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THREE-DIMENSIONAL SIMULATION FOR THE EXTRUDATE SWELL OF POLYMER MELTS FROM SLIT DIES AND ITS APPLICATION ON NORMAL STRESS MEASUREMENTS

Introduction

- ❖An excellent understanding of the swell behavior is a vital factor to provide an assistance in die design to obtain the extrudate products with desired profiles regarding the processing operations like extrusion
- ❖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 melt inside and outside a slit die with various aspect ratios
- ❖Viscoelastic parameters are tuned based on the differential multimode Phan-Thien-Tanner (PTT) constitutive model
- ❖Combining experimental and numerical tools to fundamentally study slit die swell and quantify the related normal stress differences

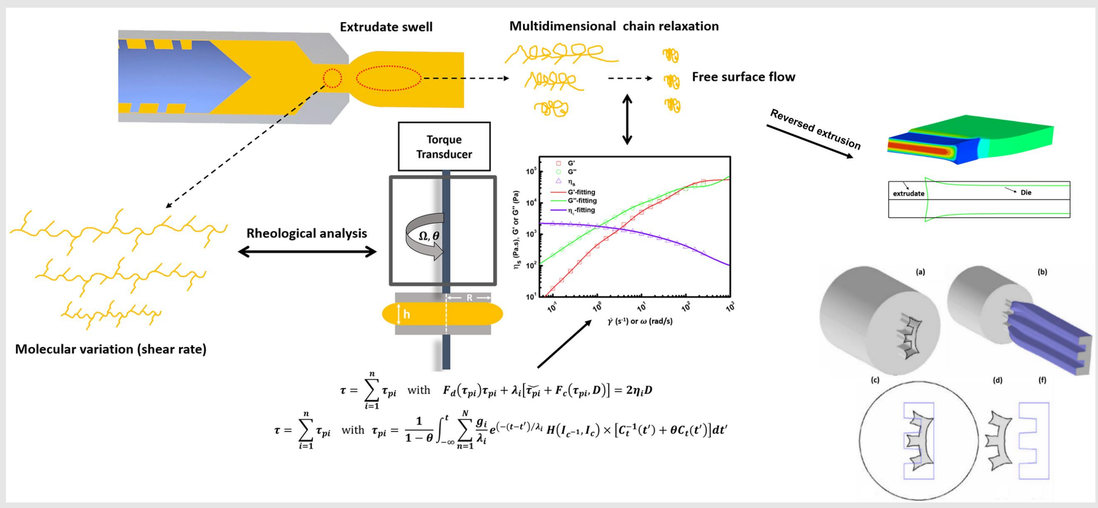
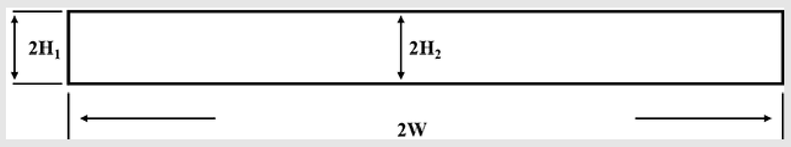


Figure 1: Schematic of the flow diagram for the whole process starting from rheological characterization to numerical simulation for extrudate swell behavior.



$$B_1 = \frac{W_{-extrudate}}{W_{-die}},\ B_2 = \frac{H_{1-extrudate}}{H_{1-die}},\ B_3 = \frac{H_{2-extrudate}}{H_{2-die}},$$

Results and discussion: 3D model with various rheological models

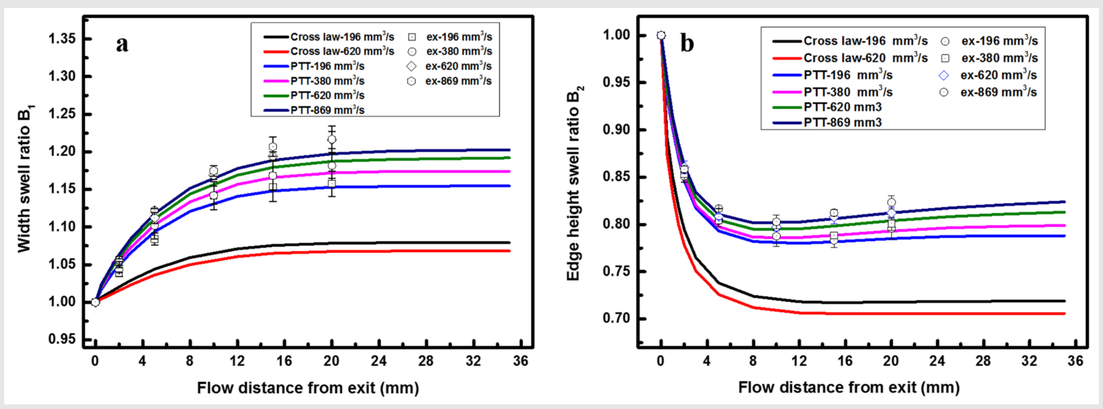


Fig. 2: Extrudate profile for B_1 and $B_2$with the axial distance from die exit at different flow rates. The curves are obtained from simulation results, while the symbols are from experiment measurements.[1]

