Letters to the Editor

Effects of Phase and Velocity Distribution on Two-Phase Pressure Pulse Propagation

Gidaspow et al.[1] have developed an unequal velocity model for transient two-phase flow and compared their results with the air/water pressure pulse propagation data of Miyazaki et al.[2] Gidaspow et al. suggest that the significant discrepancies between prediction and experimental data at higher void fractions are associated with heterogeneity in the slug flow regime. They assume that this discrepancy may be attributed to stress terms that are not allowed for in their model.

This explanation is not supported by the pressure pulse propagation velocity data of Martin and Padmanabhan,[3] which, although obtained for slug flow conditions, are consistent with the adiabatic expansion prediction of Gidaspow et al.

The influence of flow pattern on low quality two-component pressure pulse propagation velocity may instead be related to thermal effects: Slug flow patterns are not conducive to interphase thermal exchange, so propagation phenomena are best viewed in terms of adiabatic compression or expansion of the gas phase. Conversely, if the gas is distributed as bubbles, the increased interface area improves thermal exchange, and propagation occurs with isothermal compression or expansion of the gas.

The discrepancy between the theory[1] and experimental data[2] can be explained in terms of inadequate allowance for "slip" between the phases, rather than for interphase stress terms. Average cross-sectional slip values are usually determined by (a) using a drift velocity V to correct for local differences in phase velocity and (b) incorporating a "distribution parameter" C_0 to allow for the concentration of the gas phase in the faster moving region of the flow. Thus, following Zuber and Findlay,[4] the mean gas velocity $\bar{U}_g$ is related to the mean mixture velocity $\langle j \rangle$ by

$$\bar{U}_g = C_0 \langle j \rangle + V \ . \tag{1}$$

The one-dimensional treatment of slip by Gidaspow et al.[1] allows for local drift velocity V but neglects distribution effects; i.e., it assumes that $C_0 = 1$. With regard to the relative importance of C_0 and V on propagation phenomena, an analysis by Beattie[5] indicates that pressure pulse velocity:average voidage characteristics ($c : \langle \alpha \rangle$) are independent of the drift velocity (treated as a constant), but vary significantly with the distribution parameter C_0. For adiabatic gas expansion, the analysis indicates that the pressure pulse velocity is approximated by

$$c = \left\{ \frac{\gamma p / \rho_l}{\langle \alpha \rangle (1 - C_0 \langle \alpha \rangle)} \right\}^{1/2} \ . \tag{2}$$

In Fig. 1, Eq. (2), with a distribution parameter value of 2, is superimposed on the Gidaspow et al.[1] comparison of their theory with the data of Miyazaki et al.[2] The good agreement of Eq. (2) with the data suggests that the theoretical data would achieve similar agreement if the phase and velocity distribution effects were incorporated into the treatment of slip.

The velocity distribution parameter value (i.e., 2) required to achieve agreement with the nonflow data of Miyazaki et al.[2] is larger than the value expected for developed flows (i.e., 1.2). However, pressure pulse propagation data for flowing two-component systems, such as the data of Hamilton et al.[6]

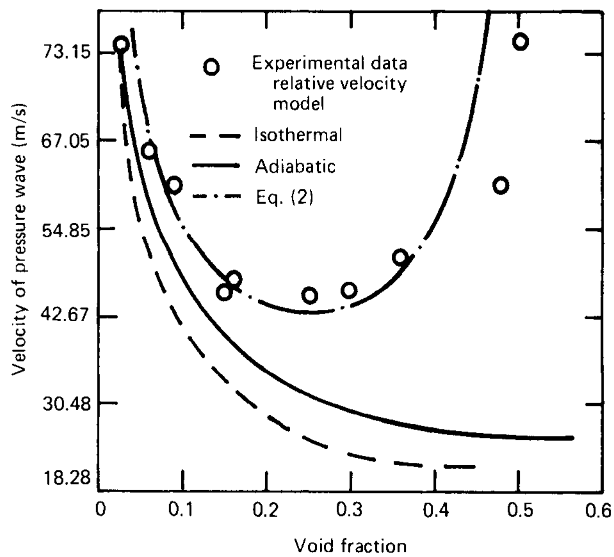

Fig. 1. A comparison of Eq. (2) with the predictions of Gidaspow et al. (Ref. 1) and the propagation velocity data of Miyazaki et al. (Ref. 2). (Adapted from Fig. 9 of Ref. 1.)

