Combining 3D simulations and experiments to evaluate the extrudate swell behavior of polymer melts and quantify normal stress differences

Dahang Tang[1], Flávio H. Marchesini[1], Ludwig Cardon[1], Dagmar R. D'hooge[2,3*]

[1]Centre for Polymer and Material Technologies, Department of Materials, Textiles and Chemical Engineering, Ghent University, Technologiepark 130, 9052 Zwijnaarde, Belgium.

[2]Laboratory for Chemical Technology, Department of Materials, Textiles and Chemical Engineering, Ghent University, Technologiepark 125, 9052 Zwijnaarde, Belgium.

[3]Centre for Textile Science and Engineering, Department of Materials, Textiles and Chemical Engineering, Ghent University, Technologiepark 70a, 9052 Zwijnaarde, Belgium.

Correspondence: Dagmar.Dhoog@UGent.be

Abstract

An excellent understanding of the swell behavior of polymer melts is vital for the die design, so that extrudate products with desired profiles can be obtained. Here we combine experimental and numerical tools to fundamentally study slit die swell and quantify the related normal stress differences [1-4]. Three dimensional simulations based on the ANSYS Polyflow software, as opposed to commonly applied 2D simulations, are utilized to comprehensively investigate melt flow behavior of commercial polypropylene and polyethylene melts inside and outside a slit die with various aspect ratios. Model validation is performed based on real time HD imaging of die swell in both height and width directions. Viscoelastic parameters are tuned based on the differential multimode Phan-Thien-Tanner (PTT) constitutive model. The results show that for fully developed flow in a slit die the swell ratio in the extrudate width direction strongly determines the flow distance needed to establish the swelling equilibrium [1]. Increasing the aspect ratio of the die geometry from 1 to 20 results in a significant change in the 3D swelling with relative changes of 10% in several directions and even absolute changes up to 30% [2]. It also delays the swelling equilibrium position. For more complex flow through an upstream contraction flow region before the actual die, decreasing the die length to die height ratio (2.5 to 40) results in an opposite variation trend of the swell ratio in the width and height directions and thus a larger anisotropic swelling degree. In contrast, the area swell ratio is kept almost unchanged [3]. The simulation results also contribute to the understanding of normal stress differences and an evaluation of the commonly applied exit pressure method to obtain such differences. It is shown that the velocity redistribution near the die exit has no impact on the actual application of the method and there is no significant viscous heat effect [4].

References:

1. D. Tang, F.H. Marchesini, D.R. D'hooge, L. Cardon, *J. Non-Newton. Fluid Mech.* **2019,** 266, 33.

2. D. Tang, F.H. Marchesini, L. Cardon, D.R. D'hooge, *Phys. Fluids* **2019**, 31, 093103.

3. D. Tang, F.H. Marchesini, L. Cardon, D.R. D'hooge, *J. Non-Newton. Fluid Mech.* **2020**, 282, 104337.

4. D. Tang, F.H. Marchesini, L. Cardon, D.R. D'hooge, *J. Rheol.* **2020**, 64.