Transient 3D FE method for predicting extrudate swell for domains containing sharp edges

polymer technology

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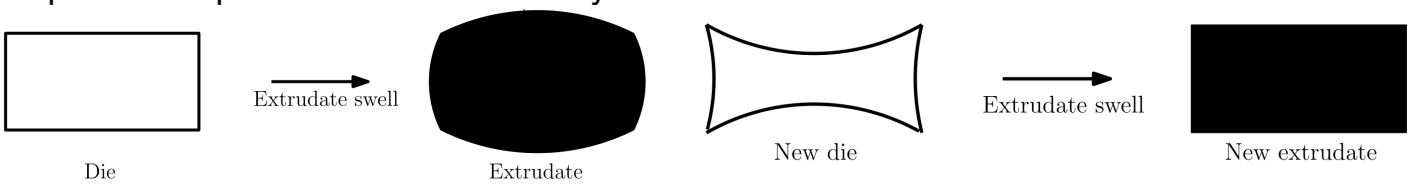
Introduction

Extrusion is widely used in the polymer processing industry. Common requirement on extrudate: **dimensional precision** ⟶ dimensions highly influenced by extrudate swell.
Experimental procedure that is currently used to obtain extrudate with desired dimensions:



⟶ Repeated until desired dimensions are obtained: time consuming and inefficient.
Solution: numerically predict extrudate swell

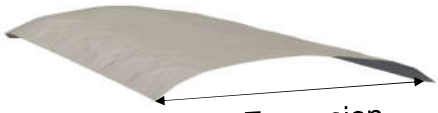
Method

Sharp corners (red) swell in two directions.
Obtain positions of the corner lines using a material line description:

$$\frac{\partial \boldsymbol{x}}{\partial t} + u_x \frac{\partial \boldsymbol{x}}{\partial x} = \boldsymbol{u}_{\text{2D}}$$

Free surfaces: 2D height problems

- Surfaces expand due to movement of the corner lines, use corner line positions for expansion:



$$\frac{\partial h}{\partial t} + u_x \frac{\partial h}{\partial x} + (u_y - u_{y,\text{line}}) \frac{\partial h}{\partial y} = u_z$$

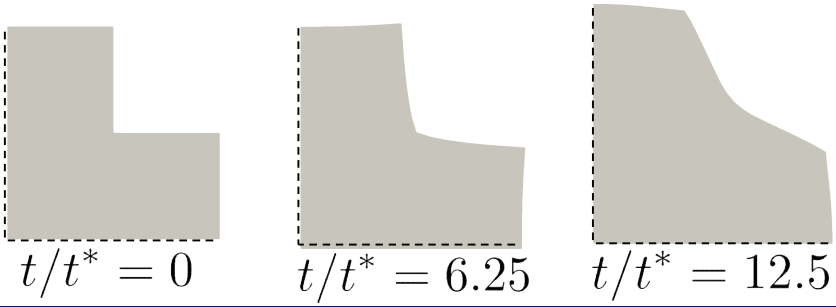
- Expanded surfaces swell:

Time stepping:

Predict free surface position → Construct the ALE-mesh → Compute new velocities and pressures → Compute conformation → Update positions material lines → Expand 2D free surface meshes → Update positions free surfaces

Results

Transient swelling for a cross-section of a 3D complex



Conclusion:

- New transient FE method developed.
- Sharp edges are contained over both time and long distance in the extrudate.
- Transient extrudate swell prediction is now possible for complex die shapes and complex fluids.