RHEOLOGICAL EFFECTS ON PURELY-ELASTIC FLOW ASYMMETRIES IN THE CROSS-SLOT GEOMETRY

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ABSTRACT

The cross-slot is a canonical geometry for the generation of a planar extensional flow with a free stagnation point. Beyond a critical Weissenberg number *Wi*, viscoelastic flows in the cross-slot geometry are well-known to undergo a transition from a steady symmetric to an asymmetric flow state, ostensibly due to ‘purely-elastic’ effects.[1] However, some prior work suggests that shear-thinning of the fluid may play an important role.[2] Here, we employ a series of polymer solutions of varying rheology to investigate in detail how the interplay between fluid elasticity and shear thinning affects the onset and development of the asymmetric flow state in the cross-slot. First, we characterize the rheological properties of hydrolyzed polyacrylamide aqueous solutions with and without salt by using standard rotational rheometry and capillary breakup extensional rheometry. We employ micro-particle image velocimetry to obtain velocity fields in the cross-slot device for each of the polymer solutions and to assess the degree of flow asymmetry *I* as a function of *Wi* and the shear thinning parameter *S*.[2] The flow broke symmetry beyond a critical *Wi*, but the degree of asymmetry was found to depend on *S*. Interestingly, for intermediate polymer concentrations, resymmetrization of the flow field occurred above a higher, second critical *Wi*. To understand these trends, we compare our experiments with numerical simulations with the linear Phan-Thien-Tanner model. Finally, we summarize the trends as a flow state diagram in *Wi*-*S*-*I* space, showing the relationship between flow asymmetry and fluid rheological properties. We demonstrate that the degree of both shear thinning and elasticity are important factors for elastic instabilities in the cross-slot geometry.

REFERENCES

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