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Experimental and Numerical Analysis of Bubbly Flow in a 4x4 Rod Bundle under Oscillating Conditions

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Extended Abstract

Floating nuclear power plants (FNPP) have received significant attention because they can produce low-carbon electric power and heat for various applications [1]. The thermal-hydraulic behavior in the FNPPs may depend on the ocean condition, and the effect of the ocean condition on the thermal-hydraulic behavior should be investigated [2], [3].

In this study, experimental and numerical simulations were performed to investigate the local bubble behaviors in the 4×4 rod bundle under rolling conditions. The experimental setup consists of a circulating pump, electromagnetic flow meters, an air compressor, a mass flow controller (MFC), a water tank, and a rod bundle mounted on a rolling platform. The air supplied from the compressor was fed into the lower part of test section through the MFC and a porous plate to generate small bubbles. Water supplied from the pump was introduced to the lower part and mixed with bubbles to make the bubbly flow. The test section made of transparent acrylic is a square channel with a width, depth, and height of 100.8, 100.8, and 900 mm, respectively. Sixteen rods with a diameter of 19 mm were installed in a 4x4 square lattice arrangement with 6.2 mm between two adjacent rods. An optical-fiber Doppler probe (OFDP) was used to measure the local time-averaged bubble parameters in the cross-sectional plane at 800 mm from the inlet Two flow inlet conditions, two rolling amplitudes (θ_{max} = 5°, 10°), and two rolling periods (T = 6, 10 s) were considered. The numerical simulations were performed to investigate the instantaneous flow characteristics, using ANSYS FLUENT. To consider the rolling condition, a frame motion with a rotation vector was set to $\Omega = \theta_{\max}(2\pi / T)\cos(2\pi t / T)$, where $\theta_{\max}$ and T represent the rolling amplitude and period, respectively.

Experimental results showed that the time-averaged void fraction distributions are wall-peaking under both stationary and rolling conditions. The distribution of measured bubble velocity peaks in the core under stationary conditions and wall-peaking under rolling conditions. Regarding the time-averaged bubble size distribution, larger bubbles are concentrated higher in the near-wall regions, while smaller bubbles show an opposite trend. The time-averaged results indicated that the rolling amplitude had a greater effect on the characteristics of the bubble than did the rolling period. Numerical simulations showed a good agreement with the experimental data. The instantaneous flow fields provided a better understanding of bubbles' complex behavior in the rod bundle channel under rolling conditions.

Keywords: rod bundle, local bubble behavior, rolling condition, optical-fiber Doppler probe

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