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CFD STUDY OF SAND EROSION IN PIPELINE USING DIFFERENT PERCENTAGE OF ETHYLENE GLYCOL AND DEIONIZED WATER

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ABSTRACT

Sand productions are inclusive of various types of major key challenges for gas and oil productions as the sand managements are rapidly growing in becoming significant to manage wells of high rates. Since approximately 70% of gas as well oil reserves around the globe are sand formations Sand production is an unavoidable by-product in oil and gas industry as 70% gas and oil reserves of the world oil are sand formation. Transportation of the particles from the wellbore to the surface will cause the damage to the amenities and tools. Wells producing gas and oils can potentially fail because of the erosion of the major solid particles. It can be illustrated through an example like producing wells having considerable amount of production of sand might affect negatively over the fitting and components of the pipeline, well tubing as well as the equipment used for the production. Thus can cause highly priced potential ecofriendly damages, equipment loss and downtime production. The current study provides outcomes gathered through examining and analyzing various factors for determining the severities and amount of the erosion of sand over the pipe bend. To solve the phenomena of the flow of the fluid, this study has used CFD. To design the pipe's elbow, CATIA-V5 is brought in use and meshing is done with the help of the ANSYS. Different cases will be studied here by varying the percentage of water and EG with respect to sand particle size 160m and 370m. Erosion rate, Skin friction Coefficient and Swirl velocity are the three major effects which will be studied further. Through the observation of the study, it can be said that material's character and flow velocity are the predominant factors which might affect the rate of sand erosion within the pipelines. The observation is made over every factor and is also analyzed.

KEYWORDS: Erosion, CFD, Pipeline, Ethylene Glycol, Deionized Water.

1. INTRODUCTION

The production is increasing in oil and gas industry as well as supply of hydrocarbons is also increasing because of increasing world population which leads to increase the demand of oil and gas. Therefore, it becomes important for us to explore the extreme environment where access to crude is very difficult. Sand production is also a major challenge. While development in technology has contributed to the development of different mechanisms for sand control, sand particles are already being created and transferred with fossil fuel, contributing to blockage, pressure fall as well as pipe erosion concerns. Pipelines are the most significant infrastructure that connects the development field to the manufacturing field. The majority of prolific hydrocarbon reserves are vulnerable to sand production, so oil and gas pipelines can include liquid, gas as well as solid particle flows. It is essential to note the complex interaction between the sand particles, fluid as well as pipe wall to get to understand the implications of sand particles on the wall of the pipe. [1]

In industries like petroleum, chemical, manufacturing and process, Multiphase gas-liquid flow occurs. Predicting tools are required in it for facilitating the design. In gas-liquid multiphase flows, several physical scenarios have been observed. And with respect to changes in multiphase pattern, this behaviour can also vary. With the change in flow behaviour, erosion pattern as well as erosion rate also varies. Several alternative opinions have been used

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to analyse multiphase erosion flow through experimental to analytical to CFD, but CFD as a systematic tool offers space for more knowledge on these situations and the physical parameters that influence them, as well as the dynamic interactions between the phases (gas-solid-liquid). Given the complexity of the stream, erosion estimation in multiphase flow is very complicated and it exclusively relies on the flow patterns in issue. It is also becoming more complex to track particles in multi-phase fluid flows.

In gas production systems and in offshore oil, sand production is very common. In petroleum and various other industries, erosion because of sand flow or particulate gas flow causes severe damage financially as well as environmentally. Prediction of such type of damages is very important for avoiding unprepared shutdown of production as well as for avoiding environmental issues. Though, during the time of gas or oil production, during the early stage of production, the amount of soil produced is not significant.

Although a massive increase in sand output is unavoidable in the end phase during which the reservoir pressure drops below 6.9 MPa, which would in turn, poses a major problem to the detection and prevention of disruption. Installation of sand exclusion systems is not generally desirable because they can hypothetically reduce the rate of production because of low pressure of reservoirs. From estimating the damages from erosion and for predicting the exposed spots in piping systems, Computational fluid dynamics (CFD) is the broad approach. For reducing this type of damages, CFD models can be used. They can reduce damages by optimizing the flow condition and geometry of the system.

Minute changes in operation conditions and various other factors are the significant factors which can cause severe damage as Erosion is a very complex procedure. This may lead to a situation in which in one production process, high erosion rates arise, but hardly any erosion occurs in other systems that are obviously very identical. The loss of metal was mainly caused by mechanical forces induced by solid materials, liquid droplets, or cavitation.

2. LITERATURE REVIEW

(Ejeh et al., 2020) [13] Studied that flow dynamics in pipes is largely affected by flow conditions. Hence, it is a very complex system. The existence of solid particles is correlated with the movement of crude oil through pipelines inside unconsolidated petroleum reservoirs. Through crude oil processing, these particles are often carried as dispersed phases and are therefore harmful to the quality of the pipe surface. This could result in the incidence of corrosion of the crevice due to pipe erosion. This paper aims to examine crude oil dynamics while pipeline flow and to define erosion hotspots for various pipe elbow curvatures in relation to the above study. Approaches which were used in this study are Practical Tracing Modeling (PTM) as well as Reynolds Averaging Navier-Stokes (RANS). Simulation of fluid dynamics as well as tracing of the particles is the main focus of this study. Post-processed findings showed that in the area with the lowest curvature radius, the fluid velocity magnitude was significantly higher. In areas of low-velocity severity, the highest static pressures as well as turbulence dissipation levels were observed. The incidence of erosive wear at the elbow was also significantly higher, and pipe curvature differed with the hotspot. The rate of particle flow, mass, and size differed and it was observed that with an increase in particle properties, the erosion rate has increased.

