A Review on Parametric Thermal Analysis of Erosion in Bends Pipes with Different Bend Angle Using CFD Analysis

Nilesh Tembhare, Prof. Mohd. Shahnawaz Ansari
OCT Bhopal, INDIA

Abstract :- In the present study, erosion wear of a 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio pipe bend has been investigated using the Computational fluid dynamics code FLUENT. Solid particles were tracked to evaluate the erosion rate along with k-ε turbulent model for continuous/fluid phase flow field. Ash - solid are injected from the inlet surface at velocity ranging from 8 ms-1 at two different concentrations. By considering the interaction between solid-liquid, effect of velocity, particle size and concentration were studied. Erosion wear was increased exponential with velocity, particles size and concentrations. Predicted results with CFD have revealed well in agreement with experimental results. it is cleared that results on 90° degree with 2.5 bend ratio pipe has low erosion DPM rate compared to all different bend angle and its results is better than all bend angle pipe with all parameters . so we can suggest this modified geometry of bend pipe with 2.5 bend ratio 90 degree because it has less DPM erosion rate and reduce the leak problem bend pipe surface.Keywords: Triple tube, heat exchanger, helical baffle, Reynolds number, Nusselt number, friction factor, heat transfer.

Keywords: Computational Fluid Dynamics (CFD), Erosion wear, Discrete Phase Model (DPM), Pipe bend, Turbulence Models, Transportation of Slurry, Discretization Techniques, Erosion Test Rigs(ETR).

I. INTRODUCTION

Many engineering industries and plants like thermal power plant, cement plant are comprise of erosion wear due to transportation solid-liquid mixture and solid-gas through pipe-line system. In thermal power plants large amount of ash (fly and bottom) is generated from coal used as a fuel for generating electricity. This collected ash in hoppers is transported through components like pipe-bend, plugged tees, tubes, valves, elbows and centrifugal slurry pump etc. to ash pond in the form of slurry (water and ash) having very large amount of abrasive and quartz in it Modi et al. (2000). Hence the pipe-line system suffers from erosion wear damage due these abrasive's impact angle and velocity. Many authors have been found erosion wear in pipeline system of production, transportation of petroleum products Edward et al. (2001), oil and gas production (Bozzini et al. (2003), Chen et al. (2004), Shah et al. (2007), Zhang et al. (2007), Okita et al. (2012)), production of oil Gnanuvela et al. (2009), erosion wear in boilers, space craft, pipe line, turbines and coal processing system Mazumder et al. (2012). Erosion wear takes place more severe in curved surface than straight section (Shah et al. (2007), Stack et al. (2011)). An example from one of the above stated components is pipe-bend or elbow which is connected in the pipe line system. The main function of the bend is to give the horizontal, vertical and inclined turn to the transporting fluid/mixture inside it. Many researchers have proposed many experimental and theoretical erosion models and expressions to evaluate the magnitude and location of solid-liquid erosion wear of the system. In the present study erosion wear is investigated in the pipe-bend using the CFD.

1.2 EROSION WEAR :- Erosion wear is a phenomenon in which material removed from the target surface by impacting solid particles at high velocity. The erosion generally occurs in channels, pipe-bends, valves, fitting components etc. These solid particles are directed by pumps and compressors in hydraulic and pneumatic system respectively industrial utilities, thermal power plants etc. Erosion is cause of failure of the parts, unpredictable damages; shorten the life of concerned parts or system. Hence the erosion leads to extra expenditure for the eroded parts. Examples: Transportation of slurry in pipe-line system at thermal power plants.

1.3 WEAR :- Wear is defined as the removal of material between the sliding surfaces due to interlocking or roughness on the surfaces. Wear tends to loss of the durability and reliability of the subjected parts. So the proper investigation and care must be taken to control it in the emerging technology.

1.4 TYPES OF WEAR :- The various types of wear are exist nature due to relative motion between the sliding surface, matters, bodies and in the mixture of physical matters solid, liquid and gas.

1.5 MECHANISM OF EROSION WEAR

In erosion wear phenomenon, the solid particles forcefully entrained in carrier fluids (liquids and gases) by pump and compressors to pipe-line where these solid particles strike at the wall of system. At the same time little amount of material is eroded away from the surface/target body due to high velocity impact of solid-particles. It is generally found in industrial processes, power stations and in many other areas while transporting the solid-liquid and gas-solid mixture through the pipe line system. The subjected components to erosion wear are pipelines, bends, elbows, tees, plates, slurry-pumps etc.

