A Rapid Response Impact Tube in Two-Phase Flow

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In a study of mercury-nitrogen cocurrent bubbly flow, Neal and Bankoff (*1*) measured time-averaged pressures on an impact tube. They found that for low nitrogen volume fraction the time-averaged dynamic pressure was nearly double the dynamic pressure for an equal mass velocity mercury flow without nitrogen bubbles. They argued that the higher pressure resulted from the liquid's acting as a series of liquid slugs separated by bubbles which, since they are not appreciably slowed down before impinging on the probe, generate an impulse pressure equal to the liquid density times its velocity squared.

EXPERIMENT

Since this result is rather surprising, an experiment was planned in which both time-averaged and nearly instantaneous probe pressure could be measured. A 1/32 I.D. stainless capillary impact (or total pressure) tube was inserted into an air-water mixture flowing upward in a plexiglas tube. For time-averaged dynamic pressure reading this probe was attached to one leg of an inclined manometer while the other leg was connected to a static pressure hole at the tube wall. Rapid variation in total pressure was sensed by attaching the probe directly to a quartz piezoelectric pressure transducer. For both arrangements bubbles were prevented from entering the probe by a slow purging stream of water metered through a coil of 0.015 in. I.D. capillary tubing. The flow over the probe and the oscilloscope trace indicating the measured total pressure were simultaneously photographed using a standard Fastex 16 mm. camera.

RESULTS

It was expected that before the initial contact of a bubble the probe would indicate the total head of the liquid (static plus dynamic pressure). Further, when a bubble passed over the probe tip, the total head would decrease by the liquid dynamic head since the air density is negligible relative to the liquid density. Figure 1 shows a typical oscilloscope trace reproduced from the Fastex record for a flow with small air volume fraction. In this flow, bubble impinging and departure on the probe were visible; they have been marked on the figure. Several points are of interest. The amplitude of the pressure drop was within 10% of the local liquid dynamic pressure as calculated from the observed bubble velocity (assuming no local slip). The rapidity of the pressure drop was consistent with an approximate probe response time calculation. The lag in pressure return is unexplained. The oscillation in pressure reading between bubbles is a static pressure oscillation due primarily to bubble collisions with the nearby probe support.

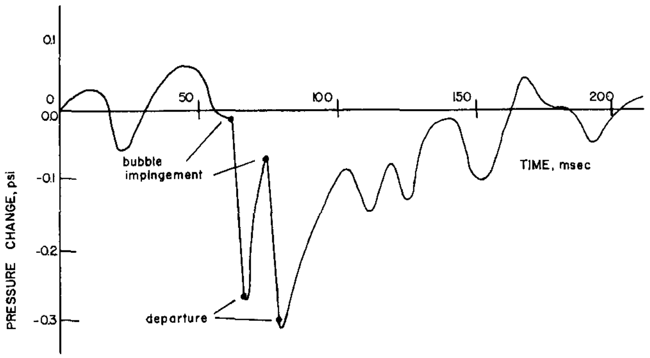

Fig. 1. Rapid response probe signal.

Based on these observations one would expect the time averaged dynamic pressure in two phase flow to be less than $\frac{1}{2}\rho V^2$ where V is the true average liquid velocity, and this was verified. The probe was connected to the inclined tube manometer and readings taken at different radial and axial positions for air-water flow with from 25 to 60% air volume fraction and superficial liquid velocity of 6 ft./sec. The time-averaged dynamic head read on the manometer was converted to an indicated liquid velocity by the usual dynamic head formula ($\frac{1}{2}\rho V^2$). For known air, Q_V, and water, Q_L, volume flow rates Marchaterre and Hoglund (*2*) give expected slip ratio, S, defined as the ratio of air to water velocity. The average liquid velocity may then be calculated from $\overline{U} = (Q_V + SQ_L)/SA_t$. The ratio of the liquid velocity indicated by the impact probe to the local calculated liquid velocity ranged from 0.45 to 0.79 with higher values occurring farthest downstream from the mixing location.

The agreement which is seen to exist between the instantaneous and time-averaged dynamic pressures shows that for air-water flows the theory of Neal and Bankoff does not hold.

LITERATURE CITED

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2. Marcheterre, J. F., and B. Hoglund, *Nucleonics*, **20**, No. 8, 142, (Aug., 1962).

Gas Holdup of a Bubble Swarm in Two Phase Vertical Flow

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The rise of a gas bubble in a confined liquid medium is somewhat analogous to the corresponding sedimentation of a solid particle; but this analogy has been misinterpreted in the past by various authors who were therefore obliged either to set narrow operating limits on the validity of their equations (*3*) or to correct them by means of empirical factors (*4*). Marrucci (*7*) derived an expression for the rise velocity of a swarm of bubbles and concluded that the rise velocity showed a weaker dependence on the fraction of solid in suspension than the settling velocity of a multiparticle suspension of rigid spheres following Happel's free surface model (*8*) (Figure 1.). He noted qualitatively that the sparse data of Nicklin (*10*) and his own data indicated a relatively small decrease in rise velocity with increasing ϵ, but quantitatively his model failed to agree with the experimental data of various other investigators. Although no explicit mention is made of the radius of bubbles which make up the swarm, Marrucci's model does implicitly indicate the effect of bubble radius on the rise velocity of the swarm.

Mendelson (*6*) recently derived an equation for predicting the rise velocity of single bubbles in infinite media