FINITE ELEMENT STUDY OF GAS-SOLID FLOW IN VERTICAL PIPES

by

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CERTIFICATE

This is to certify that the thesis entitled **FINITE ELEMENT STUDY OF GAS-SOLID FLOW IN VERTICAL PIPES** being submitted by **Rajeev Jain** to the **Indian Institute of Technology, New Delhi (India)** for the award of the degree of Doctor of Philosophy in Applied Mechanics Department is a bonafide research work carried out by him under our supervision and guidance. The research reports and the results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

An Eulerian-Eulerian model is used to simulate gas solid flows in vertical pipes. In this model the carrier phase and the particulate phase are treated as two interacting and coexisting continua. Continuum equations for the phases derived by volume averaging of the instantaneous single-phase equations are used. The volume-averaged equations obtained are further time-averaged to obtain the mean equations for the turbulent flow. Both the gas and the particle phase are considered to be Newtonian fluids.

Two-equation k-ε turbulence model is employed for the carrier gas. The standard model for single-phase flow is modified for presence of particles in line with the formulation of Elghobashi and Abou-Arab (1983). The interaction due to drag was considered in the momentum equations of the phases.

The two-dimensional elliptic system of equations is solved by the finite element method. Weak Galerkin formulation is used. The primitive variable formulation is employed. A Picard-type iteration scheme is utilized to handle the non-linearity in the advection terms, average properties and transport coefficients of the phases. Eight-noded isoparametric elements are used. Pressure is approximated by bilinear interpolating functions. Wall functions are employed for both the phases to model the flow close to the wall. Option of upwinding is incorporated.

A computer code is developed based on this formulation. It is validated for cases of developing laminar and turbulent pipe flows. The results of two-phase case are compared with the experimental results of Tsuji *et al.* (1984) and are found to be in reasonable agreement.

Parametric studies are carried out to determine the effect of different variables on the flow quantities like the hold up, pressure drop, turbulence intensity, velocity and gas and particle viscosity. The significant variables of the problem and their ranges considered are pipe diameter from 30.5 to 100 mm, particle diameter from 100 to 600 microns, volumetric concentration from 0.25% to 2.0%. Numerical values of slip and pressure drop are compared with the correlations available in literature. A correlation for slip ratio is derived using multiple regression analysis. The solid friction factor is found to lie in the range 0.01 to 0.02.

The use of finite element code in design of vertical pipes is illustrated by means of a sample design problem.

A wear model is used to estimate the erosion of pipe from the computed two-phase flow field. The effect of the parameters on the wear rate is also studied The wear rate increased as the cube of gas velocity and linearly with volumetric concentration of particles and decreased slightly with particle diameter.

A CFD code 'FLOW2P' is developed based on the Eulerian model using the finite element method, which will give the designer a tool for the design of vertical gas particle flow systems and enhance his confidence in predicting their performance.

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