Simulation of Non-isothermal viscoelastic fluid flow problem using a VMS stabilized formulation

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ABSTRACT

The production process of the polymers is mostly non-isothermal in nature, including for instance in plastication and heating and cooling sequences. Since flow properties are strongly dependent both upon rheology and temperature, it is of major interest to understand and predict such type of flows qualitatively and quantitatively. Additionally, thermally coupled problems in viscoelastic fluids has started receiving scientific interest in recent years, based on the higher mixing capacity and heat transfer properties of this kind of materials.

Thermal coupling involves some modifications both in the constitutive viscoelastic equation and in the energy equation. Particularly, temperature dependent viscosity and relaxation time are modelled using the WLF (Williams-Landel-Ferry) relation [1]. Moreover, new terms have to be considered in the energy equation, defined by the product between the stress and the velocity gradient. This is linked to the work done by the fluid on adjacent layers due to the action of the shear stress forces; this work is transformed into heat by means of an irreversible process called viscous dissipation. This effect is significant for a wide range of flows, such as high-velocity flows, highly viscous flows and fluids with a moderate Prandtl number and velocities with small wall-to-fluid temperature differences.

The stabilization technique employed to solve the coupling problem for the finite element formulation is the Variational Multiscale Method (VMS), introduced originally by Hughes [2]. Referring to the algorithm employed, it is iterative, non-monolithic and it is executed in a partitioned manner. The implementation is done in parallel form. Nevertheless, the computational effort required to run a simulation is specially high due to two main factors: the high amount of elements required to capture the physical effects, and the computation of all non-linear terms present in the equations.

Finally, numerical results have been validated with other published papers [3], particularly solutions for several Weissemberg numbers have been obtained to study the viscous dissipation effect.

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