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CFD modelling of silica sand slurry flow through straight pipelines and bends using FLUENT

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ABSTRACT

The flow of mono-dispersed particles of silica sand through horizontal pipe bend is simulated by implementing Eulerian two-phase model in FLUENT software. CFD modelling results using FLUENT software in ANSYS 15 are compared with the experimental data collected in 53.0 mm diameter horizontal bend with radius of 148.4 mm for concentration profiles. Experiments are performed on narrow sized silica sand with mean diameter of 450 µm and for flow velocity up to 3.56 m/s (namely 1.78, 2.67 and 3.56 m/s) and with efflux concentrations 3.94% & 8.82% by volume for each velocity. Concentration samples are collected from mid-vertical plane at different cross-sections in the downstream side of slurry pipe bend. It is found that concentration distributions of solids get almost uniform shortly after the bend. The redistribution of solid particles takes place downstream of the bend due to the secondary flows. This effect is seen close to the bend exit, and with increase in distance this effect decays in the mid-vertical plane. It is also noticed that the pressure drop reduces with slight increase in flow velocity Eulerian model gives fairly accurate predictions for concentration profiles at all efflux concentrations and flow velocities.

Keywords: CFD Modelling, Eulerian Model, slurry, Concentration Distribution, pipe bends, secondary flows, redistribution.

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I. INTRODUCTION

Pipeline transmission is an attractive and progressive mean for transport of a large quantity of bulk materials. Particulate flow through pipelines is used in many applications for long distance transfer of particles like metal ores, silica, clay, coal, fly ash, solid wastes etc. Pipeline flow of solid particles is very complex and is governed by a large number of factors. Slurry pipelines are used for hydraulic conveying of solid materials using water or any other liquid as a carrier fluid either for long distance transportation of bulk materials, like mineral ore to processing plants, coal to thermal power plants or for disposal of waste materials like fly ash and tailings materials to the disposal sites(K P Singh et al 2009, 2013a, 2013b). Slurry pipelines have been accepted by various industries as an extremely safe and attractive mode of solid transportation because of low maintenance, round the year availability and for being eco-friendly. These pipelines could also be laid over difficult terrains to approach the mineral rich remotest areas which are otherwise not accessible by conventional mode of transportation namely railways, roadways or conveyors. It is already well established that bends in general are prone to excessive erosion wear and hence need frequent replacements resulting in shut-downs of plants leading to loss of man hours. Ahmed et al. (1991) measured the pressure drop across a 90° bend in a horizontal plane using two multi-sized particulate slurries namely iron ore slurries and zinc tailings. From their studies they concluded that the presence of the particles reduces the additional pressure drop across the bends, an effect which they have attributed to the suppression of turbulence and secondary flow in bends.
In the present research, we are concentrating on hydraulic conveying of solids through pipelines and bends. An attempt has to be made for prediction of pressure drop and solid concentration distribution along pipe cross section using ANSYS 15 software. The modelling results were compared with experimental data.

