SIMULATION OF VISCOELASTIC FLUIDS IN 2-D ABRUPT CONTRACTION BY SPECTRAL ELEMENT METHOD

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The prediction of viscoelastic flows in complex geometries, such as in expansions or contractions, has both scientific interest and industrial relevance. Understanding entry flow of viscoelastic fluids is of importance in fundamental flow-property measurement and in extrusion of polymer melts and solutions. Although the geometry looks very simple, solutions for high Weissenberg (We) or Deborah (De) numbers are not available. One of the reasons of this failure comes from the fact that the stress components are not square integrable at the corner and are locally singular. One of the key problems in viscoelastic flows is the influence of the outflow boundary conditions, which may induce numerical instabilities if not well suited. According to our previous study about the effect of outflow boundary condition for Poiseuille flow, we found that imposing natural boundary condition introduces instability first in elements which are close to the outflow region and then propagates in the upstream direction. Adopting an adequate outflow boundary is our interest in this study. Moreover, the capability of extended matrix logarithm [1] formulation to predict flow pattern for 2-D 4:1 contraction flow has been examined. The simulation is carried out for the FENE-P fluid in the context of spectral element method. The influence of Weissenberg number, re-entrant corner shape is examined to investigate corner vortices and augment the instabilities during the simulation.

At low values of the Weissenberg number the convergence rate of the simulation is very fast and the accuracy of the numerical simulation is very high. In contrast, increasing the Weissenberg number makes the relative error vary exponentially which prevents the successful numerical simulation. The velocity and viscoelastic-stress overshoot downstream of the entry corner increase with the Weissenberg number. When the level of elasticity in the flow is enhanced, the simulation takes more time steps to reach the fully developed condition. Therefore a longer channel length after entry flow is needed. The maximum attainable Weissenberg number by the extended matrix logarithm formulation is 10 while this value for classical formulation is 8. Mesh refinement does not bring any improvement on the accuracy at critical values of the Weissenberg number. Increasing the Weissenberg number also enhances vortex intensity as measured as the maximum value of stream function and also augments the instability close to the re-entrant corner which propagates in the upstream direction. We found that employing round or sharp corner does not have very important improvement to tackle the high Weissenberg number problem. The maximum attainable Weissenberg number for both round and sharp re-entrant corner are the same and equal to We=10.

Reference

[1] **Azadeh Jafari**, Nicolas Fiétier, Michel O. Deville, A new extended matrix logarithm formulation for simulation of viscoelastic fluids with spectral elements, Comput. Fluids 39, 9 (2010), 1425-1438.