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CRITICAL CONDITIONS FOR DROPLET BREAKUP: EFFECTS OF CONFINEMENT AND COMPONENT VISCOELASTICITY

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The break-up of Newtonian droplets in a Newtonian matrix is well described by the Grace curve. Under bulk conditions the Grace curve associates a critical capillary number with every viscosity ratio. It has also been documented that wall effects (confinement) substantially affect the critical conditions for break-up. More specifically confinement suppresses break-up when the viscosity ratio is below one, whereas confinement promotes break-up when the viscosity ratio is larger than one. In this work, droplet break-up in systems with either a viscoelastic matrix or a viscoelastic droplet is studied microscopically in bulk and confined shear flow, using a parallel plate counter rotating flow cell. The ratio of the droplet diameter to the gap spacing (confinement ratio) has been varied systematically from 0.1 to 0.85, thus covering varies degrees of confinement. In addition, for the systems with a viscoelastic component, viscosity ratios above as well as below one were investigated. This allows for a full comparison with the Newtonian-Newtonian reference case. In bulk shear flow, the effects of matrix and droplet visco-elasticity on the critical capillary number for break-up are very moderate. However, in confined conditions a profoundly different behavior is observed: the critical capillary numbers of a viscoelastic droplet are similar to those of a Newtonian droplet, whereas matrix viscoelasticity causes break-up at a much lower capillary number. The experimentally observed critical capillary numbers are also compared with the predictions of the phenomenological model by Minale. Finally, the break-up mechanism has been investigated. Whereas viscoelastic droplets in a Newtonian matrix can break-up into multiple parts, only two daughter droplets are obtained in a viscoelastic matrix, up to very high confinement ratios. All these results indicate the component viscoelasticity is a factor that should not be neglected in the design of microfluidic devices and micro-scale polymer processing equipment for multiphase systems.