The extrudate-swell singularity for Phan–Thien–Tanner and Giesekus viscoelastic fluids

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Abstract

The behaviour of the stress singularity for Phan–Thien–Tanner and Giesekus viscoelastic fluids is determined for extrudate-swell (also termed die-swell). In this flow, the fluid exits a channel (or die) as a jet and forms a free-surface flow [1]. In the presence of a Newtonian solvent viscosity, the solvent stress dominates the viscoelastic polymer stresses near the transition point from the solid (stick) surface inside the die to the free (slip) surface outside the die. Consequently, the Newtonian solvent stress is $O\left(r^{-(1-\lambda_0)}\right)$, where r is the radial distance to the transition point and λ_0 is the Newtonian eigenvalue (dependent upon the angle of separation between the solid and free surfaces). This eigenvalue decreases from unity at 133^o down to $1/3$ at 270^o, this being the relevant separation angle range for extrudate-swell. We show that the viscoelastic polymer stresses are less singular with $O\left(r^{-4(1-\lambda_0)/(5+\lambda_0)}\right)$ for PTT [3], and $O\left(r^{-(1-\lambda_0)(3-\lambda_0)/4}\right)$ for Giesekus [2]. The viscoelastic polymer stresses require boundary layers at both the solid and free surfaces, with the role of those at the free-surface being particularly important to arrest the growth of the viscoelastic stresses. Comments will also be made on the Oldroyd-B model.

keywords: Non-Newtonian Flows; viscoelastic models; extrudate-swell

References

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