Numerical simulations of non-Newtonian fluids in a periodically forced enclosed cylinder

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ABSTRACT

Wall-bounded oscillatory flows of non-Newtonian fluids appear in many different situations and major efforts are being made in order to understand their transition to turbulence[1]. One of the most remarkable differences with Newtonian fluids is the fact that non-Newtonian fluids have some elastic properties that might cause the flow to become turbulent in absence of inertia (elastic turbulence)[2]. The present work addresses the analysis of the elastic instability in a periodically driven cylindrical cavity, filled with a non-Newtonian fluid. This system was chosen because simulations in an enclosed cylinder are a well-posed problem and the experimental frame can be easily constructed (the system is equivalent to a piston-driven cavity)[3].

In the present work, non-Newtonian flows are modeled using both the simpler Oldroyd-B model and the FENE-P model. As large stresses might be present, the FENE-P seems more realistic than the Oldroyd-B, although both will be used and compared. Moreover, a diffusive term is included in the constitutive equation to stabilize the integration[4]. The problem that is considered is formally similar to the thermal convection of an incompressible fluid contained in an enclosed cylinder and analogous techniques can be employed[5]: for the convection, the incompressible Navier-Stokes equations are coupled with a heat equation, while an additional stress tensor is considered in our case instead of the temperature. Thus, a second-order time-splitting method is used and the spatial discretization is via a Galerkin-Fourier expansion in the azimuthal direction and a Chebyshev collocation in the axial and radial direction. The code seems efficient and some promising results have been obtained that might bear witness to elastic instabilities.

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