STM JOURNALS

Research & Reviews: Journal of Physics
ISSN: 2278-2265 (Online), ISSN: 2347-9973 (Print)
Volume 8, Issue 1
www.stmjournals.com

Computation Modelling for Fine Particle Flow in Horizontal Slurry Pipelines

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Abstract

The coal based thermal power plant in India faces the problem of dumping of coal ash. The coal ash produced by thermal plant is transported to dumping site through slurry pipeline. The flow of fine particles at higher flow velocity in slurry pipeline is a matter of curiosity. The transportation of coal ash slurry at higher flow velocity leads to high pressure drop and requires large pumping power which ultimately affects the economy of transportation. In this study, Computational modeling using ANSYS FLUENT 17 is done for flow of Bi modal slurry of Silica sand and Fly Ash (90:10) in horizontal pipeline at flow velocity 1.78 m/s and 2.67 m/s for solid concentration 8.77% by volume. The modeling outcomes are validated with the experimental results. It is observed that the fine particles of Fly Ash in Coarser Silica sand uniformly distribute the particles and reduce the sedimentation effect. The modeling results fairly satisfy the experimental outcomes from pilot plant test loop.

Keywords: *bi-modal slurry, CFD modelling, fine particles, flow velocity, pressure drop*

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INTRODUCTION

In coal base thermal power plant, the transportation of coal ash slurry through pipelines required large input power. Various alternative energy sources with optimised hybrid power system can be used for effective utilization of input power [1]. The pipelines designed for long distance transportation of slurry are dependent on various flow parameters like critical deposition velocity, static settling concentration and pressure drop along pipeline and bends. The other major design factor, i.e., operational stability and corrosion-erosion parameters are also influenced by these flow parameters. Hydraulic conveying of solid particles through pipeline is regularly utilized as a part of industries because of its few inalienable points of interest, for example, persistent conveyance, adaptable directing, ease in mechanization and long separation transport capacity. Pipeline bends causes relatively higher pressure drop compared to the straight pipelines and leads to excessive erosion. The flow in bends for hydraulic conveying of solids particles is much more complicated than pneumatic conveying of solid particles [2]. The vast majority of the trial and computational results identified with the impact of bends in slurry pipeline framework identified with the disintegration, fixation profiles and pressure drop for the stream of solid particles [3]. It is already well established that in solid liquid flow bends need frequent replacements because of excessive erosion and wear. In order to reduce the pressure, drop through the pipe bends and to increase the life of pipe bends, complete information of the flow behaviour of the slurry along pipeline and pipe bends is very important [4–6]. Researcher experimentally investigate that bends with short radius have symmetrical flow of bimodal slurry along pipeline and for long radius bend the coarser particles migrate towards the outer wall whereas finer particles moves towards inner wall [7]. The pressure loss for iron ore and zinc tailings slurries with various particles range with in a 90° horizontal bend. Researcher found that for iron ore and zinc tailings slurries flow the additional pressure loss is reduced due to presence of the finer particles for various particles range with in a 90° horizontal bend [8]. The addition of fine particles with a range 10–30% in coarser sized slurry leads to distribution of particles homogeneously and reduce the pressure drop along pipeline [9–12]. Researcher observed that the pressure drop in bi-modal slurry decreases with increased ratio of fine particles [13]. CFD modelling using Eulerian model is applied for prediction of solid concentration distribution and pressure drop in FLUENT software and this model shows fair similarity in the experimental and computational results [14, 15]. Researcher analysed various parameters using CFD modelling that affects the rheological and flow behaviour of slurry [16–19]. However, only limited research is available in literature for understanding the flow of bi-modal slurries through pipeline and bends using Eulerian two-phase model in CFD modelling.

In this current study, the flow of bi-modal slurry with a mixture of silica sand and fly ash at 90:10 ratios with solid concentration 8.77% by volume is taken for experimental investigation for the measurements of pressure drop, concentration and particle size distribution along pipeline and pipe bends with flow velocity range keeping up to 2.67 m/s. CFD modelling is done in ANSYS FLUENT 17 for measurement of solid distribution profiles along pipe cross section and drop in pressure along pipeline and horizontal bends for same slurry sample and results are correlated with experimental outcomes.

