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BRIEF COMMUNICATION

EFFECT OF FLOW OBSTRUCTION ON VOID DISTRIBUTION IN HORIZONTAL AIR-WATER FLOW

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INTRODUCTION

Horizontal two-phase flow is of significant practical importance in the petroleum, chemical and nuclear industry. Therefore, much research effort has been expended in this area to understand the basic two-phase flow behavior and to obtain reliable thermohydraulic correlations and data to be used by designers.

The purpose of the present study is to investigate the effect of flow obstructions on void distributions in horizontal channels. The problem is of practical interest because of its similarity to the rod spacing devices in water-cooled nuclear reactors with a horizontal core configuration. The spacing devices are used mainly to maintain the bundle configuration in fuel assemblies. They affect the thermohydraulics in reactors by increasing the mixing between fuel subchannels and hence creating more favorable heat transfer conditions.

Two different shapes of flow obstructions were considered: one peripheral and one central as illustrated in figure 1, each resulting in a flow blockage of 25% of the flow area. The investigation was carried out in the annular, slug and bubbly flow regimes.

EXPERIMENTAL APPARATUS AND PROCEDURES

A schematic of the experimental loop is shown in figure 1. The test section consists of a 25.4 mm i.d., 3 metre long horizontal plexiglass tube. The air (max. flow 0.2 kg/s) and water (max. flow 1.7 kg/s) pass through a honeycomb mixer and a 3.05 m long calming section before encountering the flow obstruction. The test section can be rotated, thus, permitting local void fraction measurements at different angular locations. Along the test section, provisions were made to measure average and local void fractions.

To measure the average void fraction, quick-closing valves were located 1.22 m apart. These valves did not introduce any flow obstruction when fully opened.

To measure the local void fraction, a miniature optical probe was used in conjunction with a phase indicator and a void fraction unit. The signal provided by the probe is amplified and processed to obtain the integrated void fraction over various time intervals (0.1, 1, 10, 100 sec).

The test section can be rotated after installation thus permitting local void fraction measurements at different angular locations. Three measurement stations were located along the test section (figure 1). To obtain a cross-sectional average void fraction $\bar{\alpha}$, half of the cross-section was divided into 95 segments (the void fraction distribution was assumed to be symmetric with respect to the vertical axis). In the center of each of these

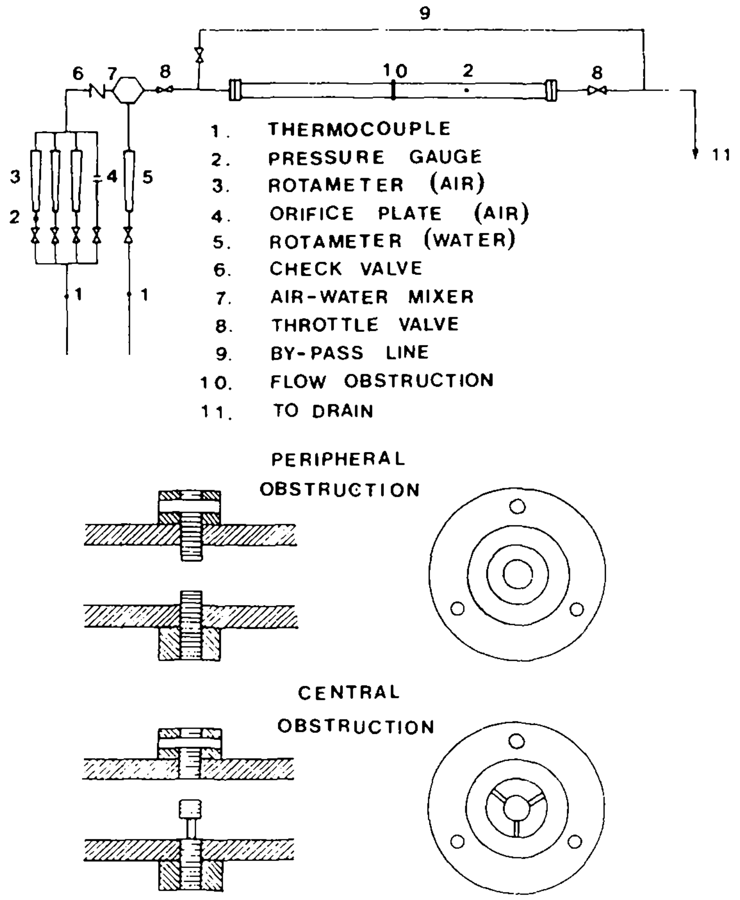

Figure 1. Experimental loop with the measurement stations.

