Simulation of Incompressible Non-Newtonian Flows Through Channels with Sudden Expansion Using the Power-Law Model

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ABSTRACT

The goal of this work is to analyze incompressible non-Newtonian flows through channels with sudden expansion. The governing equations are solved using the finite-differences explicit Runge-Kutta time-stepping scheme in nondimensional form in which continuity, momentum, pressure and tension are solved simultaneously along the grid points. Non-Newtonian fluids are usually considered to be those when the relation connecting shear stress and shear rate is not linear: that is, the 'viscosity' of a non-Newtonian fluid is not constant at a given temperature and pressure, but depends on the rate of shear or on the previous kinematic history of the fluid. In this way, there isn't a constitutive relation able to predict all non-Newtonian behavior that can occur. So, a lot of models were developed in order to try to predict non-Newtonian effects like the Maxwell, the generalized Newtonian liquid (GNL) and the ones of differential and integral constitutive equations. The power-law model, which is a special case of the GNL, is applied to predict pseudoplastic and dilatant behavior. The typical curve relating stress-deformation for pseudoplastic fluids indicates that the viscosity falls progressively with shear rate and the flow curve becomes linear only at very high shear rates. This behavior is characteristic of high polymers, polymer solutions and many suspensions. For dilatant fluids, the viscosity increases when the rate of shear is increased.
Expansions have important applications in engineering processes like in refrigeration, extrusion and free jets. The study of Newtonian fluid flows through a sudden expansion of various ratios and conditions is a classical problem which has been analyzed by many workers. So, important information about this flow are known, like critical Reynolds and bifurcation phenomena. For non-Newtonian flows, such investigation is recent and there isn't much information about it. So, this work studies the critical Reynolds for pseudoplastic and dilatant fluid flows. Numerical results for 3:1 expansion ratio show that for pseudoplastic flows the critical Reynolds number decrease, when compared to the Newtonian case, and increase for the dilatant situation.

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