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Mixing performance of various geometries - Emulsification perspective

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Abstract

Emulsions find wide use in food, drink, paint industry etc. Mixing devices and technologies such as ultrasonication, rotor-stator devices (e.g. Silverson) and high-pressure homogenizers are typically used to prepare emulsions. In this work emulsification performance of these geometries in view of the energy requirement is compared. Emulsification performance of a novel impinging-jet micromixer is also studied. Emulsification performance of the devices is tracked via emulsion quality i.e. average droplet size measurements. Comparison of emulsification performance will help in optimizing the product quality for the available energy to disperse the phases.

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Keywords: emulsion; emulsifier; ultrasonication; impinging-jet

1. Introduction

Oil-in-water emulsions find use in foods, cosmetics, paints, pharmaceutics and are of great industrial value [1, 2]. Emulsion droplet size and drop size distribution depend on the process hydrodynamics as well as the physiochemical nature of the disperse phase/continuous phase interface. Emulsification, typically, is achieved in stirred tanks (e.g. Silverson rotor-stator device) and high-pressure homogenisers. Microemulsions are however difficult to create, given their small dimensions. This is so as it require an enormous amount of energy to disrupt smaller droplets. This calls for a study to investigate the emulsification performance of the available emulsification technologies in terms of the energy value.

Ultrasonicator and impinging-jet micromixer is an alternate to stirred tank and high pressure homogenizer. The impinging jet device constitute of high velocity jet streams impinging head-on in a confined space to effectively disperse one phase into another. Ultrasonication on the other hand is

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achieved via a sonic probe operating at a high frequency.

2. Materials & Methods

2.1. Materials

Food-grade emulsions are prepared using sunflower oil, double-distilled water and Tween20 and Soya Lecithin emulsifiers. Two set of oil/water emulsions are prepared and tested: 5% (v/v) and 10% (v/v) oil content. The emulsifiers are present in water/continuous phase.

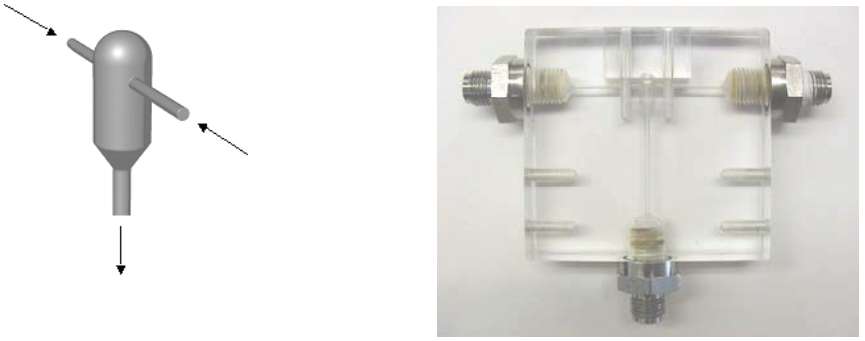

Fig. 1. (a) A schematic and (b) in Perspex Impinging-jet device (Reproduced from [4])

2.2. Mixing geometries

Four geometries are tested here: rotor-stator provided by Silverson Inc., impinging-jet mixer (Fig. 1), ultrasonicator and high-pressure homogenizer. The energy added to the emulsifying system is varied by varying (i) amplitude in the ultrasonicator (Vibra-cell, Sonics Inc.), (ii) impeller rotational speed in rotor-stator device, (iii) operating pressure in homogenizer (Armfield Inc.) and (iv) jet flowrate in a custom made impinging-jet device.

2.3. Emulsion preparation

Emulsion samples were prepared by dissolving the emulsifier in double-distilled water and subsequently adding oil to it and dispersing the two phases using different mixing devices/techniques. In ultrasonic technique the sonication probe is 10 mm in diameter and operates at 20 kHz. Sonication amplitude is varied between 20% and 80%. In case of stirred system, Silverson rotor operational speed is varied between 1760 rpm and 7520 rpm. Homogenizer is operated between 100 psi and 700 psi. Impinging jet device which has inlet diameters of 1mm each and an outlet of 1.5 mm operates at jet flowrates between 44 mL/min and 196 mL/min. Emulsion samples each weighing 150gms were subjected to varying energy levels using each of the above techniques.