CHEMICAL ENGINEERING RESEARCH AND DESIGN 87 (2009) 1631–1639

Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Emulsification capability of a dual shaft mixer

*Avinash R. Khopkar, Louis Fradette, Philippe A. Tanguy**

URPEI, Department of Chemical Engineering, Ecole Polytechnique, PO Box 6079, Station CV, Montreal, Quebec H3C 3A7, Canada

ABSTRACT

O/W emulsification capabilities of a multi-shaft stirred vessel comprising a Paravisc impeller mounted on central shaft and an off-centered rotor–stator were investigated in the case of viscous emulsions. The power consumption and the droplet size distribution were measured for different oil to water ratio using an online torque meter and a laser granulometer respectively. It was found that the rotor–stator had a reduced effect on the processing time and the droplet size distribution and that the presence of the Paravisc significantly influenced the processing time, overall energy consumption and the shape of the droplet size distribution. The study also highlighted the significant influence of the oil internal phase to water ratio on the processing and structural parameters of the emulsion.
© 2009 The Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.

Keywords: Dual shaft; Stirred vessel; Emulsification; Energy consumption; Droplet size distribution; Viscous emulsion

1. Introduction

Emulsification is a complex mixing phenomenon involving immiscible liquid phases. The process consists of dispersing one phase (called the dispersed phase) into the other phase (the continuous phase) using mechanical energy. In vessel-based processes, emulsification is usually achieved with a rotating impeller, the design of which must be chosen judiciously to generate the right combination of bulk flow and shear to obtain a good emulsion quality. This operation is not too difficult to perform with low viscosity fluids as it is possible to operate the mixer in the turbulent flow regime. However, in many situations of practical interest involving for instance the mixing of high viscosity fluids and/or significant viscosity changes during processing, turbulence can hardly be achieved. In such cases, bulk flow and shear must be generated simultaneously, a requirement that can be pretty challenging using a single impeller system.

To address this issue, stirred vessels with independent multiple (two or more) impellers have been proposed. They comprise typically a close-clearance impeller (anchor or helical ribbon) rotating at low speed that generates the bulk flow, and a high-speed impeller (rotor–stator or dispersing turbine) for the production of the intense shearing needed for the dispersion. Two mixer configurations are used in practice to carry out emulsification at higher continuous phase viscosity, viz. coaxial mixers (see for example, Espinosa-Solares et al., 2001, 2002; Foucault et al., 2006; Kohler et al., 2006) and dual shaft mixers (Kohler et al., 2006; Khopkar et al., 2007). Dual shaft mixers however, have shown certain advantages over coaxial mixer. The presence of eccentric impeller not only breaks the symmetry of the system but it also plays the role of a baffle. These hardware modifications influence the fluid dynamics prevailing in the vessel and lead to significant improvement in the mixing process. Also, the dual shaft arrangement simplifies the mechanical design of the mixer. Although the dual shaft arrangement is an attractive design as compared to coaxial mixer, to our knowledge no information is available in literature on their emulsification capabilities. The objective of the present work is therefore to shed some light on the emulsification process in a dual shaft mixer equipped with a twisted anchor impeller and a rotor–stator turbine.

In this work, O/W emulsification capability of dual shaft mixer was studied. The outcome of emulsification depends mainly on four factors: (a) hydrodynamic condition in the mixing device, (b) viscosity ratio between continuous and dispersed phase, (c) volume fraction of dispersed phase and (d) type and concentration of surfactant (Schubert and Engel, 2004). The emulsification was carried out in the experimental setup used by Khopkar et al. (2007) to understand the influence of first three parameters on the emulsification process in a dual shaft mixer.

* *Corresponding author.*
E-mail addresses: philippe.tanguy@polymtl.ca, philippeatanguy@gmail.com (P.A. Tanguy).
Received 10 March 2008; Received in revised form 11 March 2009; Accepted 1 June 2009
0263-8762/$ – see front matter © 2009 The Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.cherd.2009.06.001

Nomenclature

C	impeller off-bottom clearance (m)
D	diameter of impeller (m)
d_s	shaft diameter (m)
$d_{v,50}$	median diameter (μm)
E_V	energy consumption per unit volume (J/m^3)
H	height of liquid from the bottom of the reactor (m)
H_{Para}	height of the Paravisc impeller (m)
N	impeller rotational speed (rpm)
R_c	radius of curvature (m)
Re	Reynolds number
T	vessel diameter
T'	torque (N m)
t	time (s)
V	volume (m^3)
W_{Para}	blade width of Paravisc impeller (m)

Greek letters

δ	gap between rotor and stator (mm)
ρ	density (kg/m^3)
μ	viscosity (Pa s)
α	volume fraction

Subscripts

Para	Paravisc impeller
RS	rotor–stator
1	primary shaft
2	secondary shaft

Table 1 – Details of the experimental setup.

