Modelling the injection moulding process of semi-crystalline polymers

Modelling the Injection Moulding Process of Semi-Crystalline Polymers

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Introduction

For semi-crystalline polymers different (flow induced oriented) crystalline structures cause anisotropy in the final product. Accurate prediction of the structure is essential to influence the product properties.

Objective

- development of a numerical model for flow-induced crystallisation of semi-crystalline polymers.

Theory

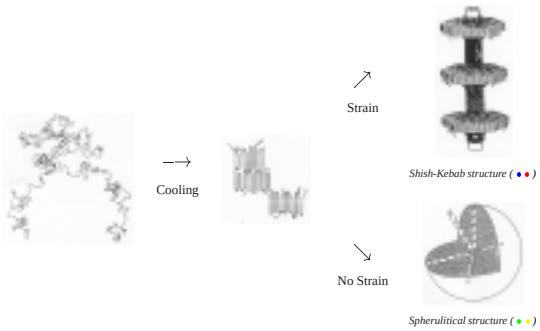

fig. 1 *The concept of crystallisation*

Depending on the amount of molecular strain during processing, different crystalline structures (fig.1) will be present in the solidified product (fig.2).

fig. 2 *A cross section of an injection moulded product*

Modelling

Models for the development of different structures:

- One for the degree of crystallinity for the spherulitical structure ξ_g [1]:

$$\frac{\xi_g}{1-\xi_g} = \phi_0 \qquad \phi_i = G^{-1}\dot{\phi}_{i-1} \qquad \dot{\phi}_3 = 8\pi\alpha$$

Solving these together with the energy equation for a 1D-problem ($T_i = 478[K]$, $T_w = T(t)$ (^{low})) gives results (center/wall , in between) comparable with the predictions of Schneider ($*$) (fig.3).

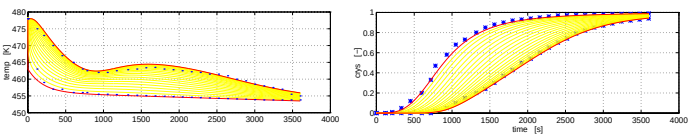

fig. 3 *Simulation results using Schneiders rate equations*

- One for the degree of crystallinity for the shish-kebab structure ξ [2]:

$$-ln(1-\xi) = \psi_0 \qquad \psi_0 = 2\pi \int_t^0 dL_{tot}\Big(\int_s^t G(u)du\Big)^2$$

$$\psi_1 = \frac{\dot{\psi}_0}{G} \qquad \psi_2 = \frac{\dot{\psi}_1}{G} = 4\pi L_{tot}$$

$$\psi_3 = \frac{\frac{\partial\psi_2}{\partial t} + \frac{\psi_2}{\tau_l}}{(\frac{\dot{\gamma}}{\dot{\gamma}_l})^2 g_l} = 8\pi N \qquad \dot{\psi}_3 = 8\pi(\frac{\dot{\gamma}}{\dot{\gamma}_n})^2 g_n - \frac{\psi_3}{\tau_n}$$

Solving these for a non-isothermal flow clearly shows the influence of the solidified layer (fig.4).

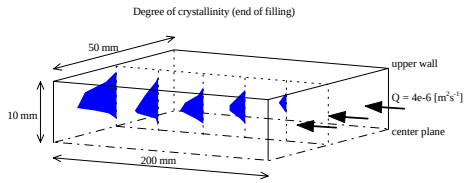

fig. 4 *Simulation results for shear induced crystallisation*

Conclusions

The models shown are a good starting point. However, strain calculations have to be incorporated.

References:

[1] SCHNEIDER ET AL.: *Non-isothermal Crystallisation, Crystallisation of Polymers (System of Rate Equations)* (Intern. Pol. Proc. II (1988) 3/4, 151-154).

[2] EDER ET AL.: *Structure Development During Processing 4: Crystallization* (Vol. 18, Material Science and Technology, Verlag Chemie, Weinheim (H.E.H. Meijer)).