A new type of mixer based on elongational flow: numerical simulation and flow visualization

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A new lab-scale mixer, based on multi-pass flow through a static mixing unit was built and tested for model polymer blend systems: two reciprocally operating pistons push the material to be mixed back and forth between two cylindrical chambers through a central static element composed by a single, small diameter die. The high efficiency of this device for dispersive mixing, compared to that of rotary Brabender-type mixers at comparable specific energy input, was attributed to the strong elongational component of the flow. The device is also characterized by efficient distributive mixing, even at low Reynolds numbers. To better understand the origin of distributive mixing in the system, finite element numerical simulations were carried out together with an experimental study for visualization of the flow. For this purpose, experiments were carried out at room temperature in a transparent system with the same geometry. The fluids were either Newtonian or viscoelastic polymer solutions containing fluoresceine and the flow was visualized with a linear laser beam. For the numerical simulations, we used the passive scalar method and more recently the area tensor method. The first conclusions which came out from the simulations and visualization experiments are the following: In creeping low conditions (Re below 0.001) the viscosity gradient in the chambers due to viscous dissipation in the mixing element leads to flow irreversibilities and eventually distributive mixing. At inertial flow conditions (Re around 10) and negligible viscous dissipation, downstream vortices appear leading to irreversible flow and mixing. The geometry of the mixing element and in particular the contraction angle between the chamber and the static mixing element was shown to have a significant influence on mixing efficiency. A quasi-Newtonian model which allows taking into account strain-hardening effects in elongational flow was used for the simulation of viscoelastic fluids.