Vessel diameter, T	0.4 m
Liquid height, H	0.47 m
Radius of bottom curvature, R_c	0.4 m
Diameter of primary shaft, d_{s1}	0.024 m
Diameter of secondary shaft, d_{s2}	0.032 m
Diameter of Paravisc, D_{Para}	0.374 m
Height of Paravisc, H_{Para}	0.45 m
Width of Paravisc blade, W_{Para}	0.05 m
Diameter of rotor–stator, D_{RS}	0.09 m
Gap width between rotor and stator, δ	2 mm

2. Materials and methods

2.1. Materials

Experimental setup of Khopkar et al. (2007) was used in present work to study O/W emulsification. The schematic of experimental setup is shown in Fig. 1. Detail dimensions of the vessel, impellers, and shafts can be found in Table 1. Experiments were carried out with aqueous solutions of glucose (partially hydrolyzed corn syrup) as continuous phase and canola oil as dispersed phase. Tap water was used for preparation of aqueous solution of glucose. The viscosity of the glucose solution was determined using a Bohlin AR-2000 viscometer with the Couette configuration. The viscosity (μ) of glucose solution was varied from 0.8 to 8.0 Pa s by varying the water content. The density of glucose solution ranged between 1364 and 1380 kg/m^3. The density of canola oil is equal to 917 kg/m^3 and viscosity equal to 0.06 Pa s. In the experiments, we used four different values of oil volume fractions, viz. 10, 20, 40 and 50 (in percentage). Type of surfactant is one of the very important parameter in emulsification process. In the present work, we have carried out experiments with only one type of surfactant. Triton X-100 (Laboratoire Mat, Canada) was used as a surfactant.

2.2. Emulsification experiments

Oil-in-water emulsification is carried out in a dual shaft mixer. Emulsification was started with non-premixed condition. This indicates that at initially, the system is at rest with the oil phase at the top and the aqueous phase at the bottom of the tank. The initial experiments were carried out with 40.0% (by volume) of canola oil as dispersed phase. The torque on each impeller was monitored to ensure complete emulsification to achieve steady state drop size distribution. These experiments were used to understand the influence of hydrodynamic conditions and viscosity ratio on the emulsification process. In the second part of the work, emulsification experiments were carried out with three more volume fractions of oil, viz. 10.0, 20.0 and 50.0% and with constant viscosity ratio ($\mu_c/\mu_d = 54$). These experiments were carried out to understand the influence of dispersed phase volume fraction on emulsification process in a dual shaft mixer.

2.3. Measurement techniques

Optical torque meters (Lorenz Messtechnik, Germany) were mounted on each shaft to measure the respective power consumption of the Paravisc and the rotor–stator. The measurement range was 0–30 N m for the Paravisc torque meter and 0–10 N m for the rotor–stator torque meter, both with 0.1% full scale accuracy. The instantaneous torque values were measured with a sampling frequency of 2 Hz. Two temperature sensors were also fitted to the vessel wall to monitor the fluid temperature. A LabVIEW (National Instruments, USA) data acquisition and control system was used to adjust the rotating speeds and record the torque and temperature values. The range of rotational speed considered varied between 25 and 60 rpm for the Paravisc and 100–1500 rpm for the rotor–stator, which ensure operatio ine the laminar regime with the fluids at hand. As the processing temperature significantly influences the emulsion properties (Sanchez et al., 1998), all the measurements were carried out at a vessel temperature equal to 21 °C (±1 °C) to avoid influence of temperature.

The overall energy consumption was obtained from the measurement of instantaneous values of torque. The impeller energy consumption was calculated as

$$P_i = 2\pi N_i T_i', \qquad P_{Total,i} = P_{Para,i} + P_{RS,i}$$
$$E = \sum_{i=1}^{m} P_{Total,i} * t_i \tag{1}$$

where T_i' is the instantaneous values of torque (obtained after subtracting the residual torque value), N_i is the instantaneous values of impeller rotational speed, P_i is the instantaneous values of power consumption of impeller, E is the overall process energy and t_i is the process time. It must be noted that in the present study, the power consumption measurements were carried out three times for same operating conditions. The values reported in the study correspond to the average value of the three measurements of each operating conditions.

The droplet size distribution (DSD) was characterized using a laser granulometer Mastersizer S (Malvern Instrument Ltd.,

Download English Version:

https://daneshyari.com/en/article/622289

Download Persian Version:

https://daneshyari.com/article/622289

Daneshyari.com