(Okafor & Ibeneme, 2019) [23] Studied that major issue which is experienced by pipeline engineers is pipe fitting degradation and related issues in gas and oil pipelines. Over time various sand control frameworks have been introduced to restrict sand at its base down the well's pit. These techniques for sand exclusion involve gravel packing at the head of the well and/or using screens to prevent the entry of sand into the pipeline. In addition to enhanced sand observation and control, these sand exclusion systems have been productive in cutting down sand output in the pipeline lines to a great extent and are commonly used as part of oil and gas production wells. The outcomes of this study are made on the basis of simulations made through utilizing a widely validated proprietary CFD model. The rate of erosion is observed to be hiked with both fluid velocity and size of the sand particle and reduced with degree of bending, diameter and radius of the pipe. Outcomes also exhibit that it is probable for determining the parameter's threshold magnitude.

(Wee & Yap, 2019) [5] Evaluated that Pipeline degradation, with its safety concerns and financial integrity, remains a big problem for the petroleum industry. By using CFD, to investigate the sand erosion behavior in diameter of 76.2mm is the main target of this research paper. Simulation erosion through fine sand particles (< 50

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Impact Factor: 5.164
CODEN: IJESS7

μm) appears to predict the erosion outcome according to literature; transportation of sand particles in the elbow is influenced by fluid particles; slightly altered geometries yield substantially different erosion outcomes. For solving the continuous phase with Navier-Stokes equations, CFD analysis is performed with Eulerian-Lagrangian approach and with particle force balance secondary phase is used. Together with low Reynolds number modification, the Reynolds Stress Model represents the continuous fluid phase turbulence nature to resolve viscous boundary effects in the near wall region as well as secondary elbow flows for more detailed performance. The proof results of this study indicate that the assumption of constant size for each sand particle resulted in a maximum wear rate prediction of more than 10 percent.

(Lospa et al., 2019) [6] To evaluate the erosion rate in bends of the pipe used in technological installations that circulate fluids along with a small proportion of solid particles in the form of sand, the authors presented the results of the CFD analysis evaluations performed by the authors. There are different curvatures and diameters and the same wall thickness in the pipe bends that were studied. To determine the area where erosion occurred as well as the rate of erosion is analyzed by the CFD analysis. At the pipe bend extrados, is the main area of erosion where it occurs. The variations observed are affected by the form of pipe bend, as the overall erosion rate rises as the curvature of the bend grows. In order to compare the CFD as well as experimental program outcomes, the study will keep going to design an experimental test framework for erosion analysis.

(Xian & Che Sidik, 2019) [10] Analyzed that water as well as ethylene glycol are usually used in the form of coolant in automobile cooling systems. By dispersion of solid particles, the thermal property is enhanced of conventional heat transfer fluid which shows higher thermal conductivity in the nano fluids. Through using nano fluid as a coolant, several previous researchers find improvement in the heat transfer rate in the automotive cooling system. However, very few limitations, such as the tribological effect on components in the automotive cooling system, are documented. Therefore this paper aimed to evaluate the erosion-corrosion effect of the nano fluid on the Perodua Kancil D37 water pump aluminum impeller. With respect to ASTM D2809-09 standard, inlet pressure, rpm of pump as well as coolant temperature are the working parameters. Graphene Nano platelets, corrosive water and ethylene glycol are used for making testing coolants. By using 3D imaging microscope, each and every pump space profile was investigated after 100 hours of continuous testing. For determining total material loss, before as well as after the testing precise weight measurement was performed. With both base coolant as well as nano coolant, it was found that now the corrosion affect seems to be the same. As nano coolant is being used of base coolant, the erosion-corrosion effect has increased material loss. Erosion corrosion effect on the impeller was observed to be limited based on the ASTM 2809-09 standard and earned a high rating in the test. Thus it is possible to consider all coolants to be used in the potential cooling system.

(N. H. Saeid, 2018) [24] Studied that 3D CFD simulation has been used for analyzing the amount of sand in choke valve as well as two-phase turbulent flow of crude oil. For the simulation of sand flow, discrete phase mathematical model is being utilized; it is also used in the system for its interaction with the oil flow. For reducing the sand erosion in the given system, the governing parameters are identified by using parametric study. Industrial oil production project is used for taking dimensions as well as valve geometry. Pressure difference between the inlet of the pipe and outlet of the pipe, flow rate of sand and valve opening percentage are the parameters considered in this study. With respect to sand flow rate, valve opening and pressure difference, the erosion rate variation is presented with the simulation results. For both large valve opening as well as small valve opening, it is observed that erosion rate is high. In between 20-30% of valve opening, minimum erosion rate is observed of every case with numerous pressure differences. In the simulations, areas with the highest erosion rate are expected.
(Mathew, 2017) [2] A complex process is to estimate the erosion in multiphase flow. The material loss from the material wall, attributed to the dominance of certain particles, is erosion. A CFD method is used in this to research the impact of sand particle motion by carrier fluids such as methane, methane-oil, mixed gases, etc. Analysis of the erosion mechanism in the single and multiphase flow is performed by the CFD package ANSYS Fluent 6.0. The prone area where material degradation is maximum can be investigated. By API recommended standards, erosion rate can be calculated which will use CFD for comparing the values numerically. Calculation of the forces impinging on the bend section is also performed along with the pressure drop.

(Wong et al., 2015) [21] FPSO vessels are commonly using the flexible pipes instead of rigid pipework for transporting gas and oil fluid in subsea pipe network. FPSO stands for Floating Production Storage Offloading.