EXPERIMENTAL SETUP

The entire experimental work was performed in fluid mechanics lab of IIT Delhi. The pilot plant test loop as shown in Figure 1 is having horizontal pipe bends with 53 mm inside diameter with a length of 30 m. Concentration profiles were estimated by testing probes were inserted at various locations along pipeline for observing solid concentration in the mid-vertical plane and distinctive statures from the base of pipeline as shown in Figure 1. The sample collection process and bend geometry are explained by Kaushal et al. [3, 13].

MODELLING RESULTS

CFD modelling is done by choosing Eulerian two-phase Realizable k-ε turbulence model in ANSYS FLUENT 17 software. A comparative analysis is done for predicted modelling outcomes and experimental results for bi modal slurry flow at various flow velocities.

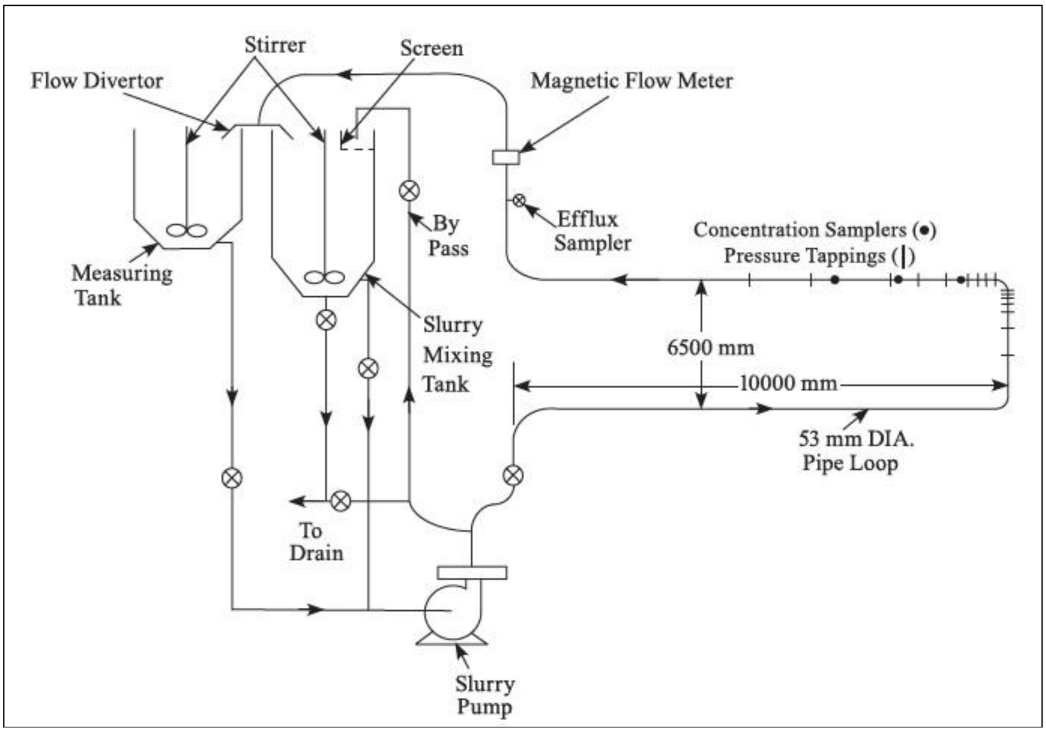

Fig. 1: *Pilot Plant Test Loop Set Up for Slurry Flow.*

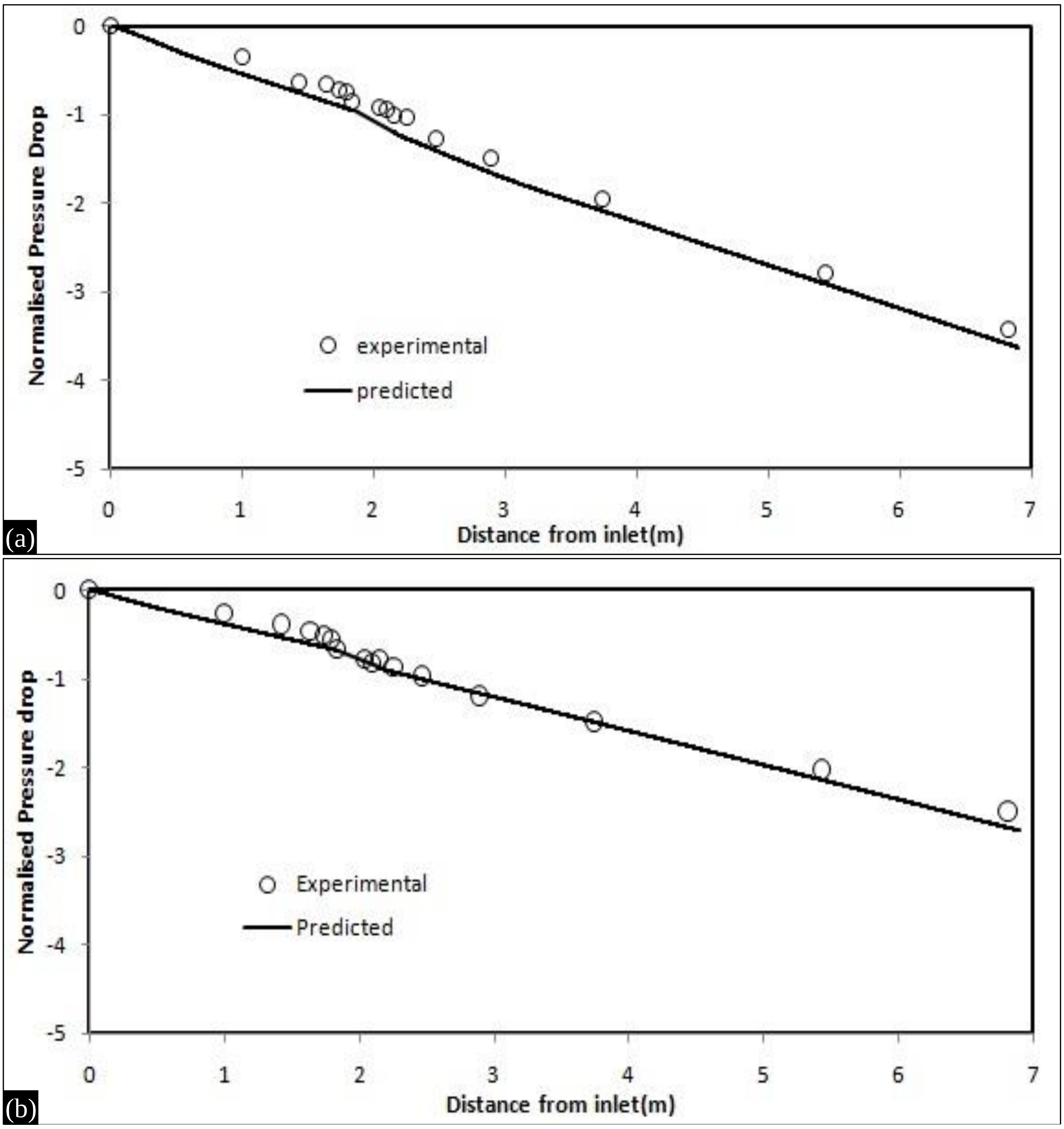

Fig. 2: *Normalised Pressure drop Along Pipeline at C_{vf} = 8.82% (Sand: Fly Ash = 90:10) at various Flow Velocities. (a) V_m=1.78m/s, (b) V_m=2.67 m/s*

Pressure Drop

The predicted normalized pressure drops along pipeline is figure out for flow of bi modal slurry at solid concentration 8.77% by volume (C_{vf}) with 90:10 ratio of silica sand at flow velocity (V_m) up to 2.67 m/s. The flow pattern of the slurry is marginally bothered when it passes over the bend as shown in Figure 2 (a) (b). There is reduction in slop of pressure drop with slight increase in flow velocity. The mixing of finer particle of fly ash in coarser silica sand slurry uniformly scattered the solid particles along pipe cross section diminished the pressure drop.

Concentration Distribution

Cross sectional concentration is calculated by using FLUENT software in ANSYS 2017.The concentration distribution for Silica sand and FA with ratio of 90:10 at solid concentration (C_{vf}) 8.77% and flow velocity (V_m) up to 2.67 m/s. Fly ash particles are constrained outwards alongside the silica sand particles as shown in Figure 3 (a) (b). The solid particles are forced to move outwards in the region of bend because of centrifugal force developed in bend and secondary flows generated by pressure. In the bend region, the effect of centrifugal force is balanced by outward increased pressure.