95 segments, the void fraction was obtained experimentally and the value found was assumed to be representative of the void fraction in the whole segment. The cross-sectional average void fraction can be approximated numerically as:

$$\alpha = \frac{\sum \alpha_i A_i}{\sum A_i} \qquad [1]$$

where α_i is the measured void fraction and A_i the cross-sectional area of segment i.

This void fraction was compared with the value obtained with the quick-closing valves.

Results and discussions

The experimental results were obtained for bubbly, slug and annular flow regimes. In all cases the flow rate is sufficiently low for the buoyancy forces to become significant when compared to the inertia forces leading to a partially stratified flow.

The strongest effects of flow obstructions were observed in the bubbly flow regime shown in figures 2(a, b), affecting both the upstream and downstream phase distributions. The bubble velocity decelerates well ahead of the flow obstructions, and significant mixing takes place just downstream. The turbulence introduced by the flow obstructions results in a breakup of the bubbles and strong secondary currents as evidenced by the appearance of gas near the bottom of the test section at tap 2. A velocity ratio smaller than 1.0 as observed for the central

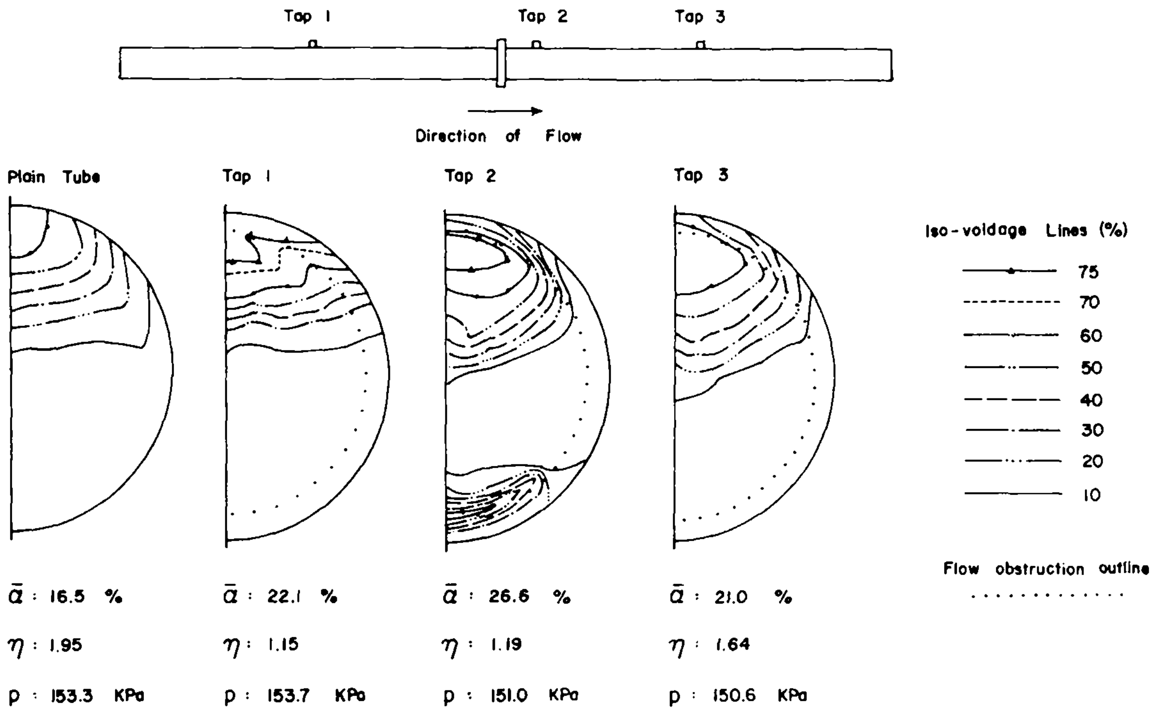

Figure 2(a). Change of void distribution. Peripheral obstruction. Bubbly flow. Water: 1.1 kg/s. Air: 0.000775 kg/s. Quality: 0.0704%.