ISSN: 2277-9655
Impact Factor: 5.164
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The innermost part of the pipe is in direct communication with the fluids created, which can also carry sand particles over time and cause inner surface erosion. The erosion rate on the surface of a substance is approximately equivalent to the square velocity of the particle impact and particles in gas move at a greater relative speed than fluid flow The use of flexible pipes would also be more prone to sand erosion in gas-dominant fields than in liquid-dominant fields. Various experimental and modeling papers on smooth bore rigid bent pipes were revealed in a study of the literature, but only little knowledge is accessible for rough bore flexible pipes. For proposing new model based on DNV-RP-O501, this paper will contribute to it for analytical prediction of the erosion rate of rough bore flexible pipe. The new model, benchmarked against literature data and CFD simulations, accounts for variations in erosion rate with particle impact angle to allow more detailed erosion profiling of the internal carcass. The work will provide a forum for further development, testing and calibration that could eventually allow versatile pipe designers, especially in dry gas fields, to improve solid particle erosion estimates.

(Hadžiahmetović et al., 2014) [9] Analyzed that by means of numerical simulations, in elbow geometry the solid particle erosion prediction is performed. ANSYS Fluent Software is used for 3D numerical simulations. By utilizing RSM (Reynolds stress model), the continuous phase is modeled. RANS (Reynolds Averaged Navier Stokes) model is the group to which RSM belongs. In reference to Lagrangian frame, the discrete particle paths are outlined. In order to effectively resolve the particle movement by the wall-bounded geometry, more sub-models are introduced into the program. Particle-wall erosion as well as collisions are among these sub-models. For pneumatic transport simulations, proper resolution of particle-wall collisions is important as it has the greatest impact on particle background, velocity and concentration components prior to the place of interest. Here, in this study elbow erosion in the case. Finnie's model of erosion is used for calculating the extraction of wall material because of erosion. With the published experimental data, modeled results were validated.

(El-Behery et al., 2010) [25] In curved ducts, numerical simulations of sand erosion are presented in this study. For the calculation of erosion rate, semi-empirical model is used. While for gas-solid two-phase flow, the simulation results are obtained by using the Eulerian-Lagrangian approach. In this model, the impact on gas phase due to solid phase is included. With the available experimental data, validation of model prediction as well as good agreement was obtained. For measuring the penetration rate in bends, CFD based correlation is developed on the basis of maximum penetration rate on many predictions. For predicting the erosional velocity, a model from this equation was developed. The obtained results indicate that as the particle size, mass loading ratio, pipe diameter rises in order to prevent failure, the flow velocity must be reduced.

(Niu & Cheng, 2009) [16] Simulation of automotive coolant was obtained in ethylene glycol–water solutions by using erosion-corrosion of aluminum alloys. For the simulation, using measurements of potential dynamic polarization curves, electrochemical impedance spectroscopy as well as weight loss, by a revolving cylinder electrode (RCE). The turbulent flow formed on RCE in the nonexistence of sand particles causes deteriorating effects and damages the oxide film on the Al electrode, which is demonstrated by the error values of the corrosion potential and the reducing film resistance, becomes even more active with the growing fluid flow. In the existence of sand particles, the oxide film starts getting weaker and damages because of the mechanical impingement of the sand particles and turbulent flow of the solution. However, there is no change observed in the interfacial reaction mechanism. Al alloy weight loss is primarily due to the involvement of the mechanical degradation of sand particles in the ethylene glycol-water-sand solution. The weight loss caused by corrosion is minimal.

3. RESEARCH GAP

After going through the literature work, it has been noticed that, different authors have presented different works and researches depending upon the region and the situation. From these literature review, various research gap has been found, which are:-

- Few researches were depended over the certain region which itself makes it confined to that region and which might not be credible for other several regions.
- Some researches have focused upon the only one type of fluid for a particular pipe material for certain industrial solution. This can be effective for the similar type of materials and conditions and is not generalized.
- In another literature, work goes for the solid material moving through a pipe line and erosion caused by it. In this, the most common fluid that flows through pipeline, is being skipped.

ISSN: 2277-9655
Impact Factor: 5.164
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4. OBJECTIVE

Pipeline is one of the major mediums in the industries to transfer a substance especially fluid from one place to another. It is seen from the base research paper that water is one of the most usual and common substance that flows and get transferred through pipeline. Due to sand particles present in water, pipeline erodes faster than the usual rate.

- Pipeline in continuous and constant contact with water gets eroded in an accelerated manner. This effect is seen by further using two other most common materials that goes through pipeline along with water and ethylene glycol.
- Pipeline erosion is being analyzed by performing the CFD simulation under the effect of sand particles of Water and Ethylene Glycol (Used in Different Percent ratio). Rate of erosion of pipeline under these fluids were analyzed and compared.
- Viscosity of the fluid has major effect on the erosion of pipeline. Thus, effect of viscosity on pipeline erosion rate is analyzed and compared.
- In addition, effect of sand size, flow orientation, elbow bending angle will also be investigated.

5. METHODOLOGY

5.1 Step of working

- A pipe elbow is designed by taking dimensions from a reference paper using CatiaV5.
- This design file is converted into STP format and then transfer to ANSYS fluent workbench for a meshing.
- After meshing had been generated, name selection is assigned.
- With name selection, boundary conditions are applied.
- Different carrier fluids are chosen for the work
- Setting the proper setup for CFD analysis procedure.
- Evaluating the results after the finish of simulation work.

5.2 Software used for study

CATIA V5

In the present study CATIA V5 software is used for CAD modeling .CATIA offer the various stages of the product development which include computer aided design(CAD),computer aided engineering (CAE) computer aided manufacturing (CAM).It also provide the platform for performing various design modules such as wireframe and surface and shape design, mechanical and electrical system design etc.