II. LITERAURE REVIEW

In the literature review the study on erosion wear by many authors have been discussed. This chapter has been made after the complete study of their research papers to describe their investigation, findings, output, and results for the erosion wear. The numerical and experimental methodology was used by the researchers to evaluate of erosion wear due to transportation of the solid particulates through hydraulic and pneumatic system.

2.1 Modi et al. (2000) performed the Jet impingement test on the 304 stainless steel specimen with coal and bottom ash slurry to evaluate the erosion wear. The high erosion wear was found with bottom ash slurry due to presence of the carbon, un-burnt coal and particles in the bottom ash. They observed that the coal particles breakdown into small particles due to collision with wall and may not have enough energy to deform the target wall surface, hence less erosion rate was found with coal slurry. Also the results revealed that the high weight loss in the initial stage and became stable in the final stage along the travel distance of both the slurries.[1]

Zhang et al. (2000) performed simulation for the solid-liquid two phase flow to evaluate the erosion-corrosion in the pipe in CFD. The k- turbulent model and Lagrangian-model were sed with the boundary conditions velocity inlet and outlet over the domain. The glass material of particles size 8 m was used as erodent material. The results obtained for the erosion rate, corrosion were found good agreement with experimental results of Nesic & Postlehwaite.[2]

Edward et al. (2001) numerically studied the solid particle erosion in Standard elbows, long radius elbows and plugged tees. They found more momentum transfer in long radius elbow instead of standard elbow. Due to the momentum the particles does not strike to the wall. The large amount of particles followed the fluid streamline or remain suspended in the fluid through the long curvature (don't strikes early to the wall). The gradual redirection of the flow leads to less erosion than instantly flow redirection. They observed the particles lose the velocity near the stagnant zone due to fluid cushion effect due this particles don't strikes the wall and low erosion wear was observed in plugged tees. Also they found low erosion depth in long radius elbow instead of standard elbow and plugged tees.[3]

Bozzini et al. (2003) studied erosion phenomenon of pipe bend in CFD code Fluent by using four phases (oil, sea water, hydrocarbon mixture and sand particles). The Discrete Phase Model was used to track solid particles of diameter 300 µm. They observed the solid particles have less transporting capacity at low velocity and settle-down pipe-bend where the erosion wear was examined at the same time they increased the gas volume flow rate in the mixture to improve the erosion rate. The total mass flow rate of particles was affecting the fluid flow behaviour not the erosion rate. The high velocity of mixture had generated high drag force and inertia force on solid particles which push the solid particles toward outer radius of bend where the high erosion rate was examined.[4]

Wood et al. (2003) performed CFD simulation to evaluate the erosion induced by sand water in steel pipe-bend of pilot and laboratory scaled. The particle tracking and turbulence models were employed in the simulation process. The almost constant velocity as well as small impact angle was observed in straight pipe but fluctuated velocity profile and high impact angle were obtained in the bend cross-section. Due to this high velocity and impact angle the high erosion rate was found in the bend zone than the straight pipe. The experimental and numerical results had found good agreement.[5]

Chen et al. (2004) studied erosion wear on 1 inch elbow and plugged tee of aluminum in CFD code CFX code by considering air and sand particles (150µm in diameter). Grid independent test and particle independent test had been carried out for both the geometries. In lagrangian model, two wall collision approaches (Stochastic rebound and Forder rebound) were used to evaluate the erosion rate at different velocities (15.24m/s, 30.38m/s, 45.72m/s). The results obtained with Forder rebound model had 15% more erosion rate in elbow and large number of re-circulations leads to local erosion rate in tee domain. But stochastic rebound model's results have made a good agreement with experimental results. Finally, the average erosion wear location was found by graphical approach for the elbow and tee.[6]

III. MULTIPHASE MODELING FOR EROSION RATE

3.1 SOFTWARE INFORMATION

Computational fluid dynamics (CFD) is an important tool which is used to solve the problems associated with fluid flow, heat flow and some reactions by simulating in computer. The CFD solve the problem by various numerical approaches and by algorithms, finally helps to optimize the solution results without any experimentation on physical models or prototype. The flow visualization characteristic of the code inside the domain make it very power-full tool in the research field and other areas. There are some governing equations are associated with the flow field and it is typically or may not possible to apply directly those equations with many variables to model.

