Bubble size distribution at the entrance of bubble column with pore sparger

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Abstract

Despite the wide use of bubble columns as gas-liquid contactors in many applications (e.g. bio-reactors, blood oxygenators, absorbers), their design and scale up is still a difficult task, due to the generally complex structure of the multiphase flow encountered in this type of equipment. Bubble size is an important design parameter, since it dictates the available interfacial area for gas-liquid mass transfer. For example, in blood oxygenators large bubbles favor CO_2 removal, whereas small bubbles favor O_2 transfer, but it is more difficult to eliminate them in the debubbling section of the oxygenator. Bubble size distribution depends extensively on column geometry, operating conditions, physical properties of the two phases and type of gas sparger. Among the common gas spargers used, fine pore plates seem to be advantageous since bubbles created by this type of gas distributor are numerous and relatively small thus offering a greater gas-liquid interfacial area for efficient mass transfer. However, information related to the performance of this kind of sparger is rather limited.

Among the two main flow regimes observed in bubble columns, i.e. the homogeneous and the heterogeneous regimes, the *homogeneous* is more desirable for applications where high gas flow rate may have undesirable implications. For example, in bioreactors, where cells and/or enzymes are shear sensitive, high gas flow rates must be avoided to provide a low shear rate environment [1]. Also, in blood oxygenators, high gas-to-blood flow ratio is one of the main causes of intravascular microemboli and organ injury during cardiopulmonary bypass and is associated with excessive hemolysis and protein denaturation [2]. Most of the early CFD studies concerning bubble column design have a limited validity, because they consider a *monodispersed* bubble size distribution at the column entrance. Consequently, in order to develop reliable predictive tools for bubble column design, it is essential to be able to predict the bubble size distribution at the column entrance for various gas-liquid systems**.**

In a previous work conducted in this Laboratory [3], the effect of liquid properties on bubble size distributions in a bubble column with fine pore sparger was studied experimentally. It was suggested that the liquid viscosity and surface tension influence both coalescence and breakage mechanisms, affecting the bubble size distribution (which is generally a unimodal or bimodal log-normal one). Another interesting finding is that bubble sizes in this type of gas-liquid contactors depend on phenomena occurring mainly onto or in the vicinity of the sparger surface.

In the present work, new experimental data on *initial* bubble size distribution and mean Sauter diameter at the homogeneous regime in a bubble column equipped with two different fine pore spargers, obtained from image analysis of fast video recordings, are reported. Various liquids covering a wide range of viscosity and surface tension are employed, while atmospheric air is used as the gas phase for all experiments. The ultimate goal of the present work is to attempt to formulate a correlation of general validity for the prediction of the initial bubble size distribution in bubble columns equipped with porous sparger.

The experimental set-up is illustrated in ***Figure 1*** and it consists of a small vertical rectangular Plexiglas® column (***cell***) with a square cross section of side length 4 cm and height 12

cm. To increase the total height of the column and to deter small bubbles returning to the sparger vicinity due to recirculation, a cylindrical Plexiglas® pipe (6.5 cm i.d. and 35 cm height) was also adjusted at the top of the column. The cell is equipped with appropriate rotameters for gas phase flow measurement and control. During the experiments, the gas is injected through a gas sparger, i.e., a round metal porous disk, 2.5 cm in diameter, installed at the center of the bottom plate. In the present experiments, two 316L SS porous disks (Mott Corp.) with nominal pore size of 40 and 100 μm were alternatively used as gas spargers. In order to study the influence of liquid properties several liquids are employed (i.e. water, aqueous glycerine, isobutanol solutions) covering a sufficiently broad range of viscosity (1.0-16.6 mPa.s) and surface tension (49-72 mN/m) values.

A high-speed digital video camera (*Redlake MotionScope PCI® 1000S*) is used for the bubble size measurements. The recorded images are also used to obtain an insight into the coalescence/breakage mechanisms occurring during bubble formation at the vicinity of the sparger. Using appropriate software (*Redlake MotionScope®*) the size distribution of the formed bubbles, *directly* after their detachment from the porous sparger surface, can be obtained from the recorded images for the various liquids and flow conditions employed (***Figure 2***). The uncertainty of the measurements is estimated to be less than 10%.

It is believed that this work will help to establish rigorous criteria for the prediction of the initial bubble size distribution at the homogeneous regime in bubble column contactors equipped with pore sparger.

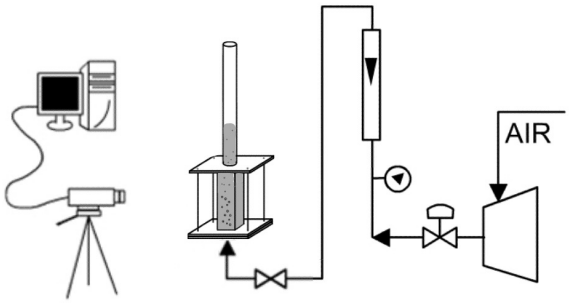

Figure 1. Experimental set-up

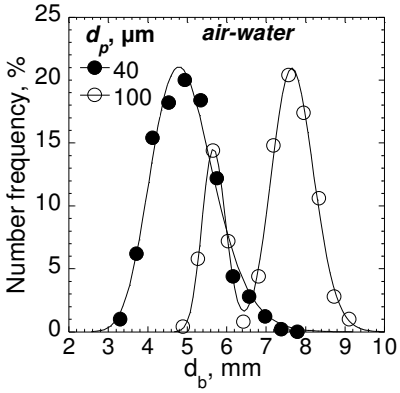

Figure 2. Typical initial bubble size distribution for the air-water system for both spargers.

References

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