Figure 3.1 CATIA logo

ANSYS

It is the software used for modeling as well as for testing the products durability, temperature distribution in product and the movement of fluid under various boundary conditions. It makes possible to analysis the condition of the model under various operating environment and also helped to simulate the effect on model of an object. The basic module of the ANSYS software is FEA, CFD.

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Impact Factor: 5.164
CODEN: IJESS7

Figure 3.2 ANSYS logo

5.3 Computational Approaches

In the last decade, CFD modeling was dramatically increased for use in the prediction of the wear damage in order to determine the system performance before adapting or after executing the systems. Researchers conducted experiments to enhance the database for CFD validation. By numerically solving the fluid flow equations and particle equations, the CFD method creates a simulation model that represents behavior of flow in real environment.

1. Discrete Phase Modeling (DPM)

The particles that are carried with the fluid are simulated using Discrete Phase Modeling (DPM) technique in Fluent as the second phase in order to simulate the particle trajectories and interactions. DPM correctly handles particle movement in association with fluid using Lagrangian tracking scheme.

According to the Fluent Theory Guide, the Lagrangian DPM model follows the Euler-Lagrange method. The fluid phase is viewed as a continuum by solving the Navier-Stokes equations, whereas the dispersed phase is analyzed by monitoring via the measured flow field a large number of particles, bubbles, or droplets. With the fluid phase, the dispersed phase shares momentum, mass, and energy.

The secondary phase is modeled by using the discrete phase modeling as the volume fraction is less than 10% of the sand present. On the basis of Lagrangian frame, by using integrating particle motion particle trajectories are calculated. For the calculation, pressure gradient force, buoyancy force, drag force and virtual mass force are considered which are as follows:

$$\frac{d\overrightarrow{u_p}}{dt} = \overrightarrow{F_D} + \overrightarrow{F_P} + \overrightarrow{F_G} + \overrightarrow{F_{VM}}$$

The force generated by interacting between the contiguous fluid as well as solid particles is known as Drag force $\rightarrow F_{D.}$ On the particle trajectories, drag force $\rightarrow F_D$ or hydrodynamic force has the more dominant effect on comparing with all the other forces acting on it.

By using the stochastic tracking model, because of turbulence in the fluid phase the dispersion of particles can be predicted. The design of stochastic tracking (random walk) involves the effect on the particle trajectories of instantaneous turbulent velocity fluctuations utilizing stochastic methods.

2. Flow modeling

Fluid motion equation or Navier-Stokes equation is solved by using CDF codes and in CFD erosion prediction, flow modeling is the first main step used. For solving the turbulence flow, Reynolds Stress Model is used in this study.

In the presence of pipe wall, flow of fluid is critically affected through a pipeline in most of the circumstances. The normal fluctuation and velocity is decreased because of the kinematic blocking as well as viscous damping near the wall. At the near wall region, change in mean velocity field occurs because of the no slip condition between the wall and the fluid. Therefore the output of turbulence kinetic energy is induced by wide gradients in

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CODEN: IJESS7

mean velocity, which affects the development of turbulence flow to the pipeline core as the fluid flow enters the pipeline core area.

In this study, for resolving the viscous sub layer a low Reynolds near wall model approach is selected. To get the viscous boundary layer and to eliminate the needs of wall function, meshing is used by this approach at the near wall region. Fine size particles cause prediction erosion and to get the accuracy in simulations is the reason for selecting this method.

3. Euler-Lagrange approach

Time-Averaged Navier-Stokes equations are solved by using fluid phase with continuous phase is used in this approach. And from the other hand, by mapping large numbers of trajectories of molecules, droplets, or bubbles by the domain of the measured flow, the dispersed process is addressed. The force which is applied on the dispersed phase is represented as an effect; on continuous phase this effect is present on the continuous phase of dispersed phase. With continuous phase in the dispersed phase energy, mass and momentum can get exchanged. As mentioned above in the flow domain, individually the particle trajectories are dealt and a low volume fraction is occupied by the second dispersed phase. Two way coupling-between two phases is used in this approach to get the realistic coupling. In between particles and continuous flow, if the 2 way coupling is used this approach becomes expensive. For using this approach, it becomes important to track large amount of particles. The major benefits of using this approach are wall interaction, particle flow interaction and collision. Therefore, computational cost becomes expensive.

4. Particle wall interaction

Because of inelastic collision with the wall, energy loss is observed by the model which is provided by ANSYS Fluent for the non-rotating particles. As per the coefficient of restitution, the boundary of the particle is rebounded off with its momentum change. The normal restitution coefficient determines the sum of momentum which is carried by the particle after the collision with the boundary in the direction normal to the wall. The sum of momentum which is carried by the particle in the direction tangential to the wall is the tangential coefficient of restitution. By the applications of Forder Rebound Model, the effect of particle wall rebound behavior described is simulated. On the basis of collision between steel and sand particles the model is proposed, and Forder Rebound Model is selected as the model here. Therefore, in this study, for predicting the particle wall behavior it becomes more suitable.

5. Erosion Modeling

Erosion modeling is the erosion ratio of erosion which caused loss of inner wall to the particle mass impacting on the wall. Basically, major portion of erosion prediction equations are based on experimental data and are empirical. The erosion mechanism is greatly affected by the particle impact angle and particle impact velocity which are also the principle variables. In the study, for analyzing the erosion rate Oka and E/CRC models are selected in a 90degree elbow. As after obtaining the results, they will be compared with the results of CFD and experiments in the previous work. After the experiment performed, the previous work of E/CRC is compared with the CFD results.

