International Conference on Multiphase Flow,
ICMF 2007, Leipzig, Germany, July 9 – 13, 2007

Tiny Bubbles and Droplets Measurement via Optical Fibre Probe Processed Using a Femtosecond Pulse Laser

Takayuki Saito

Graduate School of Science and Engineering, Shizuoka University
3-5-1 Johoku, Kita-ku, Hamamatsu, Shizuoka 432-8561, Japan
ttsaito@ipc.shizuoka.ac.jp

Keywords: optical fibre probe, single tip, bubble, droplet, femtosecond laser processing

Abstract

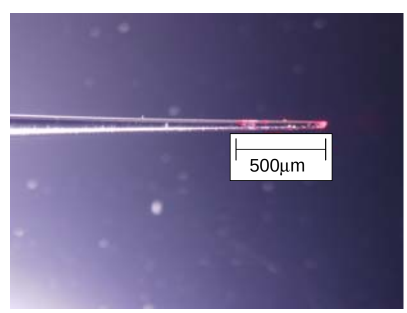
An optical fibre has interesting and useful characteristics, which are able to be applied to scientific measurement. Its Phase detection characteristic based on refraction difference between two phases was applied to bubbles/droplets measurement. Recently, demands for measurement of tiny bubbles/droplets increase in research fields of spray, automotive engine, fine chemistry, and so on. Meanwhile, laser science and engineering has made remarkable advances lately. Since femtosecond lasers spread in industry fields, their unique properties can be easily utilized for processing and measurement. In the present paper, a newly developed single-tip optical fibre probe processed using femtosecond laser is described, and its capability for simultaneous measurement of velocities and diameters of bubbles/droplets is discussed in consideration of surface tension and wettability of gas-liquid two-phase system.

Measurement of bubbles/droplets in gas-liquid two-phase flows is essential to elucidate the mechanism of the flows. Many studies on probe methods for measurement of void fraction, bubble velocities and diameters are frequently encountered. Serizawa et al. measured radial profiles of void fraction, velocities and diameters of bubbles in bubbly flows via conductivity probe, and tried to elucidate turbulence structure of the flows. Ishii et al. developed a micro four-sensor conductivity probe, and demonstrated its capability. Clark et al. studied influences of pierced positions on measured chord lengths in consideration of statistical factors.

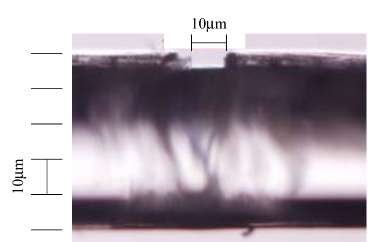
From the late 1970s when an optical fibre probe was proposed by Abuaf et al., the optical fibre probe method has been repeatedly improved in order to measure bubbles and droplets efficiently and reliably in gas-liquid two-phase flows. For rather large bubbles/droplets, a multi-tip optical fibre probe is very useful. However, simultaneous measurement of their diameters and velocities has been thought to need at least two optical fibre probes due to its measurement principle. Catellier et al. have been studying simultaneous measurement of velocities, diameters and void fraction of bubbles/droplets via monofibre optical probe energetically, and accomplished the amount of quality work.

Recently, a particular demand for measuring properties of micro bubbles/droplets has increased in multi-phase flow researches. For tiny bubbles/droplets measurement via optical fibre probe, a multi-tip probe is not applicable, because the multi-tip optical fibre probe is too large to surely pierce them. To break through this situation, the author newly developed a Single-Tip Optical-fibre Probe (S-TOP) which realizes simultaneous measurement of diameters and velocities of tiny bubbles/droplets. The author employed femtosecond pulse laser (here after, fs pulses) to process the S-TOP. In the S-TOP measurement, the relation between the reflected-light intensity at the wedge-shaped probe tip and the tip-surface area covered with a phase is used to realize the simultaneous measurement. Furthermore, a groove on the S-TOP processed using fs pulses is used to do it.

The surface tension and probe-surface wettability intensively influence the S-TOP signals. One of the aims of the present study is to evaluate the influences of surface tension and wettability on the bubble measurement in order to develop precise and reliable S-TOP method. The author specifies the gradient of leading edge (or trailing edge) of the S-TOP signal is proportional to the gas-liquid interface velocity. In the measurement of bubbles and droplets via S-TOP, this relation is effectively utilized. The influences of surface tension and probe-surface wettability on this relation are quantitatively discussed. At surface tension higher than about 50mN/m, the surface tension is dominant. On the other hand, at lower than this value, the wettability is dominant. On the basis of improvement in the consideration of the above results, the author demonstrates the simultaneous measurement of diam A and velocities of small bubbles/droplets with about 200 μm in diameter. In addition, results on bubble diameter and velocity via S-TOP processed by fs pulses are discussed.



S-TOP processed using fs pulses.



Close-up picture of groove processed by fs pulses.