Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 112 (2017) 217 – 224

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO 2016, 26-28 October 2016, Bucharest, Romania

Assessment of global void fraction in a gas-liquid stirred vessel by digital image processing

Andrei Dragomirescu[a]*, Irina Pincovschi[a], Maria Miu[a]

[a]*University Politehnica of Bucharest, Department of Hydraulics, Hydraulic Machinery and Environmental Engineering, 313 Splaiul Independentei, Bucharest 060042, Romania*

Abstract

The main goal of the study presented in this paper is to propose a non-invasive method based on digital image processing to assess the global void fraction for both the vortex and the air bubbles that form in a gas-liquid stirred vessel. Three impellers with different geometries (circular, rectangular, and trapezoidal) were tested in a laboratory scale water tank for two aspect ratios of the water column. The trapezoidal impeller has perforated blades, a secondary goal of the study being to investigate whether the perforations could decrease the power demand of the impeller while providing a high global void fraction. The results obtained show that the operation of the impellers is characterized by two critical rotational speeds, $n_{cr,1}$ and $n_{cr,2}$. The transition from the sub-critical (non-aerated) to the super-critical (aerated) regime takes place at $n_{cr,1}$. The vortex volume fraction increases up to $n_{cr,2}$ and gets stabilized beyond it. The evolution of the bubble void fraction can be described by the logistic function. When enough experimental data is available, this function allows the estimation of a third critical speed beyond which the increase in bubble void fraction becomes negligible. The usage of perforated blades did not bring a decrease but an increase in power demand. The method based on digital image processing proved to be adequate for choosing the appropriate type of impeller and for optimizing new impeller designs in applications involving gas-liquid stirred tanks.

© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016

Keywords: stirred vessel; global void fraction; vortex void fraction; bubble void fraction; digital image processing

* Corresponding author. Tel.: +4-074-056-9986; fax: +4-021-402-9865.
*E-mail address :*andrei.dragomirescu@upb.ro

1876-6102 © 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016
doi:10.1016/j.egypro.2017.03.1087

1. Introduction

Numerous industrial chemical processes, including water treatment, gas absorption, and aerobic fermentations, take place between a gas phase and a liquid phase, by generating gas bubbles inside the liquid phase. For bubble generation, spargers supplied with air by blowers are usually employed in bubble columns (BC). As an alternative, in gas-liquid stirred tanks (G-L STs) bubbles are introduced by mechanical agitation into the liquid phase through vortex entrainment from the free surface. In such a case, impellers are used to break up the vortex into bubbles.

For gas-liquid stirred tanks, the most important task is the generation of a high contact area between the gas and liquid phases – which in turn allows for high mass transfer and improved reaction rates. G-L STs achieve high specific areas (up to 100-500 m^2/m^3 [1]) by using an impeller to disperse the gas into the liquid in radial direction (Rushton impeller, concave blade impeller, etc.) or axial direction (marine impeller, pitched blade impeller, etc.). The flow induced by the impeller placed at the bottom of the tank generates a vortex, which is initiated at the free surface of the liquid inside the tank and descends towards the impeller. When the agitation starts and as long as the free surface shaped by the vortex does not reach the impeller, gas-liquid mass transfer occurs only through the free surface. Bubbles are generated inside the tank as soon as the deformed free surface comes into contact with the impeller. Until the vortex reaches the impeller, bubble formation does not occur and, consequently, no bursting takes place at the free-surface. This is called the *sub-critical* or *non-aerated regime*. When the vortex reaches the impeller, in the *super-critical* or *aerated regime*, the gas phase is dispersed inside the tank, thus providing better mixing.

Flow models with empirical correlations are generally used to describe the multiphase flow in the reactor. This approach has provided a foundation for reactor design and scale-up. The empirical information available for modeling usually describes global properties in the system of interest. The overall gas holdup or global void fraction (GVF) is an important parameter required for flow regime identification as well as for modeling, design, and scale-up of process equipment. It is defined as the fraction of the reactor dynamic volume occupied by the gas. GVF and its radial profile govern liquid recirculation, flow pattern, mixing, and heat and mass transfer in bubble column reactors and stirred tanks. In gas-liquid stirred tanks with vortex entrainment from the free surface, GVF is given by the volume fractions of the vortex and of the bubbles.

There are two main challenges regarding multiphase stirred tank reactors: *(i)* scale-up and *(ii)* Computational Fluid Dynamics Modeling [2]. Reactor scale-up – from laboratory scale to industrial scale reactor – is a big challenge regarding multiphase reactors. By scaling up to larger geometric sizes, bubble, mixing, and kinetic lengths and characteristic times do not scale in proportion.

Computational Fluid Dynamics (CFD) models have been developed to provide quantitative descriptions of flows in multiphase STs. These CFD models require experimental validation. In multiphase STs, difficulties arise in validating and improving the CFD codes. Rammohan et al. [3] and Khopkar et al. [4] have shown that current CFD attempts fail to properly capture flows in gas-liquid STs. To empower the predictive capabilities of CFD, more experimental data is required [5, 6].

GVF has been extensively studied experimentally with various measurement techniques. Some review articles in the literature present the available measurement techniques for multiphase flows [7, 8]. There are two options when considering a measurement technique: either invasive or non-invasive devices. The former are inserted into the reactor so that they can interact with the flow, the latter are either mounted on or positioned closely to the reactor for obtaining information about the flow without interacting with it. Among the non-invasive techniques one can mention: laser techniques [9, 10], tomographic techniques [11, 12], physical tracers [13, 14], pressure drop measurements [15, 16], dynamic gas disengagement [17, 18], and visualization/high-speed photography techniques [19, 20].

The main goal of this work is to develop a non-invasive method based on high-speed photography and image analysis techniques to quantify GVF in a laboratory scale stirred tank. The method proposed in this study, although not as accurate as the laser technique, can offer quick and inexpensive information on GVF and interfacial area in an ST. This method can be very useful when comparing different types of impellers with respect to their influence on aeration efficiency, where the aeration efficiency is defined as oxygen transfer rate (from gas to liquid phase) per unit total power input [21].

In the present work, a laboratory scale stirred tank and three types of impellers were used in order to identify by means of the proposed method the type of impeller and the operating conditions that maximize the two components of GVF, namely the vortex and the bubble void fractions. A secondary goal of the study was to verify whether an impeller with perforated blades could provide high bubble void fraction with low power demand. The independent variables were the type of impeller, the impeller speed, and the height of the liquid phase inside the tank.

Download English Version:

https://daneshyari.com/en/article/5445822

Download Persian Version:

https://daneshyari.com/article/5445822

Daneshyari.com