STABILITY CONSTRAINTS OF VISCOELASTIC CONSTITUTIVE EQUATIONS AND 1-DIMENSIONAL MODELING OF EXTRUDATE SWELLING BY A STABLE CONSTITUTIVE EQUATION

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In this work, we discuss new results of stability analyses for isothermal incompressible formulations of constitutive equations (CE's) for viscoelastic liquids. Two types of viscoelatic CE's, differential and single integral ones, are employed at present for analyzing flows of polymeric liquids, and both cases are studied in the following analyses. Two kinds of instabilities related to the formulation of CE's were observed for large or even modest values of Deborah numbers. They are Hadamard and dissipative instabilities. Hadamard instability depends on such quasi-equilibrium properties of the CE's as the type of differential operator in the evolution equation and the elastic potential. However, the disspative instability results from the formulations of nonequilibrium properties of CE's.

Criteria of both global Hadamard and dissipative stabilities are studied for viscoelastic CE's of differential Maxwell-like and time-strain separable single integral types with instantaneous elasticity. When applied to many popular viscoelastic models, the combined stability criteria were found to impose so severe constraints on the CE's. As a result, no single integral CE with time-strain separability could satisfy them, and only three differential models such as the FENE and the upper convected Phan Thien-Tanner models and the Leonov class of CE's were proved stable. In numerical simulation of complex flows with unstable CE's, when the flow rate becomes high enough, occurrence of various types of unphysical instabilities is inevitable. Hence, this situation raises a legitimate question, if there exists a CE or a class of CE's which can properly describe all the available experimental data within the domain of global stability. Recently, the existence of such a class of CE's was demonstrated.

With a stable viscoelastic constitutive equation, 1-dimensional modeling of isothermal swelling of polymer melts extruded from capillary and annular dies has been performed. With one empirical dissipation parameter, the swell behavior in the case of capillary die can be described satisfactorily for both cases of free swelling and stretching. The experimental data of polyethylene for annular die swelling show the violation of formulated force balance.