CFD divide the flow domain into number of cells and solve the governing equations for the each cell by converting PDE's into algebraic form.

3.2 DISCRETIZATION TECHNIQUES

In the discretization methods the governing equations are converted from partial differential and integral form to algebraic form. The various types of the dicretization methods are used in the CFD code.

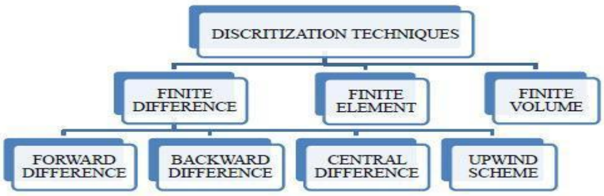

Figure 3.1: Discritization methods

a) Finite difference method

Finite difference method is one of the most common methods to obtain the numerical solution in CFD. At each node of the grid the fluid flow domain is defined and Taylor series is used for the expansion. In one dimensional flow problem simple differential equation gives smooth and analytical solution with boundary conditions.

b) Finite element method

The main feature of the FEM is that the simple piecewise polynomial functions used the elements to describe the variation of unknown flow variables. The associated error are measured by the weighted residuals concept and minimized later. The approximate solution is obtained from the non-linear equations. Any complex or any shaped geometry can be deal with this method.

c) Finite Volume Method

The conservation equations of integral form are discretized by finite-volume method in physical space. Finite volume method is concern with control volume not with grid intersections and type of grid is accommodated by itself. Generally an unstructured type grid is used instead of structured grid because it allows the option for defining the location and shape of the control volumes. But the boundaries of control volume are defined by the grid.

IV. IMPLEMENTATION WORK

SOLID LIQUID EROSION WEAR USING CFD

4.1 CFD In the present work, CFD ANSYS 19.2 multiphase euler-lagrange model is used to identify the erosion rate and to analyze the effects of velocity, particles size, and solid concentration for the erosion wear in pipe-bend. The erosion wear takes place generally in power plants due to transportation of slurry (water-bottom ash) through pipe-line system due to high velocity and impacts of solid particulates over the wall of the flow domain.

Table 4.1: Detail and Specification of the flowing domain

Geometry: Pipe -Bend				
Diameter, D (mm)	r/D ratio	Total length, L (m)	Density (kg/m3)	
50	1.5	1.5	7850	(Steel)

4.2 CFD SIMULATION AND VALIDATION

Erosion wear is material removal phenomenon due to impingement of solid particles over the surface which entrained through the carrier fluid like water. In thermal power plants bottom ash is transported in the slurry (ash-water) form with in the pipe line system which concerned with erosion wear. Various parameters are responsible for the erosion rate like impact angle, velocity, solid concentration, particle size etc. have been evaluated numerically using the erosion model in Computational fluid dynamics. At low flow velocity the of the mixture in the flow field the solid particles starts to settle down in the flow field due to low inertia, low drag and gravitational force on the particles. Where the erosion wear in the flow field takes place Bozzini et al. (2003) as shown in Figure 4.4 (b). As the flow velocity is increased, the particles starts to strike at the outer wall of the pipe bend due to inertia and centrifugal force. Hence erosion magnitude and location shifts toward the outer wall along the pipe bend curve. At the same time the transverse motion of the particles the bend curvature and outlet where particles strikes over the wall lead to maximum erosion as shown in Figure 4.9. High erosion rate is observed at the bend section than straight pipe due to variation velocity and impact angle of the particles Wood et al. (2003). Along the bend curve angle is varying from the 0-90°. The erosion wear is due to cutting action up-to impact angle 20-30° and after that deformation action takes place leads to high erosion rate.

