure behaviour of semi-crystalline polymers : role of crystallinity and strain hardening

Citation for published version (APA):
Schrauwen, B. A. G., Janssen, R. P. M., Govaert, L. E., & Meijer, H. E. H. (2002). *Deformation and failure behaviour of semi-crystalline polymers : role of crystallinity and strain hardening*. Poster session presented at Mate Poster Award 2002 : 7th Annual Poster Contest.

Document status and date:
Published: 01/01/2002

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.

Download date: 25. Apr. 2025

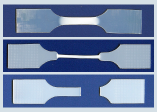
technische universiteit eindhoven

Deformation & failure behaviour of semi-crystalline polymers: role of crystallinity and strain hardening

B.A.G. Schrauwen, R.P.M. Janssen, L.E. Govaert and H.E.H. Meijer
Eindhoven University of Technology, Department of Mechanical Engineering

Introduction

Deformation and failure behaviour of polymers is important for engineering applications. For semi-crystalline polymers, temperature and flow history of processing can influence the type of deformation/failure behaviour. A qualitative distinction in deformation types:



→ I Homogeneous deformation
→ II Stable neck drawing
→ III Brittle failure

Figure 1: *3 types of deformation/failure of polyethylene.*

Objective: Rationalize the observed influence of processing conditions on the deformation/failure behaviour.

Analytical approach

Simple neo-Hookean approach for true stress [1]:

$$\sigma_t = \sigma_y + G_R\left(\lambda^2 - \frac{1}{\lambda}\right)$$

gives an engineering stress:

$$\sigma_{eng} = \frac{\sigma_y}{\lambda} + G_R\left(\lambda^2 - \frac{1}{\lambda}\right)$$

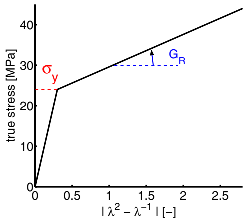


Figure 2: *True stress.*

Considere's analysis

Considere's condition for necking is met when at yield $\frac{d\sigma_{eng}}{d\lambda} < 0$. Figure 3 visualizes a transition from homogeneous deformation to necking for $\sigma_y/G_R > 3$.

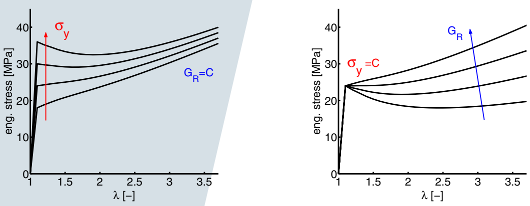


Figure 3: *Engineering stress: necking is induced by an increase in σ_y (left) or a decrease in G_R (right).*

Neck stability

Minimum value of λ_n in the neck to meet 2^{nd} considere's condition for stable necking [2]:

$$\frac{\sigma_y}{G_R} = {\lambda_n}^2 + \frac{2}{\lambda_n}$$

Stress equilibrium (defining: $\sigma_{break} = \kappa_t \sigma_y$) gives a draw ratio at break, λ_b:

$$\frac{\sigma_y}{G_R} = \frac{{\lambda_b}^2 - \frac{1}{\lambda_b}}{\kappa_t - 1}$$

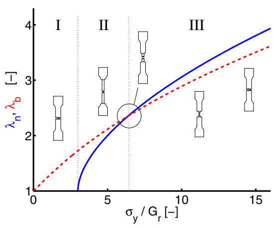


Figure 4: *3 regions of deformation/failure:*
I: Homogeneous
II: $\lambda_n < \lambda_b$, Stable necking
III: $\lambda_n > \lambda_b$, Necking rupture or brittle failure

Experimental results

Influence of thermal history

Thermal history:

- Quenched (Q)
- Slowly cooled (SC)
- Annealing of quenched samples (A)

Materials & crystallinity

	M_w	Q	A	SC
PET	76.000	0%	30%	43%
PE1	70.000	68%	77%	77%
PE2	210.000	68%	73%	74%

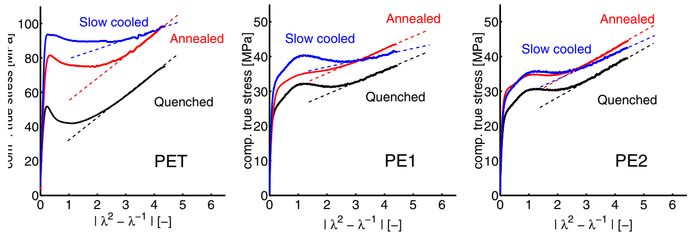


Figure 5: *Compressive true stress-strain behaviour.*

Influence on intrinsic behaviour:

- Annealing: crystallinity & lamellae thickness ↑ = yield stress ↑
- Cooling rate ↓ = disentanglement of (short) chains upon crystallization = strain hardening ↓

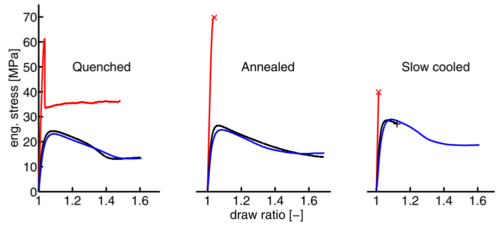


Figure 6: *Macroscopic tensile behaviour (PET, PE1, PE2)*

Influence on macroscopic deformation/failure:
Transition region II → III:

- PET: due to increase in yield stress
- PE1: due to decrease in strain hardening
- PE2: no transition due to less disentanglement and higher strenght of molecular weight

Influence of orientation

Transition region II → I

- Extrusion → low orientation → homogeneous (region I)
- Injection → high orientation → low λ at break in region I

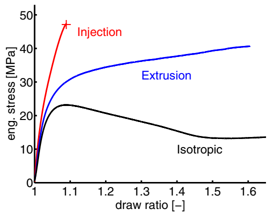


Figure 7: *Deformation PE2.*

Conclusions

- Strain hardening depends on chain entanglement density and orientation
- Yield stress depends on crystallinity/lamellae thickness
- Both can influence the deformation/failure behaviour

References:

[1] HAWARD, R.N., Polymer, *28*, 1485 (1987)

[2] VINCENT, P.I., Polymer, *1*, 7 (1960)

PO Box 513, 5600 MB Eindhoven, the Netherlands