STABILIZED APPROXIMATIONS FOR DIFFERENTIAL VISCOELASTIC FLUIDS

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Numerical methodologies for computational simulations of non-Newtonian fluid flows must be able to handle with complex features present in the mechanical behavior of this sort of fluids. For purely viscous fluids, they have to embrace both the shear-thinning and the shear-thickening of the fluid viscosity. For the fluids subjected to yield stress limit – the so-called viscoplastic fluids – they have also to incorporate some strategy for capturing, in a distinguished way, either material regions under flow or regions whereon the yield limit is not surpassed – forcing those regions to perform an apparently rigid body motion. Such a restriction for the material to start to flow must be properly addressed by the numerical methodology thanks to enormous amounts of industrial applications of yield stress fluids found nowadays – one can list, briefly, natural flows as the human blood flowing in our arteries and veins, pharmaceutical products for our personal care such as shampoo and creams, up to heavy oils from the petroleum industry. Moreover, whether some degree of elasticity should be considered in a fluid application, the numerical methods have to deal with complex rheological phenomena as elastic recoil, extensional kinematics, non-null first extra-stress differences in purely shear flows and so on. Among the real materials subjected to elastic effects, the polymer melts and polymeric solutions are immediately remembered.

In the current abstract, we are proposing numerical simulations of creeping flows of viscoelastic fluids – here described by the upper-convected Maxwell model and the Oldroyd-B model – addressed by a three-field Galerkin least-squares methodology in terms of the extra-stress, pressure and velocity. This methodology, which can be regarded as pertaining to the class of stabilized methods of finite elements, presents useful properties for the approximation of polymeric flows. First, since such a formulation does not need to satisfy the compatibility conditions inherited from the classical Galerkin method, an equal-order combination of simple finite element interpolations, for the triple stress-pressure-velocity, can be used – saving computation efforts in simulations under slow processes of convergence. Secondly, the GLS formulation can selectively add artificial diffusivity to viscous and elastic flow regions, which surely speeds up the convergence process and renders the numerical solutions more accurate.

The computations herein undertaken concern steady flows of UCM and Oldroyd-B fluid flows around a cylinder within a channel subjected to 1:8 aspect ratio between the cylinder diameter and the channel height. For Oldroyd-B flows, polymeric and solvent viscosities are 0.41 and 0.59, respectively – as suggested in some viscoelastic works. The inertia terms are dropped in motion equation and, aiming at assessing the influence of elasticity on the fluid motion, the Weissenberg number is considered from 0 to 1.5. The numerical results are physically meaningful and match the results obtained by other researchers.