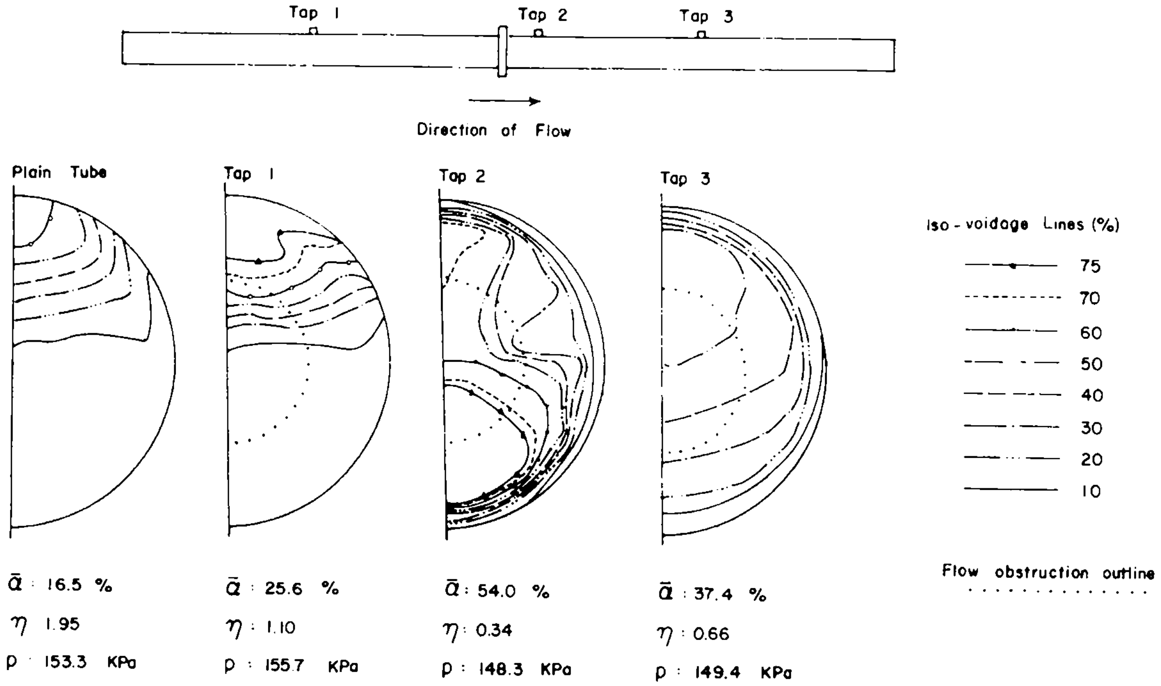

Figure 2(b). Change of void distribution. Central obstruction. Bubbly flow. Water: 1.1 kg/s. Air: 0.000775 kg/s. Quality: 0.0704%.

