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Fabrication and characterization of low-cost silica spargers: Toward smaller bubbles

Behnam Mostajeran Goortani [a,*], Roghayeh Izadi [b], Mohammad Keramat [b]

[a] Department of Nano Sciences and Technologies Engineering and Department of Renewable Energy Engineering, Faculty of Advanced Sciences and Technologies, University of Isfahan, Iran

[b] Department of Nano Sciences and Technologies Engineering, Faculty of Advanced Sciences and Technologies, University of Isfahan, Iran

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ABSTRACT

In this study, nano- and microstructured glass bead spargers were fabricated by an innovative pressureless sintering method in a temperature-controlled convection furnace. In comparison to existing commercial spargers, the spargers fabricated in the present study produce bubbles smaller than 100 μm in size. The novelty of the research is in the fabrication step of the spargers and in the study of bubble columns with bubbles in the range of 0.1 mm up to 1 mm. Scanning electron microscopy, X-ray diffraction, and porosimetry were used to further characterize the fabricated spargers. The bubble sizes and distributions were determined in an experimental setup comprising a bubble column equipped with a semi-professional camera to record the sizes and movements of the bubbles in the column. Computational fluid dynamics modeling performed using Fluent was further used as a diagnosis tool to improve our understanding of the velocity profiles and x–y coordinates of the bubbles and gas holdup in the column.

1. Introduction

Spargers are devices used for the continuous injection of gas bubbles into liquids. These porous materials have applicability in many areas, such as in bioreactors, fermentation (for aeration and gas injection), wastewater treatment, and flotation. The performance of spargers and the sizes of bubbles depend on the fabrication process and solid–liquid interface interactions. Therefore, three important tasks need to be considered in this regard. The first is a systematic study of the sintering conditions during fabrication. The second is the study of bubble formation and characterization in a bubble column. The third is an investigation of the bubble–liquid interactions in the column by means of modeling software such as Fluent. The third task provides a clear view of the velocity and location of the bubbles in the column, and this may consequently improve our understanding of the performance of spargers.

The most important commercial method of sparger fabrication is sintering of microsized particles in a furnace under pressure and under controlled atmosphere [Mott Corporation, Farmington, USA]. During sintering, at temperatures lower than the melting temperature of particles, they form necks at their contact points [1,3,2]. By controlling sintering conditions, spargers with macroporous structure [5] may be fabricated. Therefore, sintering time and temperature are two important factors in sparger fabrication for controlling the final porous structure. Zarifah et al. [6] showed that when glass particles are used and no sintering agent is employed, the pore size of the sintered surface reduces when the sintering temperature is increased from 800 °C to 1000 °C. Rahaman [4] showed that at a sintering temperature of 700 °C the neck growth increases with an increase in sintering time from 2 min to 30 min.

The size and distribution of bubbles are important factors for determining the performance of spargers. In a bubble column, these factors are determined by the gas flow rate, pore size of the sparger surface, and gas–liquid interactions. For example, Kazakis et al. [7] showed that in the case of metal spargers, the bubble size increased from 2.5 mm to 5 mm when the pore size was increased from 40 μm to 100 μm or when the gas flow rate was increased from 39.2 LPH (liters per hour) to 66.7 LPH. On the other hand, Thorat et al. [8] showed that the gas flow through a sparger is proportional to 0.73 times the power of the bubbles diameter and to 0.75 times the power of porosity. Chen et al. [9] used glass frit to produce bubble clusters 0.5–3 mm in size in a flotation experiment. The size distribution of bubbles depends on the pore size and uniformity of the sparger surface and on the liquid–bubble interactions.

* Corresponding author.
E-mail address: b.mostajeran@ast.ui.ac.ir (B.M. Goortani).

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