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Polymer Technology

Influence of processing conditions on mechanical properties of polymers
T.B. van Erp, L.E. Govaert, G.W.M. Peters, H.E.H. Meijer

Introduction

Studies in injection moulded samples of semi-crystalline polymers show a clear multi-phase structure, i.e., the skin-core morphology depicted in Figure 1. It is known that the inhomogeneity of such samples affects both physical as mechanical properties. In this study we will focus on the influence of orientation on the mechanical behavior, in particular the time-dependent yield and time-to-failure (TTF) behavior, using injection moulding products.

Figure 1: Typical phenomena during injection moulding; a) quenched skin layer, b) flow induced orientation and c) isotropic core layer.

Materials and methods

Semi-crystalline polypropylene is used to injection mould rectangular plates at two different initial flow rates (v = 10, 90 cc/s) to vary the amount of flow induced orientation throughout the sample. Optical microscopy show a clear inhomogeneous structure over both the thickness as length of the sample. However, at the end of the flow path no orientation is detected.

Figure 2: Injection moulded plates exhibit clear skin-core morphology and display diverse mechanical behavior, i.e., necking or homogeneous deformation although both ductile.

Results

The anisotropic viscoplastic model\(^1\) accurately predicts orientation dependent off-axis yield stresses as well as time-to-failure.

Figure 3: Experimental and predicted yield stress and TTF for different loading angles and initial flow rates.

Independent of initial flow rate, the deformation behavior in end-direction is similar. In contrast, lower initial flow rate results in higher yield stresses in flow-direction, due to higher degree of orientation. More pronounced is the difference within one sample, in particular for \(v = 10\) cc/s. Here, yield stress increased about 40% solely due to orientation.

Figure 4: TTF for \(v = 10\) cc/s and the ratio of TTF, i.e. \(t_f^*\).

Applying a stress level both in flow- or end-direction will results in a tremendous difference in TTF. Remarkably, the ratio of TTF of flow- to end-direction, i.e. \(t_f^*\), is about 50x for high initial flow rate up to an incredible factor of 500x for low initial flow rate.

Conclusions

- Lower initial flow rates induce higher overall orientation
- Orientation leads to pronounced anisotropic behavior, particularly for time-to-failure

References