Thermal coupling simulations with a viscoelastic fluid flow

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ABSTRACT

Production process of the polymers is mostly non-isothermal in nature. Since flow properties are strongly dependent both upon rheology and temperature, it is of high interest to understand and make predictions of such type of flows. The combination of high viscosities of polymeric melts and high deformation rates results in the transformation of large amounts of mechanical energy into heat; and consequently in a rising of the material temperature. This phenomenon is, for example, used in extruders where viscous dissipation is used to enhance melting of the material.

For viscoelastic materials, stresses depend also on the temperature. Consequently, temperature should be an independent variable in the constitutive equations for the stress tensor. This coupling is established in two ways: on the one hand the temperature-dependence of the linear viscoelastic properties is described by the principle of time-temperature superposition, and on the other hand the energy equation is modified to include the part of mechanical power which is accumulated as elastic energy. Moreover, in order to address numerical problems with high elasticity (in other words, with a high Weissenberg number), apart from the classical formulation employed for modelling the viscoelastic fluid flow, also the reformulation of equations using the well-known logarithmic reformulation is employed [1].

Regarding the computational approach, a finite element framework has been considered, considering the Variational Multiscale (VMS) method as stabilization technique (technique introduced originally by Hughes [2]). With reference to the algorithm employed, it is iterative, non-monolithic and it is executed in a partitioned manner.

Two numerical examples are explored in order to validate the model and to study the influence of the temperature coupling in the viscoelastic flow behaviour. The first one is the flow over a cylinder and the second one is the planar expansion 1:3. The last one is particularly interesting due to the formation of symmetric and asymmetric regions which play an important role in the viscous dissipation, temperature distribution and heat transfer rate.

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