Robust simulations of viscoelastic flows at high Weissenberg numbers with the streamfunction/log-conformation formulation

A new streamfunction/log-conformation formulation of incompressible viscoelastic flows is presented. The log-conformation representation guarantees the positive-definiteness of the conformation tensor and obviates the high Weissenberg number problem. The streamfunction is defined as a vector potential of the velocity field, and provides a pressureless formulation of the conservation laws, which automatically enforces the incompressibility. The resulting numerical method is free from velocity-pressure decoupling errors, and can achieve stable calculations for large Courant numbers, which improve the robustness and the efficiency of the solver. The two-dimensional flow of an Oldroyd-B fluid inside the lid-driven cavity is simulated for a large range of Weissenberg numbers. The numerical results demonstrate the second-order accuracy of our scheme, and our solutions are in good agreement with the available data from the literature for Weissenberg number 3 and below. Finally, the simulations at higher Weissenberg numbers 5 and 10 reveal a structural mechanism that sustains quasi-periodic elastic instabilities arising at the upstream corner of the moving lid.

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