V. MODELING & SIMULATION

5.1 45° DEGREE ELBOW

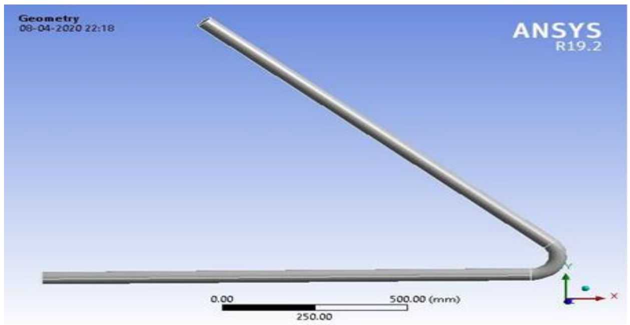

Fig. 5.14 45° Degree Elbow geometry import on ANSYS

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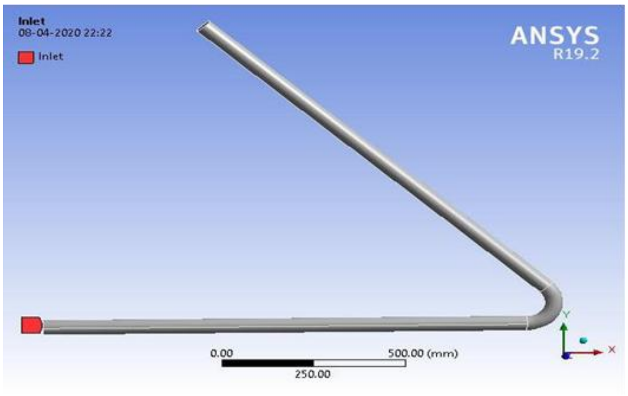