II. LITERATURE SURVEY

The particulate flow through slurry pipelines and bends has been the subject of continuing investigation since beginning of this century. All studies prior to year 1970 assumed that the concentration gradient occurs in pipelines only along the vertical plane and remains constant along the horizontal chords. The understanding of flow characteristics of solid-liquid mixtures through pipe bends is of great relevance to the slurry pipeline designers as bends are an integral part of any pipeline network. Flow in bends is quite complex and complexity is further increased for two-phase mixtures. Studies in bends for two-phase mixtures have shown that the flow in bends for solid-liquid mixture system is much more complicated than in gas-solid system. Sharp and O'Neill (1971) were probably the first ones to notice variation of concentration along horizontal chords. Karabelas (1977), developed a semi-empirical model for prediction of concentration profile as well as distribution of each particle size fraction across the vertical diameter of the pipe cross-section. Seshadri et al. (1984) compared the experimental results on multi-sized particulate suspensions of zinc tailings with the predicted profiles by Karabelas model (1977) and were able to identify the shortcomings of the model. Kaushal D.R. et al. (2002a) modified the Karabelas model by considering the effect of efflux concentration on particle diffusivity and settling velocity. Kaushal and Tomita (2002) compared the solids concentration profiles based on modified Karabelas model with experimental data and observed that the model predicted more asymmetric profiles for larger particles and less asymmetric profiles for finer particles.Wang et al., (2003) had employed k-ε turbulence model to predict solid concentration distribution profile in solid-liquid baffled stirred vessels. Simulation results are in good agreement with the experimental data for solid concentration in two cases with average solid concentration up to 20%. Kaushal, D.R. et al. (2005) conducted experiments in 54.9 mm diameter horizontal pipe on glass beads with mean diameter of 440μm. Flow velocity was up to 5 m/s and overall concentration up to 50% by volume for each velocity. A kumar (2014 a, 2014b, 2015a, 2015 b) observed distinct change in concentration profiles indicating a sliding bed regime while concentration distribution in the horizontal plane remains constant irrespective of flow velocity and overall concentration. Kubiki, and Simon, LO (2012) compared CFD modeling technique and Discrete Element Method (DEM) for solid distributions in horizontal pipelines. The Eulerian multiphase model correctly predicted the distribution of solid particles in horizontal pipes for wide range of particle sizes and pipe diameters. DEM simulation is more accurate than the Eulerian model but it requires about 7 times more computing time than Eulerian model.Jiang and Zhang (2012) investigated the flow of slush nitrogen using the 2D Eulerian multiphase approach. The k-ε model is used to model the turbulent two-phase flow and kinetic theory of granular flow to account for particle-particle and particle-wall interactions. The effect of the flow velocity and solid concentration on the flow characteristics of slush nitrogen are investigated. Slurry flow of coarser particles of of glass bead 440μm mean diameter was simulated by Kumar, Navneet et al. (2012) using Eulerian model for flow velocity up to 5 m/s and three overall concentrations up to 30% by volume. A block-structured non-uniform grid is chosen and a control volume finite difference method is applied. The modelling results for pressure drop and concentration profiles are found to be in good agreement with the experimental data. In the present study, Kaushal and Tomita (2002) model for the prediction of distribution of solid concentration distribution across mid-vertical plane is chosen for modification. Mukhtar et al. (1991), in their study with multisized particulate slurries, showed that there is a redistribution of particles belonging to different size fractions, with larger particles being more affected. This phenomenon was more prominent at higher velocities. The finding of these studies was that there is a substantial amount of redistribution of solids within the bend with fine particles moving towards the inner wall and coarser particle moving out. Mukhtar et al. (1995) used commercially available 90° mild steel bend with 100 mm NB with 21cm radius of curvature and radius ratio 4 in pilot plant test loop to carry out the pressure drop across the pipe bend. They found that the bend loss coefficient for a long distance 90° bend for flow of multisized particle slurries is less than that for water and it is relatively independent of solid concentration. Zhang, H. et al. (2012) performed numerical simulation based on CFD and DEM for slurry transportation process to predict the puncture point location in the elbow. The results showed that the puncture point location is influenced by the slurry velocity and the location of maximum erosion moves to downstream when slurry velocity increases. Maximum erosive location was observed at approximately 40° for both U- shaped and 90° elbow. K P Singh (2014, 2015, 2016a, 2016b) experimentally observed pipeline slurry flow of mono-dispersed particles through horizontal bend and numerically simulate by implementing Eulerian two-phase model in FLUENT software. A hexagonal shape and Cooper type non-uniform three-dimensional grid was chosen to discretize the entire computational domain, and a control volume finite difference method is used to solve the governing equations. The modelling results of Kaushal, D.R. et al. (2012) were compared with the experimental data collected in 53.0 mm diameter horizontal bend with radius of 148.4 mm for concentration profiles and pressure drops. Kaushal, D.R. et al. (2013) investigated the ability of Eulerian model in Fluent software to predict the pressure drop and concentration profile across a 90° horizontal bend in slurry pipeline transporting silica sand. Measured and predicted normalized pressure drop showed good agreement for the flow of silica sand slurry having particle diameter of

450µm in the efflux concentration from 0% to 16.28% at different flow velocities from 1.78 to 3.56 m/s. The concentration distribution gets almost uniform shortly after the bend.

Above review has revealed that only limited studies have been carried out for slurry flow through pipe bend. The studies available in literature for three dimensional modelling of slurry flow in pipe bend are very scant. Considering these facts, CFD modelling has been used for slurry flow through pipe bends in the present study.