6. Mathematical Model and Numerical Method

By utilizing the ANSYS Fluent 15 package, the computational modeling is performed is performed in this present work. There are four steps used in CFD based erosion modeling which are as follows: 1) Flow modeling, 2) Secondary Phase Modeling, 3) Erosion calculation and 4) Result validation. Euler-Lagrangian approach is used for simulating the sand erosion in the finite volume models. The computational formulation utilized in the simulation of sand erosion in finite volume frameworks is the Euler-Lagrangian method in which the fluid phase is viewed as the continuous phase, which would be handled in the same way as it was handled for a single-phase system by time balancing of the Navier Stokes method, while the sand particle is considered as the dispersed phase and is resolved by the motion equation.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Flow modeling

In CFD erosion prediction, flow modeling is the first step here. For analyzing the fluid motion equation or for Navier-Stokes equation, CFD codes are being used. Here, for solving the turbulence flow, Reynolds Stress Model (RSM) is used in the study as shown below:

$$\frac{\partial}{\partial t}\left(\rho\overline{u_i'u_j'}\right)+\frac{\partial}{\partial x_k}\left(\rho u_k\overline{u_i'u_j'}\right)=-\frac{\partial}{\partial x_k}\left[\rho u_k\overline{u_i'u_j'u_k'}+\overline{p'(\delta_{kj}u_i'+\delta_{ik}u_j')}\right]+\frac{\partial}{\partial x_k}\left[\mu\frac{\partial}{\partial x_k}\left(\overline{u_i'u_j'}\right)\right]$$

$$-\rho\left(\overline{u_i'u_k'}\frac{\partial u_j}{\partial x_k}+\overline{u_j'u_k'}\frac{\partial u_i}{\partial x_k}\right)-\rho\beta(g_i\overline{u_j'\theta}+g_j\overline{u_i'\theta})$$

$$+p'\left(\frac{\partial u_i'}{\partial x_j}+\frac{\partial u_j'}{\partial x_i}\right)$$

$$-2\mu\overline{\frac{\partial u_i\partial u_j}{\partial x_k\partial x_k}}-2\rho\Omega_k\left(\overline{u_j'u_m'}\varepsilon_{ikm}+\overline{u_i'u_m'}\varepsilon_{jkm}\right)$$

Due to the existence of pipe walls, fluid flow from the pipeline is severely affected in most of the situations. In the mean velocity field, changes occur because of the no slip condition between the fluid and the wall. Near the wall, the normal fluctuation and velocity decreases due to kinematic blocking and viscous damping. Though, production of turbulence in kinetic energy is caused because of the large gradient in the mean velocity. In this study, for resolving the viscous sub layer a low Reynolds near wall model approach is selected. To get the viscous boundary layer and to eliminate the needs of wall function, meshing is used by this approach at the near wall region. Fine size particles cause prediction erosion and to get the accuracy in simulations is the reason for selecting this method.

Secondary Phase Modeling

The secondary phase is modeled by using the discrete phase modeling as the volume fraction is less than 10% of the sand present. On the basis of Lagrangian frame, by using integrating particle motion particle trajectories are calculated. For the calculation, pressure gradient force, buoyancy force, drag force and virtual mass force are considered.

Particle Wall Interaction

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6. Modeling

Modeling of pipe elbow in CATIA software:

The art of representing the system or object is known as the modeling. With graphical information and non-graphical information, the complete representation of the structure is defined as geometric modeling. In the

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Impact Factor: 5.164
CODEN: IJESS7

database of the computer, mathematical description of the non-geometry structure and geometry structure are generated as well as on the graphics screen, the image of an object is generated.

Geometrical requirement of the pipe elbow is important in the design of the pipe elbow. Physical shape as well as different strength considerations is unavoidable for the physical shape and structural requirement of the pipe. In the design, empirical relations and various other factors are used which are based on the experiment. In various aspects of design, graphical solutions can also be useful apart from the analytical methods.

Case description

The geometry of the case consists of 1000mm vertical length of the pipe and which has 76.2mm of internal diameter which is connected with the horizontal pipe having 1.5D radius and section is 600mm with the curvature of 90degree elbow. This length was chosen to allow full development of turbulence flow field and does not increase the cost of computation. From the inlet, continuous and dispersed phase will flow and it will exit from the outlet. Stainless steel 316 was selected for the wall material. On CATIA V5, the model is designed.