Fig. 5.16 45° Degree Elbow geometry inlet

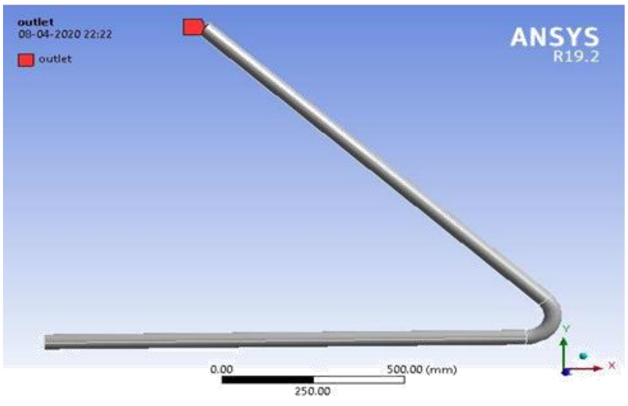


Fig. 5.17 45° Degree Elbow geometry outlet

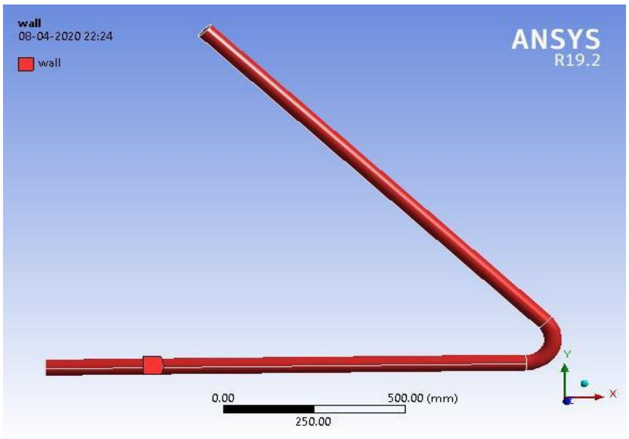


Fig. 5.18 45° Degree Elbow geometry wall

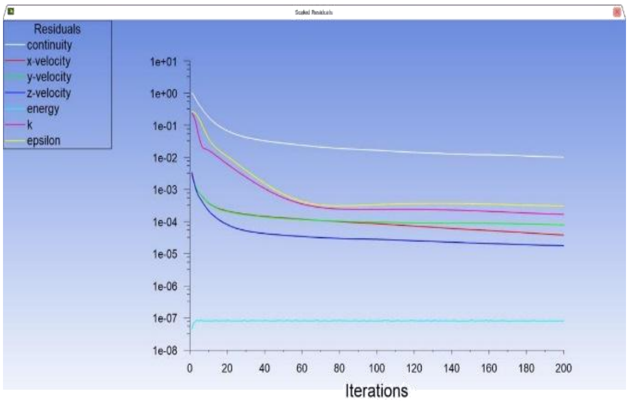


Fig. 5.19 45° Degree Elbow iterations up to 200

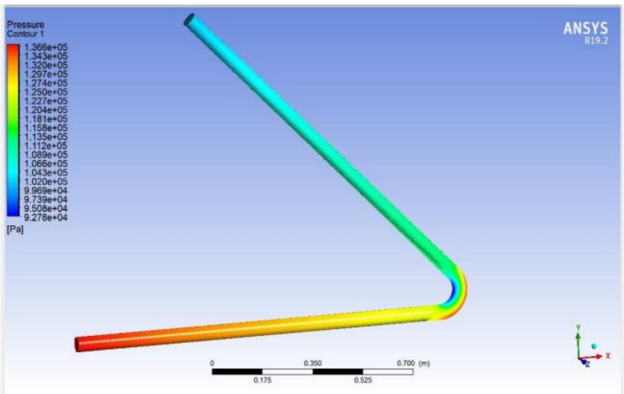


Fig. 5.20 45° Degree Elbow pressure results

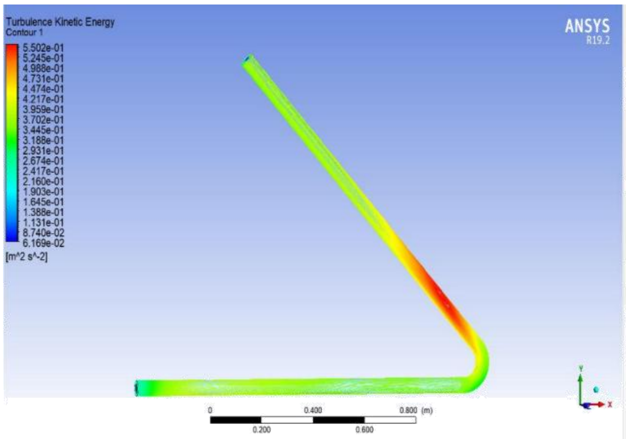


Fig. 5.21 45° Degree Elbow turbulence kinetic energy results

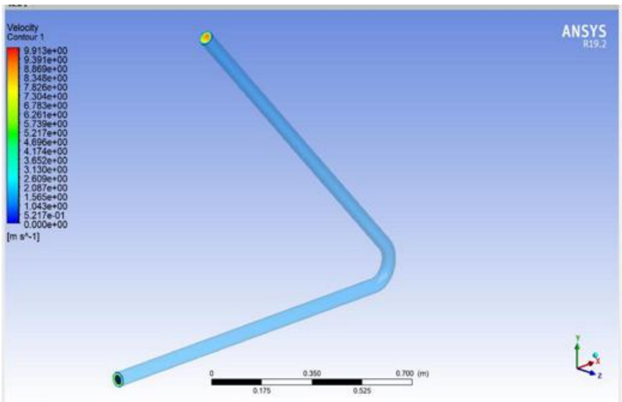


Fig. 5.22 45° Degree Elbow velocity results

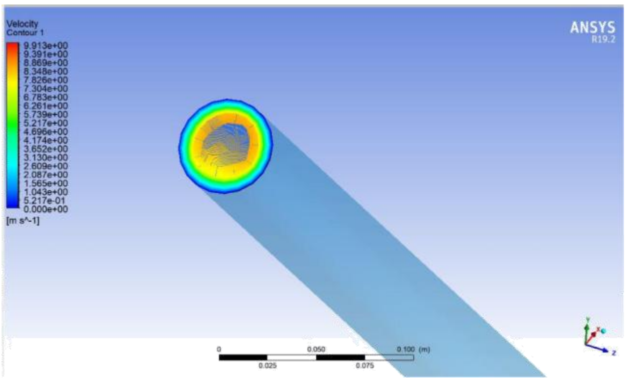
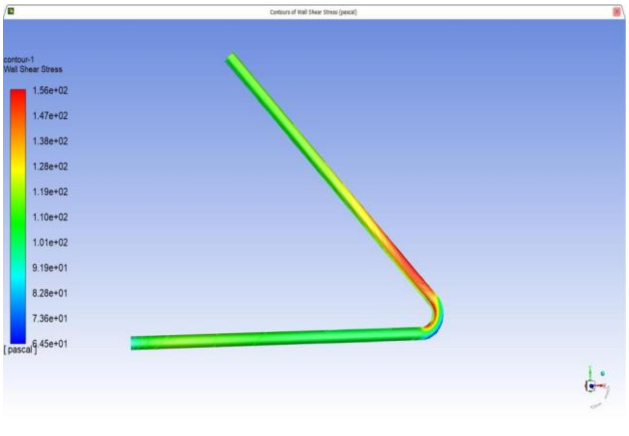


