Microstructure development and rheological characteristics of highly concentrated emulsion during emulsification

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Emulsions containing a dispersed phase volume fraction (φ) of higher than the maximum packing volume fraction of closely packed monodisperse spheres (~0.74) are referred to as highly concentrated emulsions (HCEs). HCEs retain their original structure at volume fractions exceeding the critical value because of the virtue of polydispersity and droplet deformation within the system [1]. HCEs have applications in a variety of fields such as the food industry, pharmaceuticals, cosmetics, petroleum products and commercial explosives. Microstructural development of highly concentrated water-in-oil emulsions during the emulsification was investigated by varying the refining time. Furthermore, the rheological characteristics are also studied to investigate the influence of evolved morphology.

Emulsion samples were prepared using the high-shear mixer and emulsion samples were collected at different stages of emulsification to investigate its structural and rheological characteristics. Different characterisation techniques including confocal laser scanning laser microscopy, cryo-SEM were used to characterise the system, in addition to the rheometer. Water-in-oil emulsion system, in which the dispersed phase constitutes > 90 wt% of total emulsion was chosen for the current study. The dispersed phase of the emulsion comprises of an aqueous solution of inorganic salts; solution of a polyisobutenyl succinic anhydride (PIBSA) based emulsifier in a blend of two industrial-grade hydrocarbon oils constitutes the continuous phase.

During the initial stage of emulsification, a crude polydisperse emulsion of large droplets were formed by gradually incorporating the aqueous droplets into the oil blend. In the second stage, the applied high shear rate resulted in decreased mean droplet size and narrower distribution width. The droplet diameter decreased exponentially and the Sauter mean diameter converged to an asymptotic value; further, extended periods of shearing did not reduce the diameter. Sauter mean diameter depends on the shearing rate and the rupture rate likely to be a function of both the crude emulsion diameter and the shearing rate [2]. It can also be observed that extended refining during emulsification results in a narrowed polydispersity of the droplets. Furthermore, the emulsion viscosity increased significantly with refining and this can be attributed to the reduction of the mean droplets size with mixing time [3]. The storage modulus, yield point and flow stress also increased with an increase in refining time. The change in rheological characteristics can thus be correlated with the emulsion microstructure that results from the emulsification conditions.

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