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Conclusions and final remarks

The mechanisms responsible for the turbulent drop breakup of a single droplet and diluted O/W emulsions in a rotor – stator mixer and through an orifice in a pipe were analyzed by visualization of the flow with a high-speed camera and by determining the drop size distribution change as an emulsion is subjected to a turbulent flow.

For the case of drop breakup in a rotor – stator mixer, two mechanisms were identified. The first one, the vortex and jet mechanism, acts in two steps. Initially, the upper layer of dispersed phase (low-density fluid) is fragmented into larger spherical and non-spherical droplets by the vortex generated because of the circular motion of the rotor. Then, the particles are redirected to a jet zone emerging from the stator holes, where, as explained by Calabrese et al. (2000), they are subjected to a turbulent stress. Depending on the magnitude of the energy dissipation rate in the jet zone (proximity of the stator holes) and time scale (time in which the stress acts), the droplets can be deformed and finally broken. The second mechanism is a mechanical breakup caused by the high shear stresses that droplets suffer in the rotor – stator gap. The high shear stresses are produced by the velocity difference between the rotor and the stator. Due to the magnitude of the shear stresses, this mechanical mechanism probably is the responsible for produce the smallest droplets in the flow.

In the case of breakup through an orifice in a pipe, it was shown that breakage only occurs downstream of the restriction. The breakup takes place at a certain distance from the edge of the orifice (L_b, breakup length). At this breakup length, the radial gradient of axial velocity in the flow (turbulent stress) is large enough to overcome the resistance stresses (exerted by the droplet) and produce the rupture of the droplet. The generated daughter droplets enter in a recirculation zone, where apparently, the deformation stresses are not strong enough to produce additional fragmentation. In some cases, the flow pattern can carry the daughter droplets to breakup regions, where more daughter droplets are produced. These observations are in agreement with the previous observations made Galinat et al. (2005) for the case of drop breakup through an orifice plate. However, from the observations made in this work, it is possible to conclude that the orifice length does not influence the breakup mechanisms.

The interfacial tension and dispersed phase viscosity effects were similar for both geometrical cases. Low magnitude of deformation, low fragmentation rate and larger equilibrium drop sizes were particular characteristics for high interfacial tension and moderate dispersed phase viscosity systems. It was demonstrated that for the case of breakup through the orifice, and at experimental conditions evaluated in this work, L_b depends strongly on the interfacial tension.

Experimental maximum stable drop diameter data were obtained for the turbulent breakup of diluted O/W emulsions in both studied cases. Analysis of the data revealed that maximum stable drop sizes were in the inertial sub-range, characterized exclusively by the energy dissipation rate per unit mass ε. A linear mechanistic model for the inertial sub-range, based in Kolmogorov's theory of isotropic turbulence, was developed to aid in data interpretation and provides a basis for correlation. The model was adjusted to experimental data using a non-linear optimization tool based in the Generalized Reduced Gradient code (GRG2), and its precision was calculated from the root mean squared difference between experimental and predicted data. Good predictions were obtained for the breakup in the mixer at the two levels of viscosity tested; however, this was not the case for the breakup of a moderate viscosity oil through the orifice. The relative low precision of the model used to correlate the breakup through the restriction lied in the lack of consideration of the time scale required for the breakup. In addition, a linear curve fitting based in a power law model, showed that interfacial effects drive the breakup process in the restriction. The similarity for the C_3 and C_4 coefficients found for the model in both geometrical cases, allows to have a rough approximation of the maximum stable drop size that will be obtained in the breakup through the orifice from drop size data at equivalent energy dissipation rates in the rotor – stator mixer.

Future work will focus in a deeper analysis of the turbulent drop breakup phenomenon for the case of a single droplet (considering both geometrical cases). A statistical analysis will allow having an idea of the fragmentation process, determining the main properties in the flow field (velocity field, shear stress field, breakup probability zones, etc.). Then, numerical simulations could be made to validate experimental data and finally determine if the kinematics of both processes have a natural correspondence between them. In addition, efforts will be directed to the determination of novel mechanistic models for breakup in diluted emulsion systems that include residence time in the high deformation rate zone, and resulting drop size as a function of the initial (upstream) drop size distribution.