Fig. 5.23 45° Degree Elbow velocity zoom results



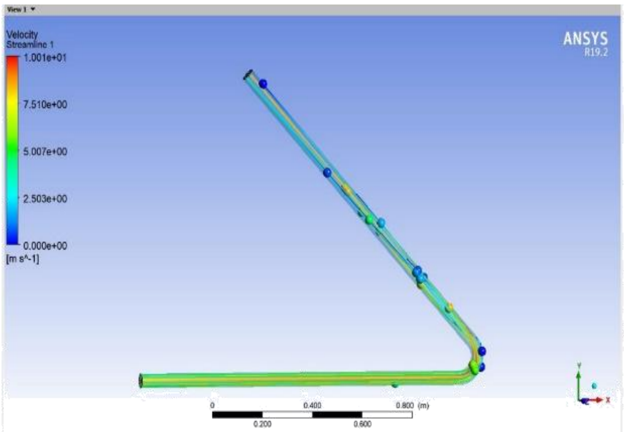


Fig. 5.24 45° Degree Elbow wall shear stress results

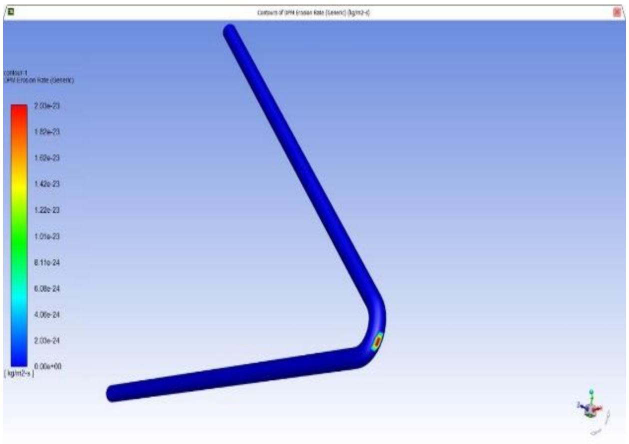


Fig. 5.25 45° Degree Elbow stream line velocity results

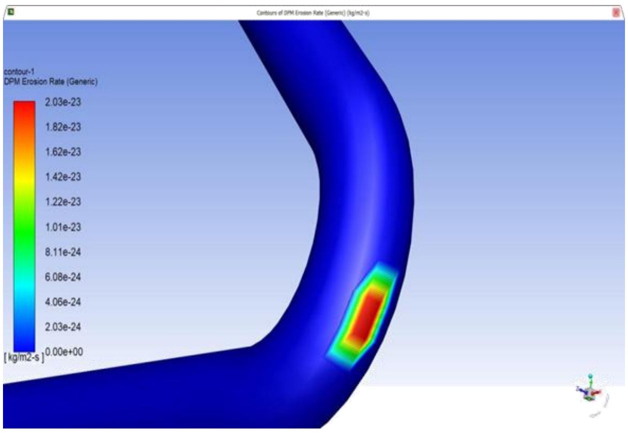


Fig. 5.26 45° Degree Elbow DPM erosion rate results

Bending Ratio(r/d)	2.5 r/d	1.5 r/d	1.5 r/d	1.5 r/d	1.5 r/d
Bend Angle	90°	90°	45°	60°	30°
Pressure (Pa)	1.20E+05	1.30E+05	1.36E+05	1.36E+05	1.37E+05
Turbulence kinetic energy (m2/sec2)	2.44E-01	3.06E-01 5.50E-01		5.44E-01	8.22E-01
Velocity(m/sec)	9.15	8.72	9.91	9.98	9.99
wall shear (Pa)	1.06E+02	1.39E+02	1.56E+02	1.57E+02	1.59E+02
DPM erosion rate (kg/m^2s)	9.57E-26	1.31E-25	1.26E-23	6.11E-25	8.07E-25
velocity streamline velocity (m/sec)	9.13	1.03E+01	1.01E+01	1.09E+01	1.01E+01

Here cleared seen above table bend pipe with different bend angle Pressure Turbulence kinetic energy velocity wall shear DPM erosion rate and velocity streamline velocity results find out.

