Investigation of single bubbles rising in narrow rectangular channels with Particle Image Velocimetry

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Keywords: 2D PIV, multiphase flow, bubbles, narrow rectangular channel, rising path, Kármán vortex street

The detachment of deposition layers on flat sheet membrane surfaces with the help of aeration motivates the investigation of the rise of single bubbles in a narrow rectangular channel whereas the equivalent bubble diameter is in the range of the gap distance. The investigations are conducted in a model system consisting of a rectangular acrylic glass channel filled with water. The focus of this work is on the general flow behavior and the shear stress on the walls induced by the bubbles. The shear stresses are the crucial factor in the cleaning process of the membrane surface.

The three parameters channel depth (5-7mm), bubble size (3-9mm) and superimposed liquid velocity (0-20cm/s) can be varied in this investigation although the results shown here are all without superimposed liquid velocity. Rectangular acrylic glass channels with different channel depths were constructed. The width is 160mm and the height is 1500mm. At the bottom of the channel the needle of a 50ml Hamilton Gastight syringe can be inserted into the channel through a septum. The syringe is operated with a Harvard Apparatus Pump 11 Elite syringe pump which injects a specific volume of gas into a small cup which is fixed on a rotatable rod. This rotatable rod can be turned with a servo motor which again is located outside of the channel. Additionally inlets are located at the bottom of the channel through which liquid can be pumped with a defined volume flow. The system is automated with LabVIEW so that the whole process of establishing a defined liquid volume flow, inserting a bubble, releasing a bubble and recording the measurement data works automatically. The automation allows a high-level of repeatability which simplifies the analysis of the data.

The PIV system used for this study is a FlowMaster 2D-PIV system from LaVision. It consists of a pulsed Nd:YAG Laser with a maximum double pulse rate of 15Hz. The images are recorded with a progressive-scan Imager Pro SX 5M CCD camera with a 12bit range and a resolution of 2456 pixel by 2058 pixel. LaVision’s DaVis 8 is used for the data analysis. As the experiments are done with a multiphase flow, fluorescent particles and a cut-off filter for the lens are used to ensure that the CCD chip will not be destroyed by laser reflections from the bubble’s surface. The system is investigated from two sides. The long and the short edge of the channel is of interest to get a general understanding of the 3D rising behavior.

Figure 1 shows an exemplary flow pattern near a 5mm bubble rising in a channel with a channel depth of 5mm. The alternating, counter-rotating eddies in the bubble wake form a Kármán vortex street. With increasing eddy age, the eddies are stable regarding their rotational center but grow in size and decrease in vorticity.

Generally the focus here is on the rising path and shape of the bubble, the velocity field and the vorticity induced by the bubble. The results for the camera position normal to the long edge are according to findings for free rising bubbles. An oscillating movement of the bubble is found which results in a serpentine like rising path. This is further explained with clockwise and anti-clockwise rotating eddies in the wake of the bubble. The results for the camera position normal to the short edge show an oscillating movement for a bubble smaller than the channel depth as well but at the same time the development of the eddies in the wake seems to be hindered by the close walls.