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[1] D. GIDASPOW, F. RASOULI, and Y. W. SHIN, *Nucl. Sci. Eng.*, **84**, 174 (1983).

[2] K. MIYAZAKI, Y. FUJII-E, and T. SUITA, *J. Nucl. Sci. Technol.*, **8**, 606 (1971).

[3] C. S. MARTIN and M. PADMANABHAN, *J. Fluids Eng.*, **101**, 44 (1979).

[4] N. ZUBER and J. A. FINDLAY, *J. Heat Transfer*, **87**, 453 (1965).

[5] D. R. H. BEATTIE, "Pressure Pulse and Critical Flow Behaviour in Distributed Gas-Liquid Systems," *Proc. 2nd Int. Conf. Pressure Surges*, London, British Hydromechanics Research Association (1976).

[6] L. F. HAMILTON, R. NYER, and V. E. SCHROCK, *Trans. Am. Nucl. Soc.*, **10**, 660 (1967).

(also quoted by Gidaspow et al.) and Martin and Padmanabhan,[3] are described by Eq. (2) with $C_0 = 1.2$.

Beattie's analysis indicates that the distribution parameter also influences choked flow velocities. It is recommended that two-phase propagation analyses, such as that of Gidaspow et al.,[1] incorporate phase and velocity distribution effects in the treatment of slip between the phases.

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Reply to "Effects of Phase and Velocity Distribution on Two-Phase Pressure Pulse Propagation"

It is very nice that Beattie[1] was able to fit the pressure pulse propagation data with just one fitted parameter. His simple expression for critical flow is useful. However, in the age of supercomputers, the empirical distribution or the drift flux theory as ably presented by Nicoll et al.[2] has been to some extent superceded by the two-fluid theories, such as the one we had presented for one-dimensional flow. For two dimensions, we[3-6] recently used a two-fluid theory to predict time-averaged void fractions, bubble sizes and shapes, and velocity profiles for fluidization of solid particles without the use of any fitted parameters. A stress term was used to keep the particles from collapsing to a volume fraction of one. Beattie's remarks and his use of fitted parameters show that more work is needed to fully understand unequal velocity, critical two-phase flow.

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[1] D. R. H. BEATTIE, *Nucl. Sci. Eng.*, **86**, 241 (1984).

[2] G. INAYATULLAH and W. B. NICOLL, "Application of the Drift-Flux Formulation to the Prediction of Steady, Periodic and Transient Two-Phase Flows," *Proc. NATO Advanced Study Institute, Two Phase Flows and Heat Transfer*, Vol. 1, p. 209, S. KAKAC and F. MAYINGER, Eds., Hemisphere Publishing Corp., Washington, D.C. (1977).

[3] D. GIDASPOW, C. LIN, and Y. C. SEO, *I&EC Fundamentals*, **22**, 187 (1983).

[4] D. GIDASPOW and B. ETTEHADIEH, *I&EC Fundamentals*, **22**, 193 (1983).

[5] D. GIDASPOW, Y. C. SEO, and B. ETTEHADIEH, *Chem. Eng. Communications*, **22**, 253 (1983).

[6] B. ETTEHADIEH, D. GIDASPOW, and R. W. LYCZKOWSKI, "Hydrodynamics of Fluidization in a Semi-Circular Bed with a Jet," accepted for publication in *AIChE J.* (1983).