EXPERIMENTAL INVESTIGATION OF GAS-LIQUID FLOW IN MONOLITH CHANNELS USING MONOFIBER OPTICAL PROBES

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Abstract

This work relates to experimental investigation of hydrodynamic parameters in co-current gas-liquid flow in monolith beds using an optical fiber probe. Parameters studied include local gas holdup, bubble frequency, bubble velocity, and bubble length distributions. The effect of flow velocities, fluid properties and different distributor configurations is reported. Finally, these observations are rationalized in the perspective of overall liquid distribution measurements done in the monolith beds under identical flow conditions.

Keywords

Monolith reactor, Monofiber optical probe, Bubble dynamics, Gas-liquid Distributor

Introduction

Monolith reactors are considered as potentially attractive for multiphase applications (Satterfield and Ozel, 1977). Many advantages have been reported in literature for their use in multiphase reactions such as negligible pressure drop, short diffusion lengths, mechanical integrity and superior mass transfer properties. The role of distributor has been recognized as major influence on hydrodynamics in monolith. The hydrodynamics above the monolith imposed by distributor (at the monolith inlet) is responsible for the hydrodynamics that translates and propagates inside the monolith channels. Besides this, for multiphase reactions, heat and mass transfer rates are strongly affected by the flow structure inside the channels (Bercic and Pintar, 1997; Kreutzer et al., 2005). Therefore, it becomes important to assess the local gas-liquid hydrodynamics inside monolithic channels.

Although several hydrodynamics studies in monoliths have been reported with advanced techniques such as MRI and computed tomography, the reported measurements have been limited to holdup data only. In addition, they have their limitations of being expensive with low spatial and temporal resolution. Optical fiber probes have been reported as a reliable and minimally intrusive measurement technique for gas-liquid flow (Boyer et al., 2002), and effective for getting a better insight into the local flow structure. Recently optical probe technique has been demonstrated to study bubble hydrodynamics inside monolith (Yuan et al., 2014). However, that study was limited to certain flow conditions for a particular distributor only.

In the present study the main objective is to experimentally investigate the hydrodynamic parameters such as local gas holdup, bubble frequency, bubble velocity, and bubble length for different distributors using mono fiber optical probes. The validation of using two monofiber probe technique and the developed processing is done with data obtained through simultaneous video imaging using a transparent capillary. In this work,

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different distributor configurations used are: *single pipe*, *multipipe* and *packed bed distributor*.

Methodology

Figure 1 shows the schematic of setup used to validate the measurements done by the optical probe. A 3 mm capillary is placed in a container filled with water. Air is introduced at the bottom of capillary using syringe infusion pump to generate bubbles in the capillary. Two mono fiber optical probes of 200 μm with 0.05 m apart are inserted in the capillary as shown. To validate the reliability, synchronous measurements are taken with optical probe and a high speed camera.

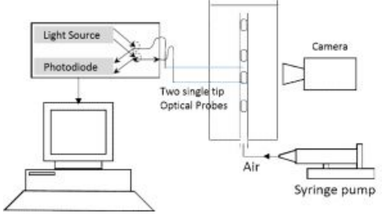
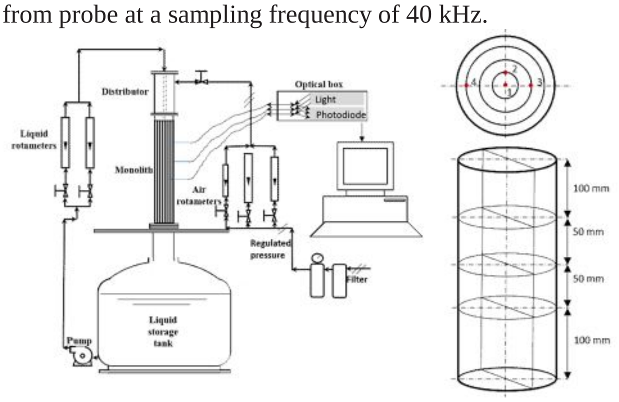


Figure 1. A Schematic of setup for the probe validation

The schematic monolith reactor flow setup used in the current work is shown in Figure 2(a). Monolith made of cordierite material, of diameter 0.076 m, length 0.305 m and of 200/12 part, which have been acquired from Corning Incorporated, USA, is used for the investigation. It is housed inside Perspex@ column, with a liquid distributor configuration above this. The cold model setup operates in the cocurrent downflow mode, using air as the gas phase and water as the liquid phase. The two phases are introduced at the top through different distributor configurations. A total of 12 optical probes are inserted into pre-selected channels at three axial levels as shown in **Figure 2(b)** and all the probes are connected to an A/D unit and then to a computer to record the output signals from probe at a sampling frequency of 40 kHz.



(a) *(b)*

Figure 2. (a) Monolith reactor flow setup (b)Optical probe positions in the monolith bed at r/R=0;0.25;0.5;0.75 and axialy at height of 0.1;0.15;0.2 m from the top

Figure 3 shows a comparison of a videometric image with the voltage signal obtained from one optical probe. Further data processing is done using Matlab subroutines. The local void fraction is then measured taking the ratio between the total duration for which the probe is in the air over the total acquisition time. Similarly local bubble frequency is obtained as the total number of bubbles hitting the probe's tip. Single bubble velocity is calculated from the lag time between the signals obtained from the two probes in same channel as discussed by Yuan et al. (2014).

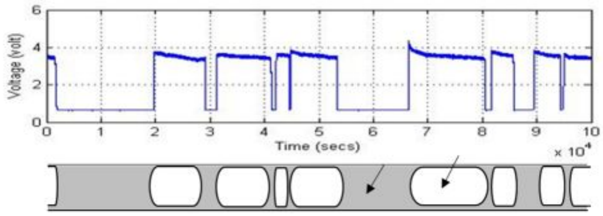


Figure 3. Typical recorded voltage signal

Outlook

The measured values of different hydrodynamic parameters obtained within the central channel is compared with those obtained at other radial locations. Finally all measurements are used to determine averaged values and assess the local gas-liquid distribution. Furthermore, the outcome of this study is compared with the results obtained with the flow distribution studies performed on the same monolith using gravimetric collection technique. A typical result of the flow distribution experiment is shown in Figure 4.

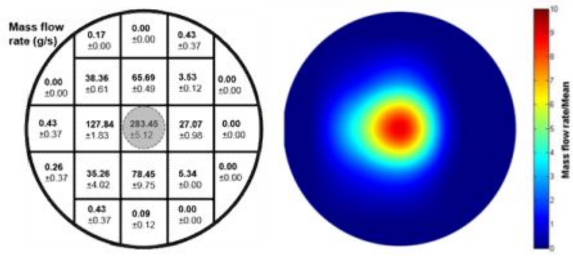


Figure 3. (a) Raw data plot and the corresponding (b) contour plot for single ½" pipe distributor obtained through liquid collection technique

The final contribution will discuss the trends of all the studied parameters with explanation for all the configurations.

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