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An analytical relation for the void fraction distribution in a fully developed bubbly flow in a vertical pipe

O. Marfaing[a*], M. Guingo[b], J. Laviéville[b], G. Bois[a], N. Méchitoua[b], N. Mérigoux[b], S. Mimouni[b]

[a]Den-Service de thermo-hydraulique et de mécanique des fluides (STMF), CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France

[b]Electricité de France R&D Division, 6 Quai Watier, F-78400 Chatou, France

[*]Corresponding author. olivier.marfaing@cea.fr

Summary

The problem of a steady, axisymmetric, fully developed adiabatic bubbly flow in a vertical pipe is studied analytically with the two-fluid model. The exchange of momentum between the phases is described as the sum of drag, lift, wall and dispersion contributions, with constant coefficients.

Under these conditions, we are able to express analytically the void fraction profile as a function of the liquid velocity and pressure profiles. This relation is valid independently of the Reynolds stress model in the liquid phase – and can serve as a verification case for multiphase flow codes.

The analytical void fraction profile vanishes at the wall, as a result of the balance between dispersion and wall forces. It presents a peak near the wall for upward flows, whereas its maximum is reached in the center of the pipe for downward flows. This is illustrated by calculations performed for upward and downward bubbly flows with the NEPTUNE_CFD code.

Keywords: two-fluid model, analytical relation, verification, wall force, lift force, dispersion force, drag force, NEPTUNE_CFD

Notations

B constant in equation (22), determined from the knowledge of the average void fraction over a cross-section

C_D drag coefficient

C_L lift coefficient

C_{W1} , C_{W2} wall coefficients