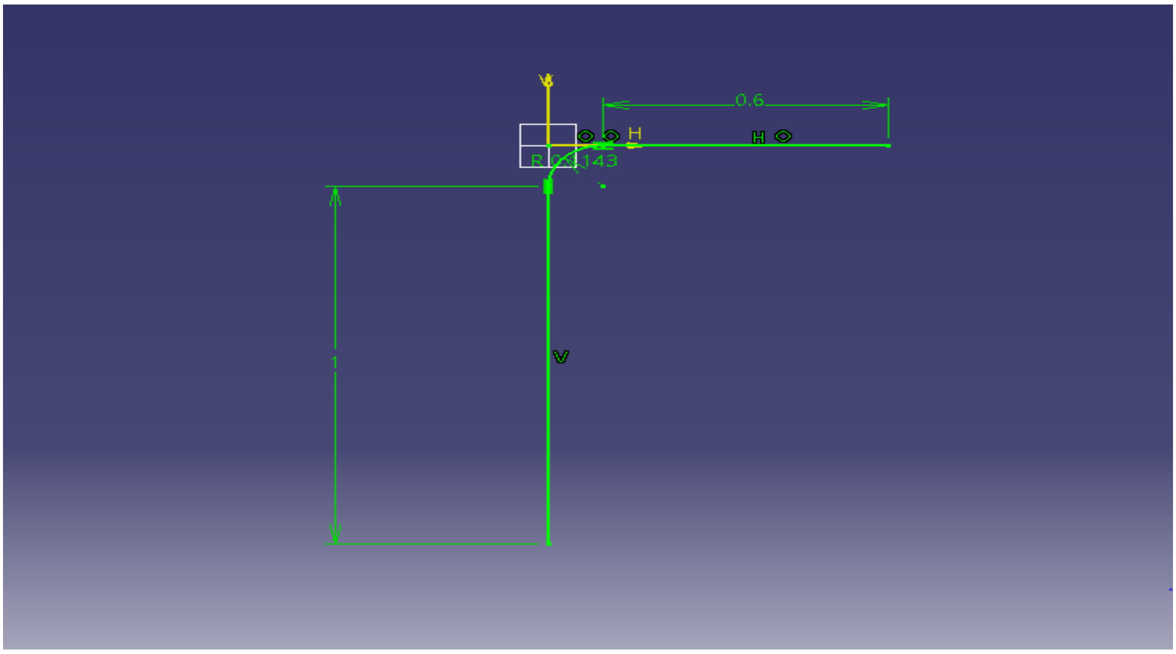

Figure 3.3 Pipe Sketch

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Impact Factor: 5.164
CODEN: IJESS7

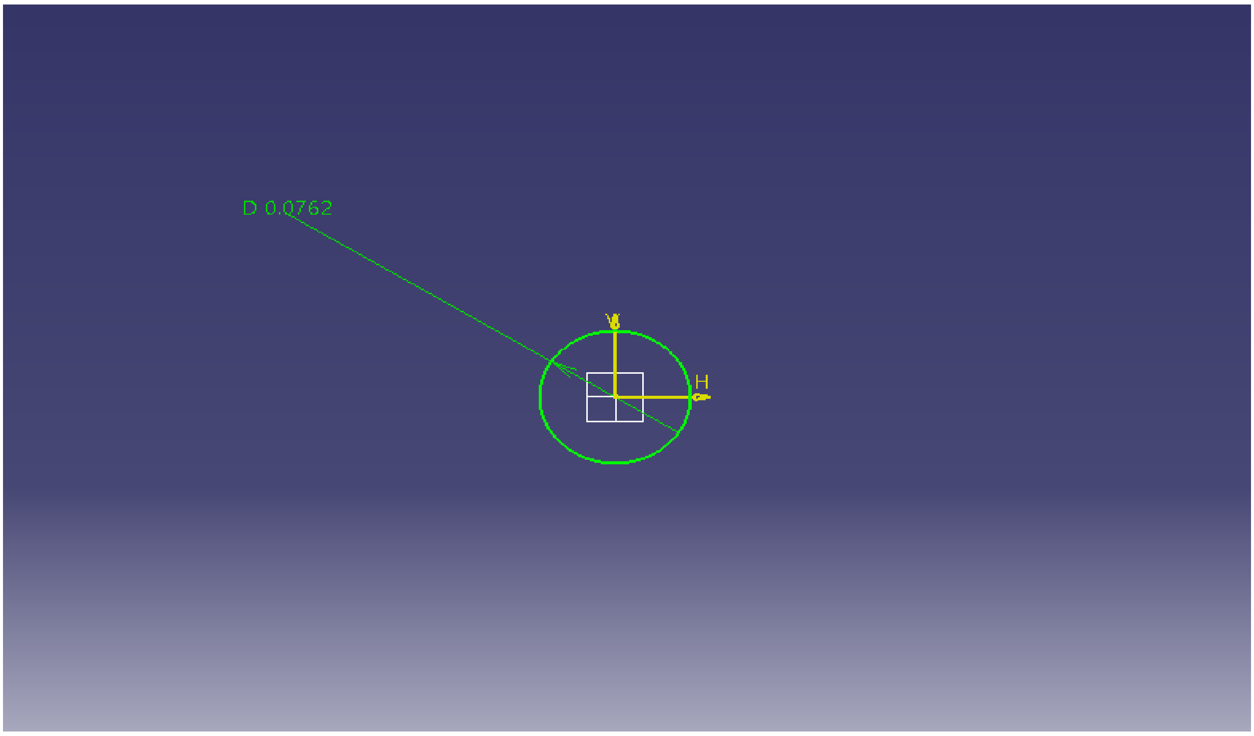

Figure 3.4 Circle sketch for rib command

In a CATIA, a 2D sketch is converted into 3D by using a rib command, following are 3D view of pipe elbow,