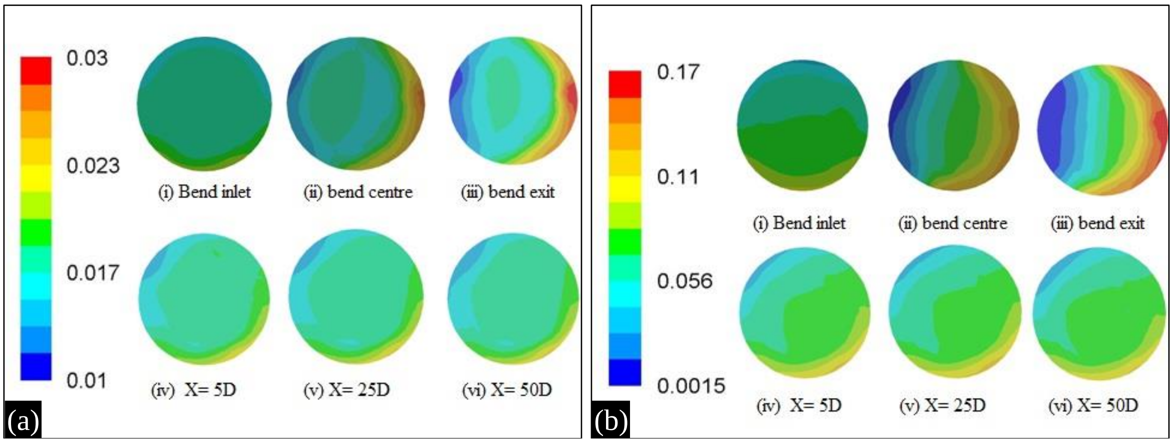

***Fig. 3:** Fractional Cross-sectional Concentration Contour at Various Locations Along Pipeline for FA and Silica Sand for Sand: Fly Ash = 90:10 at V_m = 2.67 m/s and C_{vf} = 8.77%. **(a)** Fractional Concentration Profile of FA at Different Location. **(b)** Fractional Concentration Profile of SILICA Sand at Different Location.*