III. EXPERIMENTAL SETUP

In the present study, pilot plant test loop with horizontal pipe bend having inside diameter of 53 mm and length of 30 m is used. **Fig. 1** shows the schematic layout of the pilot plant test loop. The loop is described in detail by Kumar (2010) Kaushal et al. (2013). Concentration profiles were measured by sampling tube in the mid-vertical plane in the downstream of bend exit at different locations and different heights from the bottom of pipeline as shown in **Fig. 2**. The sample collection process and bend geometry is explained in detail by Kaushal et al (2016).

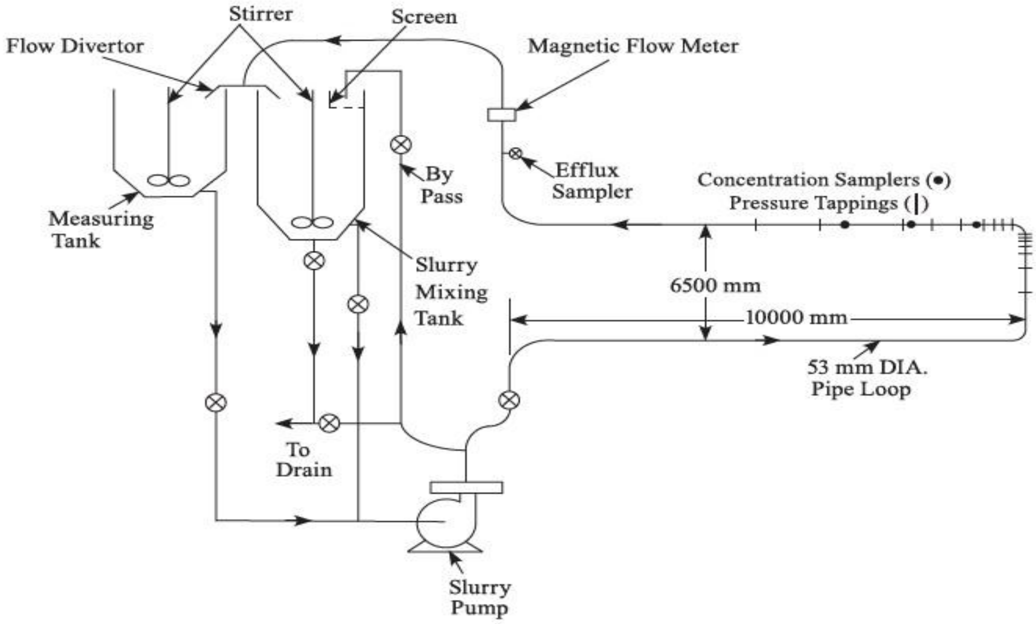

Figure 1. Schematic diagram of pilot plant test loop [Kumar (2010), Kaushal et al. (2013)]

IV. RESULTS AND DISCUSSION

Cross-sectional concentration distributions as predicted by CFD at three different locations (namely, bend inlet, bend exit, X = 25D where X is the distance from bend exit) for efflux concentration 3.94%, & 8.82% at flow velocities 1.78m/s & 2.67m/s are shown in Figures. In these figures, left hand side represents the outer wall, whereas right hand side represents inner wall of the bend. The concentration distributions are skewed towards the bottom and this skewness being higher for lower velocity of 1.78m/s. At higher velocities of 2.67m/s, the concentration distribution is more uniform. At bend centre, bend exit the particles are forced outwards due to the secondary flow. This secondary flow influences the motion of particles even after the bend and the increased concentrations at the outer wall of bend can be clearly seen at these locations for all the concentrations and flow velocities. It is observed that in upstream side of bend inlet, X = 25D flow behavior is almost similar to the flow in straight section. The concentration profile becomes more uniform downstream of bend exit.