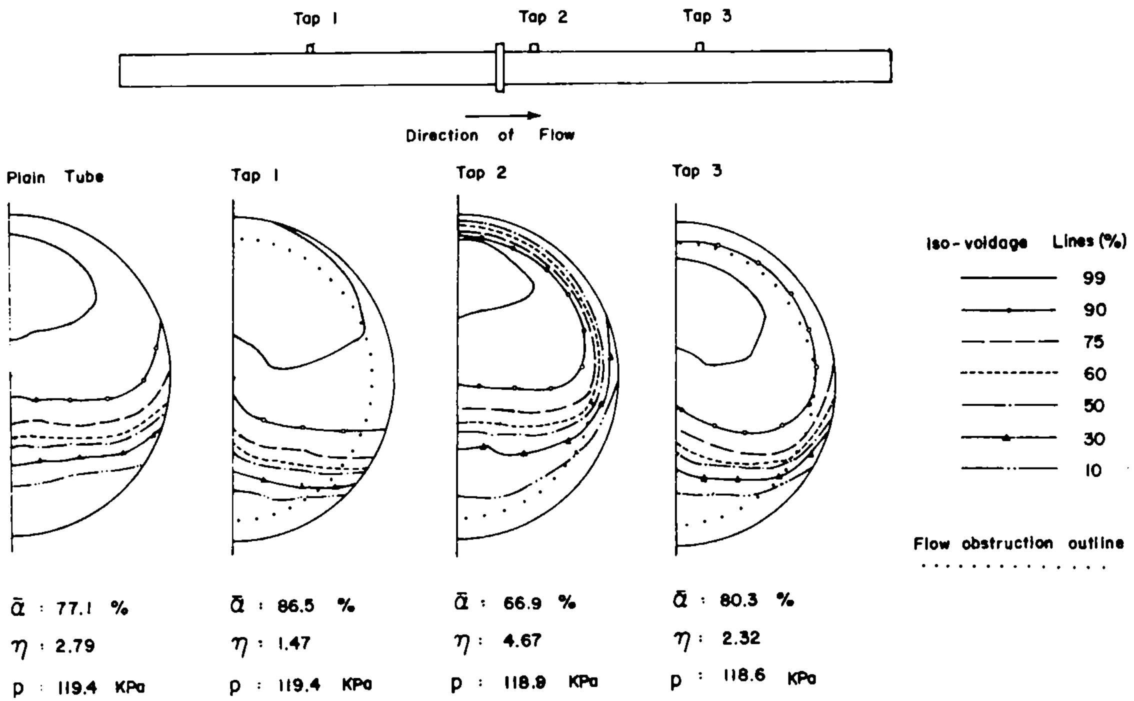

Figure 3. Change of void distribution—peripheral obstruction. Slug flow. Water: 0.2 kg/s. Air: 0.00268 kg/s. Quality: 1.32%.

obstruction suggested possible recirculation. At tap 3 ($L/D = 12$) the phase distribution recovers for the peripheral obstruction; for the central flow obstruction which has a considerably stronger effect, the flow does not recover until $L/D > 30$. Note that the dotted line indicates the outline of the flow obstructions (shown in detail in figure 1).

For annular flow, both types of flow obstructions result in an acceleration of the lower density phase, hence an increase in the velocity ratio and a decrease of the void fraction. Visual observations indicate that significant air entrainment inthe liquid film occurred just downstream of the peripheral flow obstruction.

The central flow obstruction appears to have a stronger effect on the phase distribution, presumably because it intercepts the faster flowing central fluid. This obstruction seems to homogenize the two-phase mixture and counteract the buoyancy forces to a greater extent than the peripheral flow obstruction. The effect of flow obstructions becomes small for $L/D > 15$.

In general, annular flows are considerably less affected by obstructions than bubbly flows. It was found that the average of the measured void valued decreased by less than 5%.

The slug flow is more affected by the obstruction than the annular flow. Because of the presence of the slugs primarily in the upper part of the test section, the peripheral obstruction affects the phase distribution to a greater extent than the central obstruction. In figure 3, a large reduction in velocity ratio just before and a large increase just after the peripheral obstruction can be noticed. Visual observation showed that just downstream of the obstruction, the flow regime resembles stratified annular flow while the slugs of air are formed again near tap 3, twelve diameters downstream.

CONCLUSIONS

The flow obstructions tested affect the flow regime, the upstream and downstream void fraction. The shape of the flow obstruction and the initial flow regime are significant factors in determining the flow obstruction effect. For $L/D > 30$ the flow obstruction does not appear to affect the phase distribution.

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