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Ultra-fast x-ray tomography for multi-phase flow interface dynamic studies

Abstract

Use of X-ray CT (Computer Tomography) system has been extended from medical fields to a variety of industrial applications [1, 2]. Among them is the visualization of multi-dimensional void distribution of two-phase flow in tubes. Mitsutake et al. [3] and Morooka et al. [4] used medical X-ray CT scanners modified for void fraction measurement within rod bundles. The results were comparable with their predictions based on three-fluid model. Recently Tiseanu et al. applied cone beam tomography to bubbly flow in a vertical pipe and obtained sharper void peaks near the wall than previously reported [5]. Cone beam tomography is a 3D visualization technique and allowed them to collect multi-slice data in vertical direction within the same amount of scanning time as 2D systems. Gamma-ray is another form of generating high energy photons. Kumar et al. built a tomography system based on Cs-137 gamma ray source for void distribution measurement of a bubble column [6]. Although gamma ray sources eliminate the beam-hardening effect, low photon flux results in long scanning time. However, these systems are not applicable to dynamic interface detection of multi-phase flow because of low time resolution compared to transition time of interfaces. To visualize dynamic interfaces in multi-phase flow, time-resolved X-ray CT scanners have been developed by Hori and Akai [7], Hori et al. [8], and Misawa et al. [9] (Fig. 1). Scanning time of these systems is reduced by an order of two compared to existing ones. In pursuit of time resolution, however, spatial resolution is sacrificed due to less numbers of detector elements and views. The present paper describes the concept of fast scanning capability, hardware development, and measurement results of gas-liquid two-phase flow in a vertical pipe. Finally, to evaluate the measurement capability of the fast X-ray CT, the wire-mesh sensor [10] was installed in the flow loop and both systems were operated for the same two-phase flow simultaneously. The results showed that the time series of cross section averaged void fraction agreed to each other for slug flow at large void fraction, but that the wire-mesh sensor was suitable for bubbly flow at low void fraction. From the comparison of the time series data, coerced deformation of slug bubble interface was suggested for the wire-mesh sensor.

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