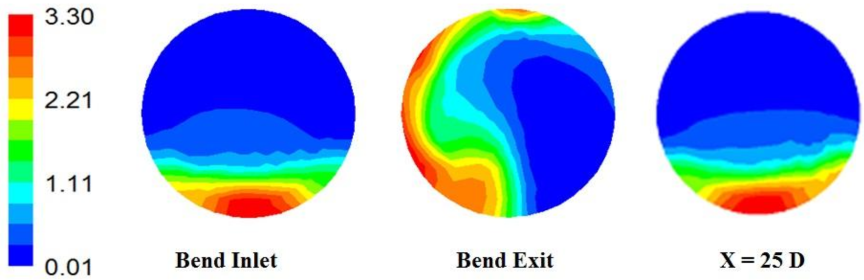

Figure 2. Concentration contours along pipeline at bend inlet, bend exit and at distance X= 25D

V. CONCLUSIONS

The ability of implemented Eulerian model in FLUENT software in ANSYS 15 is to predict the pressure drop and concentration profile across a 90° horizontal pipe bend in slurry pipeline transporting silica sand using standard input parameters was investigated. Overall, there was broad qualitative and quantitative agreement in trends and flow patterns. The results suggest that the Eulerian model is reasonably effective with the slurry pipe bend in the horizontal plane. The possibility of using ANSYS 15 software is examined when it is applied to slurry flow in a bend. The experimental data available in literature has been compared with the predicted data obtained by using Shyamlal Obrien model. We could get many interesting results by this approach, which are comparable to the measurements.

Followings are the specific conclusions based on the present study:

a. Concentration distributions of solids get almost uniform shortly after the bend.
b. The redistribution of solid particles takes place downstream of the bend due to the secondary flows. This effect is seen close to the bend exit, and with increase in distance this effect decays in the mid-vertical plane.

VI. SUGGESTIONS FOR FUTURE WORK

a. The effect of particle density and shape of particles on the flow path could be determined using different size and density of materials.
b. Further improvements in pipeline meshing should give better agreements.
c. Experiments and simulations should be carried out for pressure drop in long pipelines.
d. Experiments and modelling to be performed on critical flow velocity and critical flow concentration.

REFERENCES

[1]. Ahmed, M., (1991). Investigations of the flow of multi-sized heterogeneous slurries in straight pipe and pipe bends. Ph.D. Thesis, I.I.T. Delhi.

[2]. Alexandre, R.G. and Rasteiro, M.G. (2001). Pipe flow of solid-liquid suspensions with a broad size range. PARTEK, International congress for particle technology.

[3]. A Kumar, Kanwar Pal Singh, B Kumar(2015 b) "CFD modeling for silica sand slurry in horizontal pipeline system" YMCAUST international journal of research volume 3(2) ISSN 2319-9377

[4]. A Kumar, S Gupta, K P Singh and D R Kaushal(2014a) "CFD Modelling for pressure drop in pneumatic conveying through pipe bend" International Journal of Advances in Engineering Sciences 4(3) 16-19

[5]. A Kumar, S Gupta, K P Singh and D R Kaushal(2014b) "CFD Modelling of slurry flow in pipeline system for solid concentration distribution" IJAER 9(special issue number 7) 733-742

[6]. A Kumar, K P Singh, S Gupta and D R Kaushal(2015a) "CFD modeling for solid-liquid flow in pipeline" YMCAUST international journal of research volume 3(1) ISSN 2319-9377,pp 105-109

[7]. Jiang, Y.Y. & Zhang, P. (2012). Numerical investigation of slush nitrogen flow in a horizontal pipe. ELSEVIER, Chemical engg. Science 73(2012) 169-180.

[8]. Karabelas, A.J. (1977). Vertical distribution of dilute suspension in turbulent pipe flow. AIChE Journal, 23(4), 426-434.

[9]. Kaushal, D.R., Seshadri, V. and Singh, S.N. (2002a). Prediction of concentration and particle size distribution in the flow of multi-sized particulate slurry through rectangular ducts. Applied Mathematical Modeling, 26(10), 941-952.

[10]. Kaushal, D.R. and Tomita, Y. (2002). Solids concentration profiles and pressure drop in pipeline flow of multi-sized particulate slurries. International Journal of Multi-phase flow, 28(10), 1697-1717.

[11]. Kaushal, D.R., Sato, K., Toyota, T., Funatsu, K. and Tomita, Y. (2005). Effect of particle size distribution on pressure drop and concentration profile in pipeline flow of highly concentrated slurry. IJMF 31 (2005) 809-823.

