Stabilisation of the purely-elastic instabilities in cross-slot geometries using surface tension

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The cross-slot geometry consists of mutually bisecting rectangular channels with two opposing inlets and two opposing outlets. In such geometries, due to presence of a free stagnation point at the centre of the geometry, a significant strain rate may develop that is of particular interest in the design of extensional rheometers for example.

In the current work, we simulate two phase viscoelastic fluid flows in this geometry using a volume of fluid method. The stress components of the viscoelastic material are simulated using a simplified Phan-Thien and Tanner model with a log-conformation approach. The combined effects of the capillary number (the ratio of the surface tension force to the viscous force), the Weissenberg number (the ratio of the elastic forces to viscous forces), extensibility parameter (ε) and the solvent-to-total viscosity ratio (β) of each of two phases and the ratio of the total viscosities of two fluids (the K parameter) are investigated in 2D geometry. It is shown that the surface tension force plays an important role in the shape of the interface of the two fluids near the stagnation point. By reducing the surface tension force the interface of the two fluids becomes curved and this can consequently change the curvature of stream lines in this region. In this scenario, for fixed values of β, Wi, ε and K parameters the surface tension is shown to have a stabilising effect on the associated steady symmetry-breaking instability. The K parameter is shown to change the location of the stagnation point and the interface position of the two fluids. By increasing the K parameter, the local value of the Weissenberg number near the corners of the geometry is significantly increased and this can consequently lead to a time-dependent purely-elastic instability in 2D geometries. Finally, the Weissenberg number and ε parameter have a destabilising and stabilising effect, respectively.