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Extrudate Shape of Three-Dimensional Viscoelastic, Non-Isothermal Extrusion Flows

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Abstract

A 3D transient non-isothermal finite element code is developed to predict the extrudate shape of viscoelastic fluids emerging from an asymmetric keyhole shaped die. The corner-line method is employed to model the movement of the free surfaces. The code is tested using two benchmark problems. First the corner-line method is tested employing a trumpet shaped object during a 3D uniaxial extensional flow. Secondly, the implementation of the energy balance and therefore the viscoelastic material behaviour is tested employing a non-isothermal pipeflow. For both benchmark problems convergence was obtained, giving confidence that the 3D non-isothermal swell problem is correctly implemented. The influence of shear-thinning, elasticity and temperature on the form of the extrudate is systematically studied. Results are shown for isothermal flows also as for non-isothermal flows, with isothermal and non-isothermal die walls. Results for isothermal die walls show increasing extrudate swelling with increasing elasticity which the swelling opposes extrudate bending. Shear-thinning on the opposite hand, opposes swelling, which initially promotes bending, but also flattens the asymmetric velocity profile, resulting in less extrudate bending for top amounts of shear-thinning. Furthermore, extrudate bending was observed even for purely viscous, isothermal extrudates, suggesting that bending is caused by asymmetry within the viscous stresses. Extrudate swelling are often influenced by the wall temperature of the die and non-isothermal die walls can cause a change in bending direction.

Extrusion is widely utilized in the polymer processing industry. Common requirement on the extrudate is dimensional accuracy. However, the size of the extrudate are highly influenced by a phenomenon called extrudate swell. For Newtonian fluids, having a continuing viscosity, extruded from cylindrical dies, the swell ratio is about 13% when physical phenomenon, inertia and gravitational forces are often neglected. For viscoelastic fluids, the swelling is far larger and therefore the final diameter of the extrudate are often several times the diameter of the die. This effect is attributed to normal stresses within the material.

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