[12]. Kaushal, D.R., Thinglas, T., Tomita, Y., Kuchii, S. and Tsukamoto, H. (2012). CFD Modeling for pipeline flow of fine particles at high concentration. IJMF 43, 85-100.

[13]. Kaushal, D.R., Kumar, A., Tomita, Y., Kuchii, S. and Tsukamoto, H. (2013). Flow of mono-dispersed particles through horizontal bend. IJMF 52, 71-91.

[14]. Kubicki, Dominik and LO, Simon (2012). Slurry transport in a pipeline- Comparison of CFD and DEM models. Ninth international conference on CFD CSIRO, Melbourne, Australia 10-12.

[15]. Kumar, Navneet, Kaushal, D.R. and Kumar, Arvind (2012). Computational study of the two-phase flow in horizontal slurry pipeline. International journal of mechanical and Production Engineering (IJMPE).

[16]. K P Singh, A Kumar, K M Assefa and D R Kaushal(2015) "Experimental investigation on the rheological behavior of fly ash slurries without and with the addition of chemical agents" IJERT, ISSN 2278-0181volume 4, 196-200

[17]. K P Singh, A Kumar, K M Assefa and D R Kaushal (2016 a)"Rheological analysis and CFD modelling of FA slurry at different particle size in straight pipeline using ANSYS" International conference on sustainable development through research in engineering and management(SDREM-16) held on 26-27 December 2016 at YMCAUST, Faridabad

[18]. K P Singh, A Kumar and D R Kaushal(2016 b) "Experimental investigation of effects of chemical additives on the rheological properties of slurry in sustainable pipeline transportation" International Conference cum Workshop on "Tools, Techniques and Practices for Improving Sustainable Manufacturing" GLA University Polytechnic 23rd -24th January 2016.

[19]. K P Singh (2009) "Simulation of Thermal Power Plants", Proceedings of International Conference on Innovative Technologies, p-662, June 18-19, 2009, PDM Bahadurgarh (Haryana).

[20]. K P Singh and S Singh (2013 a) "CFD Modelling For Slurry Pipeline Flow: A Literature Review" Proceeding of National Conference on Recent Trends and Innovation Civil Engineering held at BRCM CET, Bahal.pp 146-150, 15th-16th November, 2013

[21]. K P Singh and N Kumar (2013 b) "Numerical simulation of finer particles at higher concentration for pipeline flow" Proceeding of National Conference on Recent Trends and Innovation Civil Engineering held at BRCM CET, Bahal.pp140-145, 15th-16th November, 2013

[22]. K P Singh, A Kumar and D R Kaushal(2014) "CFD modeling of slurry transportation in pipeline for Concentration Distribution using different models" national conference on recent advances in mechanical and civil engineering(RAMCE-2014), GHAZIABAD during 4^{th}-5^{th} april, 2014
[23]. Mukhtar, A., (1991). Investigations of the Flow of Multisized Heterogeneous Slurries in Straight Pipe and Pipe Bends. Ph.D. Thesis, I.I.T. Delhi.
[24]. Mukhtar, A., Singh, S.N. and Sheshadri, V. (1995). Pressure drop in a long radius 90° horizontal bend for the flow of multisized heterogeneous slurries. IJMF vol-21, No.2, pp. 329-334.
[25]. Sharp, B. B. and O'Niell, I. C. (1971). Lateral diffusion of large particles in turbulent pipe flow. Journal of Fluid Mech., 45, 575-584.
[26]. Seshadri, V., Malhotra, R. C. and Adiseshu, C. (1984). Prediction of distribution of solids across the cross-section of a slurry pipeline. Proc. 13th Nat. Conference on Fluid Mechanics and Fluid Power, R.E.C., Trichurapalli.
[27]. Wang, Feng et al. (2003). CFD simulation of solid-liquid two phase flow in Baffled stirred vessels with Rushton impellers. Third international conference on CFD, CSIRO, Melbourne, Australia.
[28]. Zhang, Hao, Tan Yuanqiang, Yang Dongmin, Trias F.X., Jiang S., Sheng Y., and Oliva A. (2012). Numerical investigation of the location of the maximum erosive wear damage in elbow: Effect of slurry velocity, bend orientation and angle of elbow. Powder Technology, 217, 467-476.

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