So Find out bend pipe pressure results on 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio resulrs are respectively $1.20E^{+05}$ Pa, $1.30E^{+05}$ Pa, $1.36E^{+05}$ Pa, $1.36E^{+05}$ Pa, and $1.37E^{+05}$Pa

So Find out bend pipe Turbulence kinetic energy results on 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio results are respectively $2.44E^{-01}$ m^2/sec2 , $3.06E^{-01}$ m^2/sec^2, $5.50E^{-01}$ m^2/sec2 , $5.44E^{-01}$ m^2/sec2 and $8.22E^{-01}$ m^2/sec^2

So Find out bend pipe velocity results on 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio results are respectively 9.15m/s, 8.72 m/s, 9.91 m/s, 9.98 m/s and 9.99 m/s

So Find out bend pipe wall shear results on 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio results are respectively $1.06E^{+02}$ Pa, $1.39E^{+02}$ Pa, $1.56E^{+02}$ Pa Pa, $1.57E^{+02}$ Pa, $1.59E^{+02}$ Pa

So Find out bend pipe streamline velocity results on 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio results are respectively 9.13 m/s , 10.3 m/s, 10.1 m/s, 10.9 m/s and 10.1 m/s

So Find out bend pipe DPM erosion rate results on 90° degree with 2.5 bend ratio pipe, 90° degree with 1.5 bend ratio, 0° degree with 1.5 bend ratio, 45° degree with 1.5 bend ratio, 60° degree with 1.5 bend ratio, 30° degree with 1.5 bend ratio results are respectively $9.57E^{-26}$ kg/m^2s, $1.31E^{-25}$ kg/m^2s, $1.26E^{-23}$ kg/m^2s, $6.11E^{-25}$ kg/m^2s and $8.07E^{-25}$ kg/m^2s.

VI. CONCLUSIONS

Computation fluid dynamics code FLUENT was used analyze the slurry erosion in pipe bend for the flow bottom ash slurry. based on the results conclusions are given below:The erosion wear in the horizontal pipe bend is greatly influenced with velocity of the flowing medium.At low velocity settling takes place in the pipe bend due to low inertia and gravitational effect on the solid particulate, leads to erosion at bottom side of pipe line. Erosion wear takes place sever times more in curved sections than straight once. Significant of the solid concentration is very less for the erosion wear.

REFERENCES

[1] Modi O.P., Dasgupta R., Prasad B.K., Jha A.K., Yegneswaran A.H. and Dixit G., , “Erosion of a high-carbon Steel in Coal and Bottom-Ash Slurries”, Journal of Materials Engineering and Performance, 9:522-529, 2000

[2] Zheng Z., Xuewen C. and Yugui Z.,“Numerical Simulation of Erosion Corrosion in the Liquid Solid Two-Phase Flow”, Chinese Journal of Chemical Engineering, 8(4):347-355.,20003.

[3] Edwards J.K., McLaury B.S. and Shirazi S.A., “Modeling Solid Particle Erosion in Elbows and Plugged Tees”, Journal of Energy Resources Technology, 123:277-284, 20014.

[4] Bozzini B., Ricotti M.E., Boniardi M. and Mele C., “Evaluation of Erosion– Corrosion in Multiphase Flow via CFD and Experimental Analysis”, Wear, 255:237-245, 2003

[5] Wood R.J.K. and Jones T.F., “Investigations of Sand–Water Induced Erosive Wear of AISI 304L Stainless Steel Pipes by Pilot-Scale and Laboratory-Scale Testing”, Wear, 255:206-218, 2003

[6] Chen X., Mclaury B.S. and Shirazi S.A., “Application and Experimental Validation of a Computational Fluid Dynamics (CFD)-Based Erosion Prediction Model in Elbows and Plugged Tees”, Computer and Fluid, 33:1251-1272, 2004

[7] Habib M.A., Badr H.M., Mansour R.B and Said S. A. M., “Numerical Calculations of Erosion in an Abrupt Pipe Contraction of Different Contraction Ratios”, International Journal for Numerical Methods in Fluids, 46:19-35, 2004

[8] Wood R.J.K., Jones T.F., Ganeshalingam J. and Miles N.J., “Comparison of Predicted and Experimental Erosion Estimates in Slurry Ducts”, Wear, Vol. 256:937–947, 2004

[9] Gnanavelu A., Kapur N., Neville A. and Flores J.F., “An Integrated Methodology for Predicting Material Wear Rates Due to Erosion”, Wear, 267: 1935–1944, 2009

[10] Graham L.J.W, Lester D and Wu J., “Surry Erosion in Complex Flows: Experiment and CFD”, CSIR :1-6, 2009