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Slug and Churn Flow Induced Forces on Piping in Vertical Upward Flow – A CFD Study

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Abstract

Internal multiphase flow-induced vibration (MFIV) in pipe bends poses serious problems in oil and gas, nuclear and chemical flow systems. The problems include high amplitude displacement of the pipe structure due to resonance, fatigue failure due to excessive cyclic stress induced by fluctuating forces and structural wear due to relative motion of pipe and its support. Numerical simulations of two-phase flow induced fluctuating forces and its frequencies at a vertically upward pipe with 90^0 bend have been carried out to investigate the characteristics of MFIV in pipes of 0.0525m, 0.1016m and 0.2032m internal diameters (I.D.). The CFD simulations of 35 cases of slug, cap bubbly and churn turbulent flow induced fluctuations at the bends were carried out using the volume of fluid (VOF) model for the two-phase flows and the $k-\epsilon$ model for turbulence modelling. Simulations results based on 0.0525m I.D. show good agreement of the volume fraction fluctuation frequencies of slug and churn flows with the reported experiment of Liu et al [1]. The behaviours of the flow induced void fraction, forces and stress as functions of gas superficial velocities in the 0.0525m I.D. pipe showed a good correlation to the observed behaviours in the 0.2032m I.D. pipe. The same correlation was not prominent in the 0.1016m I.D. pipe and was attributed to the transition behaviour of gas-liquid two-phase flows caused by Taylor instability in pipes of non-dimensional hydraulic diameter of $18.5<D_h*<40$. Also, based on the present study, modification of Riverin correlation [2] which was based on small scale laboratory experiment to predict RMS of flow induced forces was carried out by adjusting the constant parameter C to 20. This modification, improved the predictive capability of the model for a wider range of pipe sizes and gas volumetric fractions between 40% and 80%.

References

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[2] J. L. Riverin, E. Langre and M. J. Pettigrew, “Fluctuating Forces Caused by Internal Two-phase Flow on Bends and Tees”. J. Sound Vib., Vol. 298, 2005, pp. 1088-1098.