Cavitation for Emulsions

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Liquid – liquid emulsions are widely used in major chemical industries like pharmaceutical, agricultural, cosmetics, paint and food. Emulsions are realised by introducing energy into the desired liquid – liquid systems. Various devices stirrers, rotor-stator systems, and high pressure homogenizers are used for emulsification. Efforts are however being made continuously to develop better ways of realising emulsions (better ways of providing required energy) and better control on resulting emulsion characteristics. There is an increasing interest in using cavitation as a clean, energy efficient method for the production of highly stable emulsion systems. The cavitation process progresses through the formation, growth and collapse of cavities or microbubbles. The cavity implosion results in localized hot spots with very high temperature, pressure and intense shear. High intensity ultrasound, or acoustic cavitation (AC) techniques demonstrate excellent emulsification performance in comparison to more traditional mechanical methods, such as high-speed homogenizers and microfluidizers[1,2]. A number of examples in open literature have described the successful application of AC to generate highly stable nanoemulsions in water insoluble systems[3]. Another potentially exciting application area for cavitation assisted emulsification is in the food processing industry, and in particular the dairy industry, where AC has been again found to successfully homogenize particle sizes down to the nano-range[4]. In this talk, we will discuss some of the recent results on using cavitation for emulsions.

Despite the promising results of using AC for emulsions, it should be noted than though AC can be readily used on a laboratory scale, it is difficult to extend their application to commercial scale. Hydrodynamic cavitation (HC) is emerging as an attractive alternative method for the preparation of stable emulsions, offering a range of additional benefits above AC, including; lower energy consumption, continuous flow operation, and potentially easier routes to scale up. HC generated emulsions for food processing applications have been found to achieve comparable droplet size distributions to AC methods[4]. HC systems are commonly based on forcing flow through small restrictions, such as an orifice or venturi, and are thus prone to clogging and contamination in a similar manner to microfluidizers. Recent developments in cavitation reactors based on swirling flows have opened a potential route to realizing the benefits of HC which removes the risk of clogging and erosion[5]. In this work, we present ongoing research on the production of stable oil - water emulsion systems at QUB using both AC and HC methods. In the first part, we will present the results from AC based emulsions to bring out the relative influences of power input, irradiation time and phase concentrations on the final droplet size distributions. The vortex based cavitation devices are then used to compare results from HC based emulsions with those from AC. Characteristics of emulsions prepared with HC will be directly compared with AC methods, highlighting any relative differences in final emulsion properties and total energy consumption. In order to understand the complex multi-phase flow field that develops in vortex based cavitation device, a full 3D, multiphase, transient CFD simulations were carried out. These CFD results were used for quantitatively relating predicted energy dissipation rates with emulsion properties. The presented approach, computational models and results will provide a sound basis for gaining additional insights for enhancing applications of hydrodynamic cavitation to the area of emulsions.

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