Results and discussion: measurements of normal stress difference at high strain rates

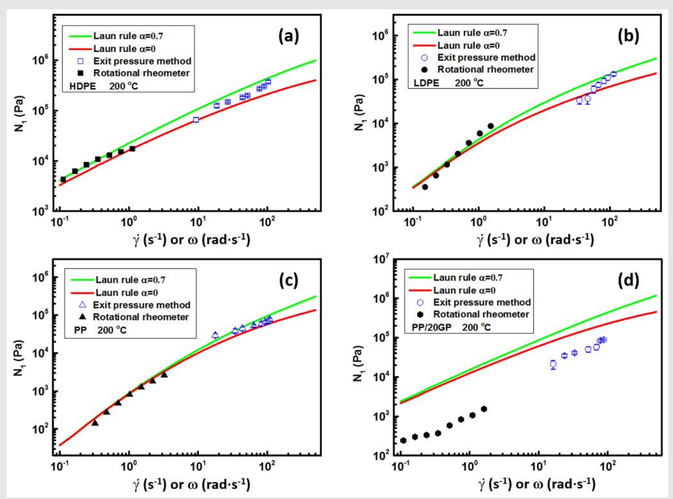


Figure 5. First normal stress difference N_1 for polymer melts at various shear rates/frequencies obtained from different methods: (a) LDPE; (b) HDPE; (c) PP and (d) PP/20GF melt. Curves, black solid symbols and blue open symbols represent the $N_{1\text{-}L}$ data from Laun rule for exponent of 0 (red) and 0.7 (green), rotational rheometer. For the neat melts the Laun rule can be applied to a first approximation (exponent close to 0.7). [4]

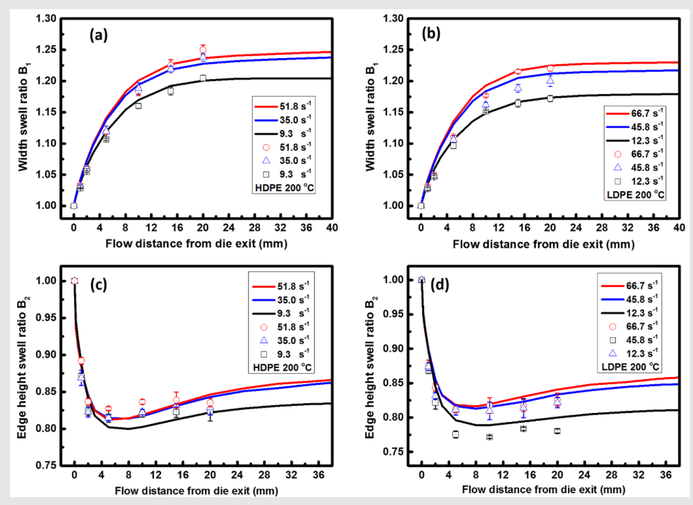


Figure 6. Simulated (curves; 3D isothermal simulations using the PTT model) and experimental (symbols) evolutions of the swell behavior in the extrudate width; (a) and (b)) and edge height direction B_2 for HDPE and LDPE melts at 200 °C at different shear rates. [4]

