압출공정에서의 3차원 유동 스크류 특성

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Screw characteristics of three-dimensional flows in the extrusion process

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Introduction

Screw extrusion processings are being used in many cases for blending or compounding in order to produce uniform mixtures. Important design considerations for the single-screw extrusion process[1-6] are the screw characteristics(SC), residence time distribution(RTD), and deformation characteristics(DC) as a mixing measure. The present paper concentrates on the relationship among the throughput, screw speed, and pressure gradient along the down-channel direction, namely, SC, for the real three-dimensional geometry of the extruder to simulate the screw characteristics. In the case of single-screw extruders there is a considerable amount of literature analytical, experimental, and numerical studies about this relationship. However, there is few for dealing the real geometry with the viscoelastic constitutive equations.

Governing equations and numerical methods

We present the governing equations in the strong form for the single-screw extrusion process in an Oldroyed-B fluid in the one-side periodic frame along the down-channel direction.

$$\bullet\ \nabla \cdot u = 0,\ \nabla \cdot \sigma = 0, \quad \text{in } \Omega$$

$$\bullet\ \sigma = -pI + 2\eta_s D + \tau_p, \ \text{in } \Omega$$

$$\bullet\ \lambda \overset{\nabla}{\tau}_p + \tau_p - 2\eta_s D = 0$$

The above equations represent the continuity, the momentum balance, and the constitutive relation of the Oldroyd-B fluid, respectively. σ, u, p, D, I, τ_p, η_s, η_p, and λ are the stress, the velocity, the pressure, the rate of deformation tensor, the identity tensor, the polymer stress, the viscosity of Newtonian solvent, the polymer viscosity and the relaxation time, respectively.

We use the extra-stress tensor due to the polymeric contribution being zero as an initial condition. In the down-channel direction, we impose use the periodic boundary condition to keep the continuity for both inlet and outlet boundaries for the velocities and the polymeric extra-stresses.

In the week formulation, these periodic boundary conditions are combined with the Lagrangian multipliers together with including the pressure gradient term. In order to extend the Newtonian fluid system to incorporate the viscoelastic fluid we employ the DEVSS method developed by Guenette and Fortain[7] and DG[8] for the discretization of the viscoelastic constitutive equation.

The inlet and outlet boundary conditions for the polymer stress have been treated to meet the continuity of the polymer stress as periodic conditions in the down-channel direction. In order to apply the pressure gradient along the down-channel direction we added the additional forcing vector due to the pressure gradient on the inlet boundary.

Numerical results and discussion

The geometry of the real single-screw extruder is shown in Fig.1.