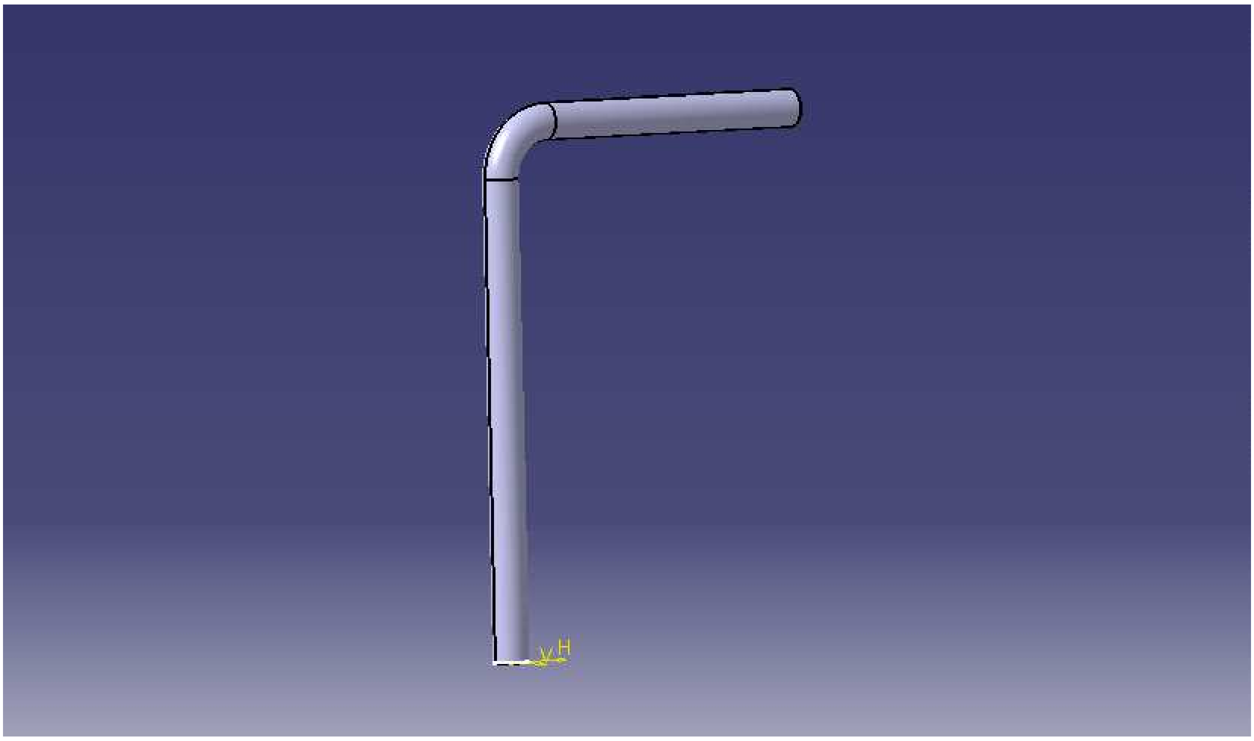

Figure 3.5 3D Model

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Impact Factor: 5.164
CODEN: IJESS7

5.4 Computational Fluid Dynamics

Meshing

In the Computer Aided Engineering Simulation Procedure, Meshing is regarded as the integral part. Speed, accuracy and convergence are the parameters which are influenced by the mesh. Moreover the time it will take to design and mesh a model is always a large portion of the overall time it requires to get results from a CAE solution. So, better solutions can be obtained by using better and automated meshing tools.

After generating design in CATIA model is converted into STP file in order to transfer it to ANSYS for the further simulations, mesh generation and name selection is performed,
The following number of nodes and element are generated in meshing:

In relatively tiny computational cells, flow domain must be used. Computation of flow variables will be permitted by these cells and after that they can be stored up at the cells location. For resolving the viscous boundary layer, 12 inflation layers have been used in this study. Each layer has a thickness of 0.2mm. 0.2mm is the thickness of the mesh adjacent to the wall. And towards the center, the size of the mesh gradually increases. On the basis of mesh type, mesh independence was determined along with the size and medium type. Mesh configuration shown in figure 4.6 is the hexahedral mesh type. For the simulation, 23m/s is considered as the inlet velocity.

