A STUDY ON THE FLOW OF MULTI-SIZED PARTICULATE SOLID-LIQUID MIXTURES IN HORIZONTAL PIPELINES

By

RAKESH MISHRA
Department of Applied Mechanics

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DEDICATED TO MY PARENTS

Father: Sri. R. P. Mishra

Mother: Smt. P. K. Mishra

CERTIFICATE

This is to certify that the thesis entitled **A STUDY ON THE FLOW OF MULTI-SIZED PARTICULATE SOLID-LIQUID MIXTURES IN HORIZONTAL PIPELINES** being submitted by **Rakesh Mishra** to the **Indian Institute of Technology, Delhi (India)** for the award of the **Degree of Doctor of Philosophy in Applied Mechanics** is a record of bonafide research work carried out by him under our supervision and guidance. The thesis in our opinion, has reached the requisite standard fulfilling the requirement of Doctor of Philosophy Degree.

The research report and the results presented in this thesis have not been submitted in parts or in full to any other University or Institute for the award of any degree or diploma.

Singh 22/7/96

(S.N. Singh)
Professor
Deptt. of Applied Mechanics
Indian Institute of Technology
New Delhi- 110016

V. Seshadri 22.7.96

(V. Seshadri)
Professor
Deptt. of Applied Mechanics
Indian Institute of Technology
New Delhi- 110016

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Rakesh Mishra
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(RAKESH MISHRA)

ABSTRACT

Slurry pipelines are being extensively used for transporting solid materials in bulk quantities over large distances in various industries. The present knowledge of the flow mechanics of solid-liquid mixtures is far from complete. There is substantial empiricism in the design methodologies for slurry pipelines used for multi-sized particulate solid-liquid mixtures. The present study is aimed towards the better understanding of different facets of the flow of multi-sized solid-liquid mixtures. Based on the literature review the scope of the present study was envisaged. Different aspects of the work carried out are outlined below.

(i) Determination of concentration and velocity fields in pipeline for multi-sized particulate slurry flow.

(ii) Design and development of wear resistant bends and to investigate the wear and flow characteristics in the conventional and modified bends.

(iii) Prediction of flow parameters for the flow of multi-sized particulate solid-liquid mixtures in horizontal pipelines.

The experimental studies have been carried out in a pilot plant test loop existing in the Fluid Mechanics Laboratory of the I.I.T. Delhi. Special fixtures were fabricated to carry out the concentration and velocity field studies. Modified bends were also fabricated and installed in the same loop to study the wear and flow characteristics in these bends.

Flow of solid-liquid mixtures in pipelines is generally in heterogeneous regime. Currently, the concentration is assumed to be constant along horizontal chords which may not be really true. The particle sizes vary over three orders of magnitude for multi-sized slurries and hence are affected differently by the flow parameters. In the present study, the concentration distribution and the distribution of different particle

sizes has been measured experimentally along six horizontal chords at different heights from bottom of the pipe to establish the effect of flow velocity and efflux concentration. The study has revealed that the larger size particles are non-uniformly distributed both along the vertical and the horizontal planes. The finer particles however are distributed uniformly throughout the pipe cross-section.

Reported studies on the velocity field in a pipeline of a multi-sized slurry flow are limited. A two-hole offset probe with a modified differential pressure measuring system has been used in the present study for the determination of the velocity field for the flow of multi-sized particulate solid-liquid mixtures in a pipeline over a wide range of efflux concentrations and flow velocities. Velocity measurement along four diametrical planes namely, vertical, horizontal and two diagonal planes ($\pm 45^0$ planes) show that velocity profiles along vertical plane are asymmetric with peak velocity point displaced towards the top wall. Velocity profiles were also asymmetric along the two 45^0 planes with extent of asymmetry being less than the vertical plane. Along the horizontal plane, the velocity profile was seen to be symmetric.

An attempt has been made to develop wear resistant bends for the flow of solid-liquid mixtures in a pipeline. The two bends designed and fabricated are diverging-converging in shape and have same inner radius as the conventional bend but gradually varying area of cross-section. The area of cross-section of these bends increased from inlet to the centre and then decreased from centre to the outlet. The area ratios of the two bends were 1.5 and 2 respectively. Extensive wear tests have been performed on three bends namely, conventional bend and two modified bends. Experiments have shown that modified bend with an area ratio 2 is less prone to wear as compared to the other two bends. The maximum wear in area ratio 2 bend is even less than the maximum wear in straight pipe. Solid distribution across the

middle plane of the bends was also measured to establish dependence of wear on solid distribution pattern. Analysis of the data has shown that solids are more uniformly distributed in modified bends and there is no tendency of the particles to move out. It is also observed that modified bends are less susceptible to deposition as compared to straight pipe and conventional bend. Pressure drop studies on these bends has shown that pressure drop across modified bends is higher in comparison to the conventional bend.

Accurate prediction of flow parameters helps in designing a slurry pipeline optimally. In present study, different models available in literature for prediction of flow parameters such as pressure drop, concentration profile, velocity profile and wear rate have been identified and their applicability to the flow of multi-sized slurries analyzed. Comparison between predicted and author's data showed discrepancies which prompted author to attempt modifications in some of the existing models. Suitable modifications were incorporated to increase the accuracy and range of applicability of such models. One of the important modification incorporated is the use of static settled concentration in place of maximum packing concentration as a correlating parameter, since for a multi-sized slurry static settled concentration can be determined more easily and accurately as compared to maximum packing concentration. Experiments were conducted to establish the dependence of static settled concentration on particle size and specific gravity. Results show that static settled concentration increases with increase in particle size and decreases with increase in particle density. Based on the results, an empirical correlation has been proposed for predicting static settled concentration of multi-sized slurries using weighted mean diameter as the representative particle size.

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