Results and discussion: impacts of geometrical characters

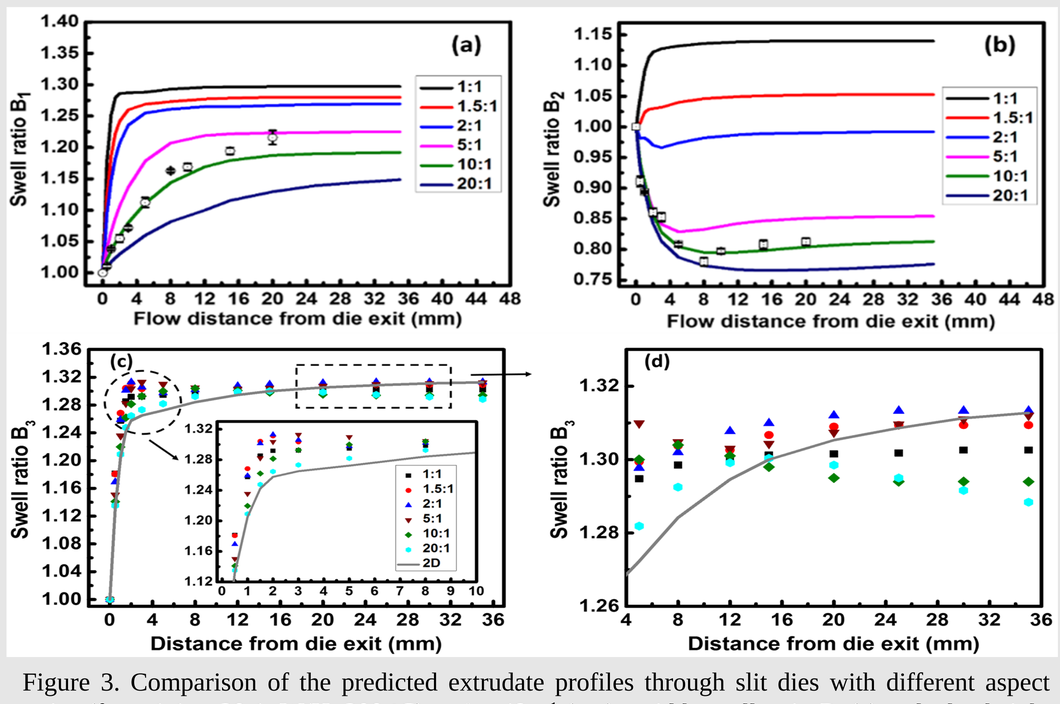


Figure 3. Comparison of the predicted extrudate profiles through slit dies with different aspect ratios (from 1:1 to 20:1; W/H; 200 ºC) at $\dot{\gamma}_a$= 48 s^{-1} (top) : width swell ratio B_1 (a) and edge height swell ratio B_2 (b). Symbols indicate the experimental data for aspect ratio of 10. (c) and (d) the evolution of the extrudate swell: comparison between the 3D and 2D modelling simulations. Simples indicate the results from the 3D simulation while curves represent the 2D modelling results at $\dot{\gamma}_a$= 48 s^{-1} [2]

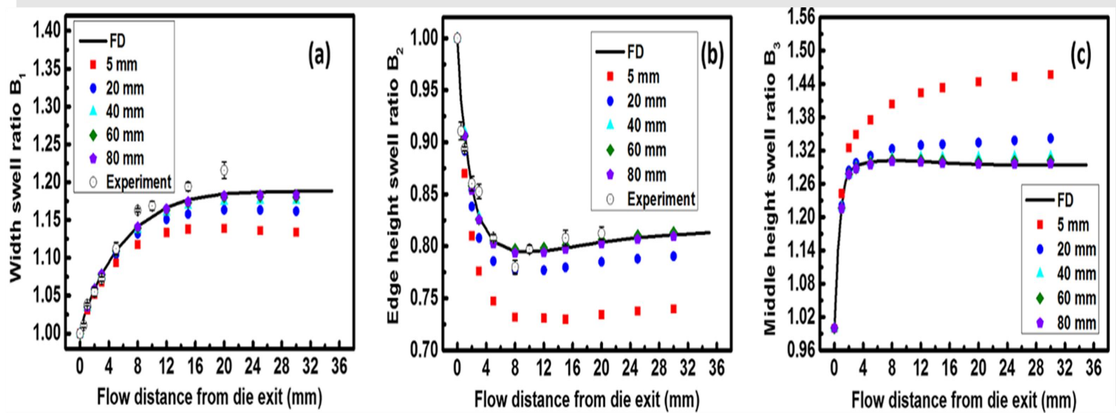


Figure 4. Impacts of upstream contraction on the evolution of extrudate swell with varying die length: 5 mm to 80 mm. (a): width swell ratio; (b) edge height swell ratio; (c): middle height swell ratio. [3]

Conclusions

- ❖ PTT constitutive model is able to predict the extrudate swell behavior well; The distance to achieve the balanced final swell behavior depends on the swell behavior in extrudate width direction.
- ❖ Rheological characters causes a big impact on the 3D extrudate swell behavior. A comparison between 2D and 3D simulations on the extrudate swell shows a big difference due to the side wall confining effects of slit dies (three-dimensional effect).
- ❖ Swell ratio predicted by PTT model with parameters obtained by fitting the exit pressure method based N_1 data, correspond well to the measured swell ratio data of polymer melts, which validates the exit pressure method for measuring the normal stress difference at high shear rate.

Reference

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.

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