Quantification of flows of non-Newtonian fluids in terms of energy dissipation rate: viscometry, mobility and process monitoring

Wook Ryol Hwang

In this work, we propose a systematic approach in quantifying of non-Newtonian fluids for pressure-driven flow, including the power consumption, the effective Reynolds number, the effective viscosity and the relationship of pressure drop and flow rate in terms of energy dissipation rate [1, 2, 3]. The quantification method will be applied to on-line viscosity measurement, mobility and tortuosity characterization for porous media and process monitoring. Two constants (i.e., the coefficient of effective shear rate and the coefficient of energy dissipation rate), which depend nearly on the flow geometry, are adopted to quantify flow characteristics of continuous flow system, independent of fluid rheology. The flow quantification method for non-Newtonian fluids in a pressure-driven flow will be addressed with the example flow problem: a circular pipe flow, an expansion-contraction flow, a flow in a Kenics mixer and a microfluidic system. Then the application of the flow quantification will be proposed for viscometry and characterization of porous media. First, we show that the quantification method with the two flow numbers provides sufficiently accurate viscosity as a function of the shear rate, as the viscometer does, for a given geometry of pressure-driven flow of non-Newtonian fluid [4]. Secondly characterization of flows in porous media will be discussed with an energy-based interpretation of Darcy's law and the permeability. Mobility of non-Newtonian fluids (i.e. the relationship of pressure drop and flow rate) and the tortuosity for flows in porous media will be reformulated in terms of the flow quantification approach. Finally, we introduce the process monitoring technique via on-line viscosity measurement in an extrusion die and injection molding processes, which might be employed for in-situ process identification.