3D extrudate shape prediction for complex extrusion flows

polymer technology

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Introduction

Extrusion is used to obtain products with a desired cross-sectional shape (Fig. 1). However, extrudate swell and bending highly influence the extrudate dimensions.

Desired extrudate shapes are traditionally obtained through trial-and-error. Our objective is to numerically predict the extrudate shape and hence optimize the die.

Fig. 1: Polymer extrusion products.

Problem definition

Extrudate shape is influenced by:

- Extrudate swell (viscoelasticity)
- Extrudate bending (asymmetric dies, non-isothermal flow)

A keyhole-shaped die, as shown in Fig.2, is used as a test case. Because of the die asymmetry, swell and bending can both be studied.

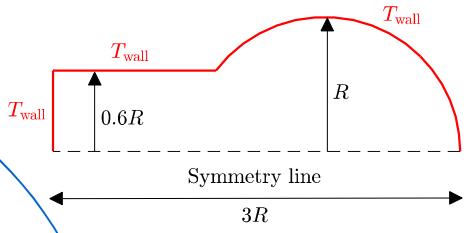

Fig. 2: Schematic description of the keyhole-shaped die.

Results

Increasing the fluid elasticity (Wi) increases swell, whereas it opposes bending (Fig. 4).

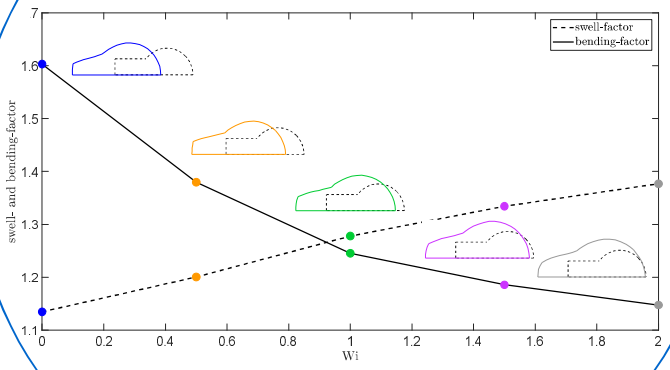

Fig. 4: Swell- and bending-factors with corresponding cross-section of the keyhole-shaped extrudate for increasing Wi.

Method

A FEM framework with the c orner-line method [1] is used to predict the extrudate shape in time. It is assumed that the fluid is incompressible and that inertia can be neglected

The 3D steady state mesh to discretize the problem is shown in Fig. 3. The mesh is refined near the die exit, where the element size is ten times smaller than the bulk element size.

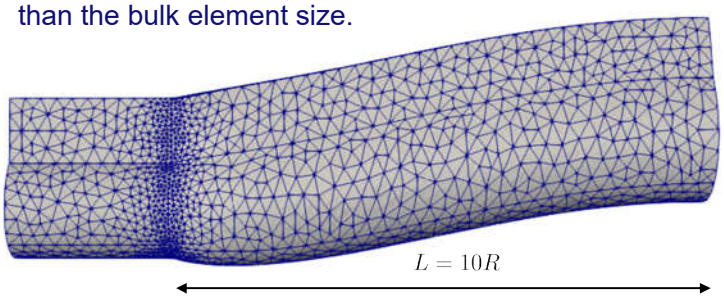

Fig. 3: 3D steady state mesh.

Conclusions

- Elasticity highly influences the extrudate shape, since it increases the swelling.
- Elasticity seems to oppose the bending effect.
- Bending is caused by v viscous stresses.

Final goal: develop a complete framework to predict the extrudate shape and optimize the die. For now the method can predict:

- ✓ Transient phenomena that influence the final extrudate shape.
- ✓ Final extrudate for complex die shapes.
- ✓ Extrudate shape development in time for complex fluids.

[1] M.M.A. Spanjaards, M.A. Hulsen, P.D. Anderson, Journal of Non-Newtonian Fluid Mechanics, 270:79-95, 2019