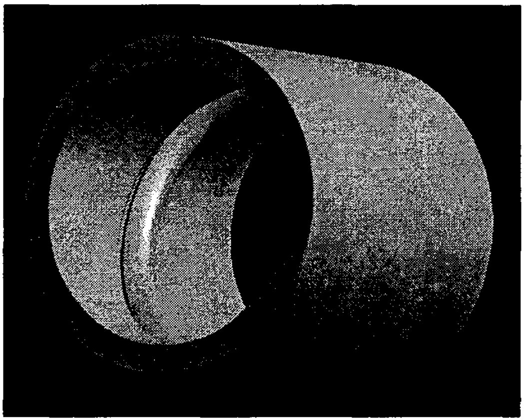


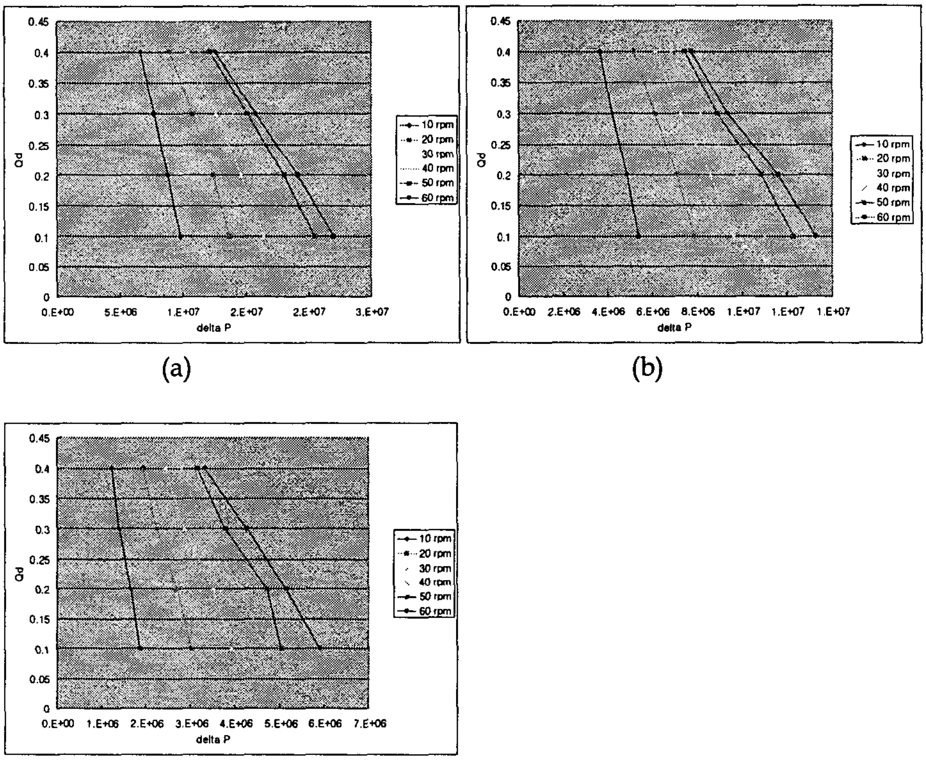
Fig. 1. The cross-sectional view of the real screw extruder.

In this geometry, radius of the barrel, pitch, flight width are 45(mm), 45(mm), and 5(mm), respectively, and three different flight depths of 2.5(mm), 3.7(mm), and 7.5(mm) are used.

For the generalized Newtonian fluid we use the modified Cross model as a viscosity function as:

$$\eta(\dot{\gamma}) = \eta_0/(1+C\dot{\gamma})^{1-n}$$

where η_0 =0.1165, C=0.0728, n=0.8389(MKS in Unit).



(a)

(b)

(c)

Fig.2. Dimensionless volume flow rate as a function of pressure difference (Pa) for three different flight depths (h): (a) h=0.25(mm), (b)h=0.37(mm), (c)h=7.5(mm) with changing the barrel speed(rpm).

For the given screw speed, the bulk flow rate is decreasing with increasing the adverse pressure difference. The extent of dimensionless flow rate clearly increases with increasing the flight depth for the given pressure difference as shown in FIg. 2.

In order to investigate the viscoelastic effects on the screw characteristics, Fig. 3 shows flowrate as a function of time for several different pressure gradients in the viscoelastic fluid. In this geometry, we use rectangular geometry, i.e., expended geometry of the real geometry with the flight width, flight depth, relaxation time, the polymer stress, the viscosity of Newtonian solvent being 1, 1, 1, 1, and 1, respectively, and three different pressure gradient being 10, 0, -10. As shown in FIg. 3, we can see the convergent solutions and the effect of pressure gradient on the flowrate.

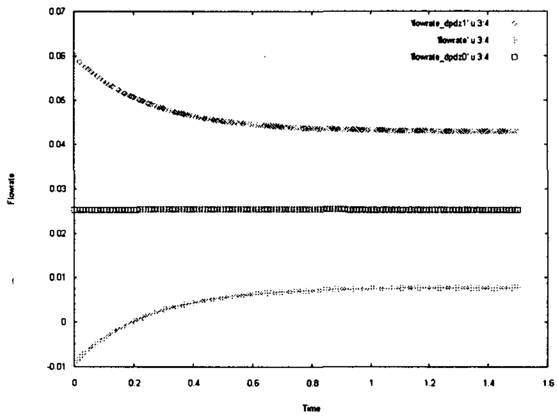


Fig.3. Flowrate as a function of time for several different pressure gradients in the viscoelastic fluid(pressure gradients: 10, 0, -10).

Acknowlegements

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