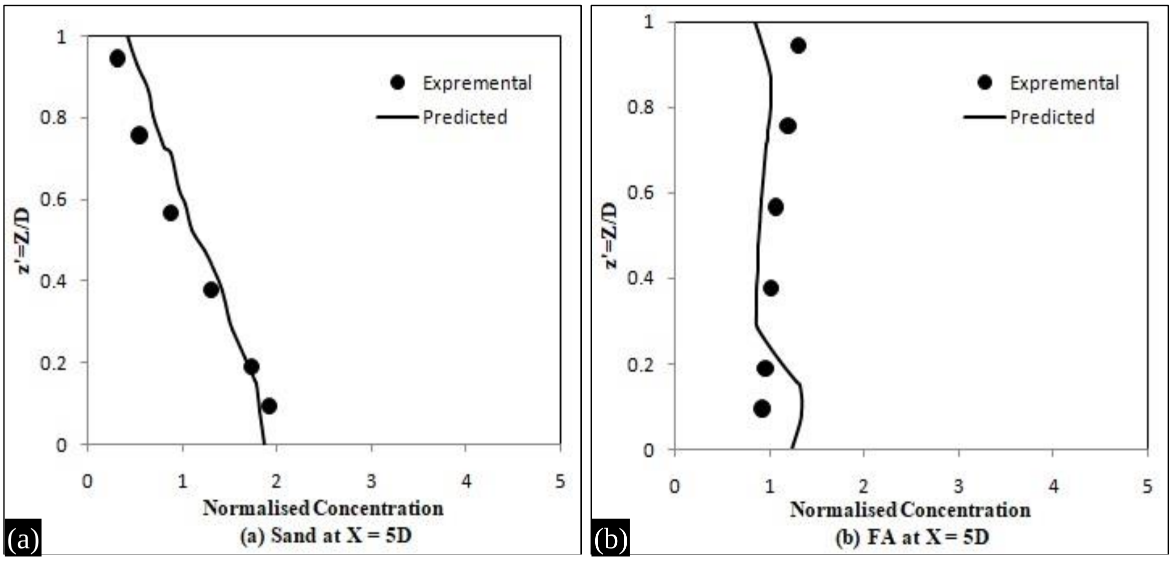

***Fig. 4:** Concentration Distributions at V_m = 1.78 m/s. (a) Sand at X=5D, (b) FA at X=5D.*

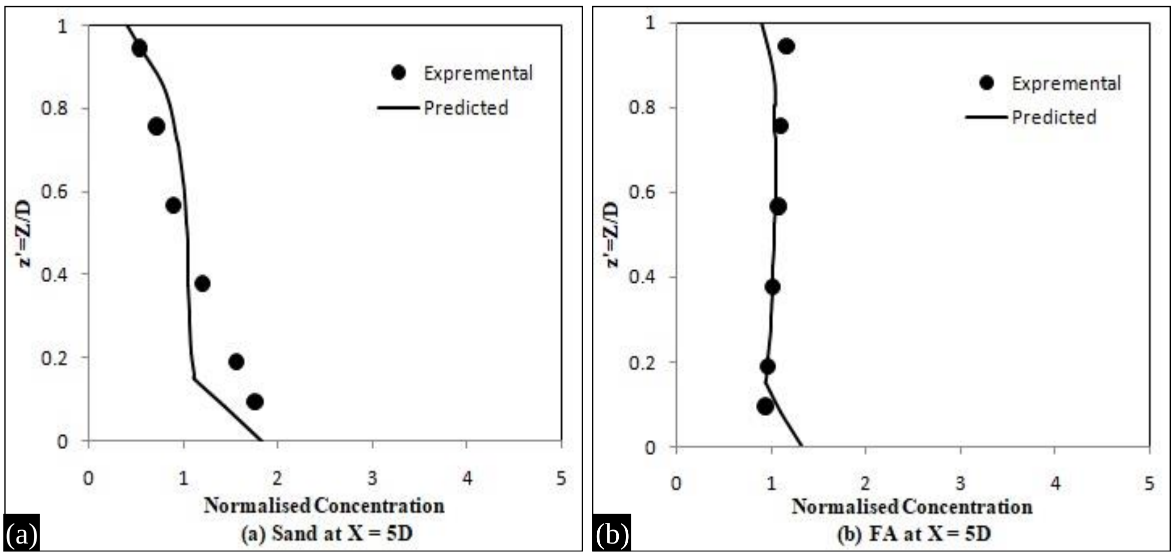

***Fig. 5:** Concentration Distributions at V_m = 2.67 m/s. (a) Sand at X=5D, (b) FA at X=5D.*

Secondary flow appears near to the wall as the fluid velocity is very small so the flow is driven by pressure. From Figures 4 and 5, it clear that the predicted results for normalised concentration hold good resemblance with experimental results at $X = 5D$ from bend outlet. The predicted concentration profile almost matches with experimental results at all velocity at given concentration.

CONCLUSION

The following conclusions are made on the basis of the present study:

1. The predicted CFD modelling result for pressure drops and concentration holds reasonable exactness with the measured experimental results collected for the flow of bi-modal slurry in the efflux concentration up to 8.82% for the flow velocity up to 2.67 m/s.
2. Secondary flow is observed in the pipe bend and it causes movement of solid particles towards outer region of pipe bend and hence slightly disturbs the flow pattern of slurry in pipe bends.
3. The presence of fine particles of FA in the coarser Silica sand slurry leads to uniform scattering of solid particles along pipe cross section and avoid sedimentation of coarser particles.
4. The predicted pressure drop reduces as the velocity of slurry flow increase from 1.78 m/s to 2.67 m/s.

NOMENCLATURE

C_{vf}: Volumetric solid concentration (%)
D: Pipe diameter (m)
V_m: Flow velocity (m/s)

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Cite this Article
Kanwar Pal Singh, Arvind Kumar, Deo Raj Kaushal. Computation Modelling for Fine Particle Flow in Horizontal Slurry Pipelines. *Research & Reviews: Journal of Physics*. 2019; 8(1): 1–6p.