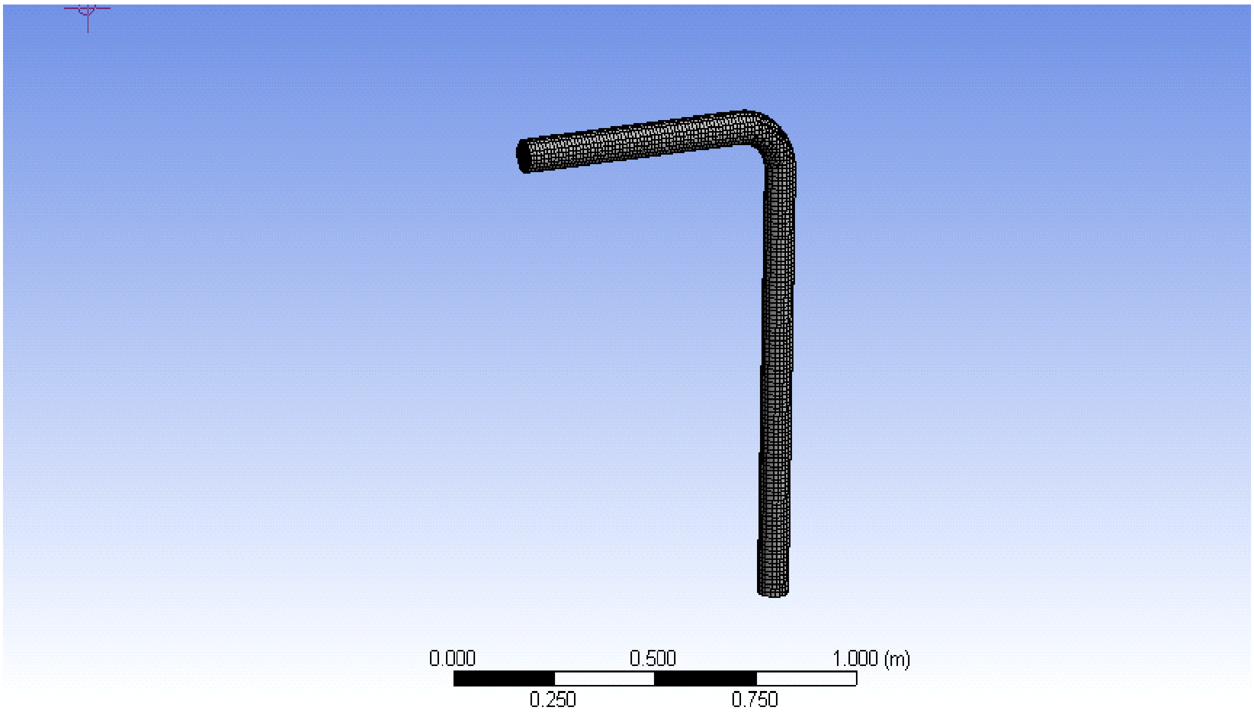

Figure 3.6 Meshing

ISSN: 2277-9655
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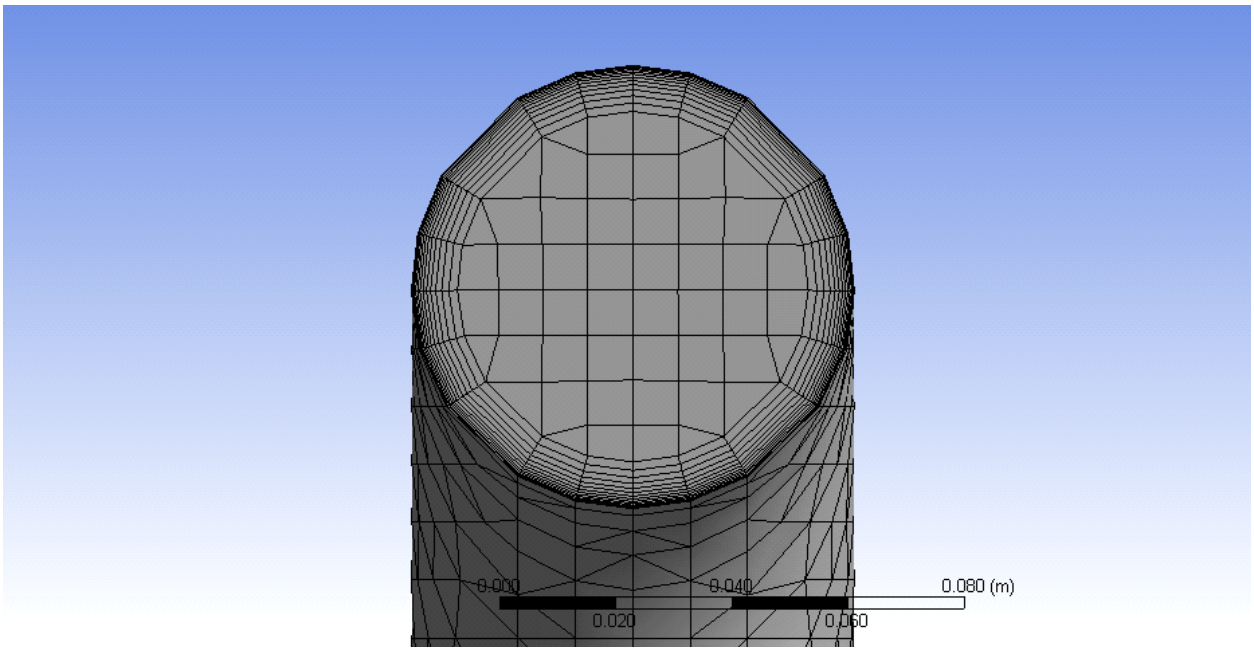

Figure 3.7 Meshing with Inflation

Name Selection and Boundary Conditions

It is important to define boundary conditions for the completion of flow modeling. Pressure outlet, velocity inlet and wall are the available boundary conditions in this study. The atmospheric pressure at the pressure outlet was supposed by specifying the zero-gauge pressure and the flow velocity at the velocity inlet was specified by the magnitude normal to boundary. After that, name selection of the pipe must be assigned and on the basis of chosen base paper, suitable boundary conditions must be provided. And at last, material property is assigned.

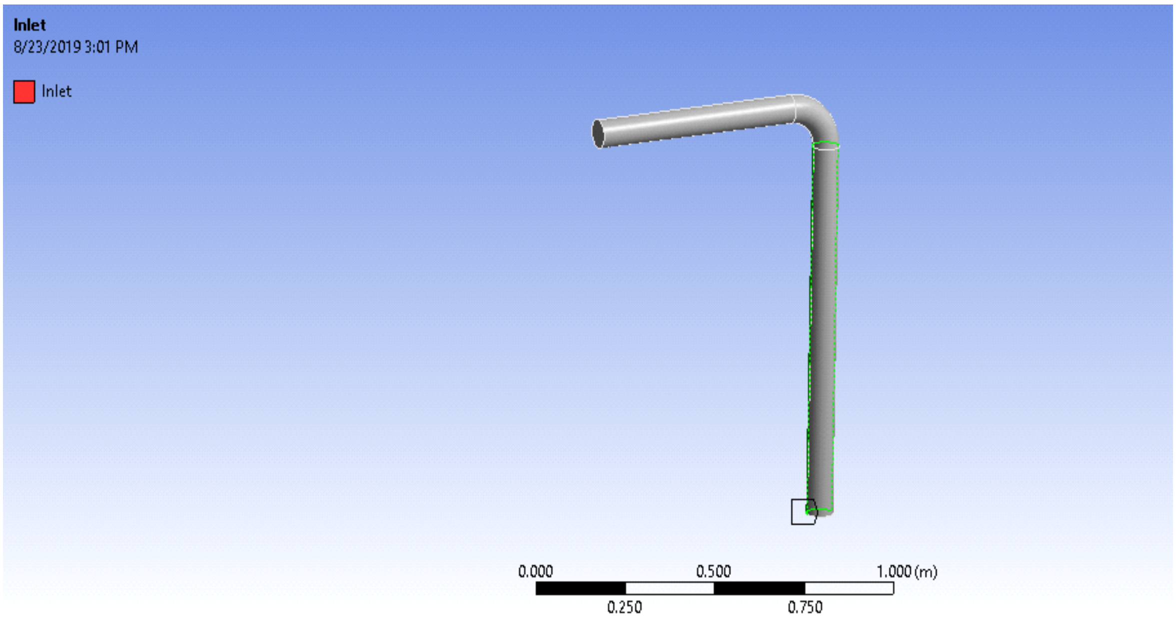

Figure 3.8 Inlet

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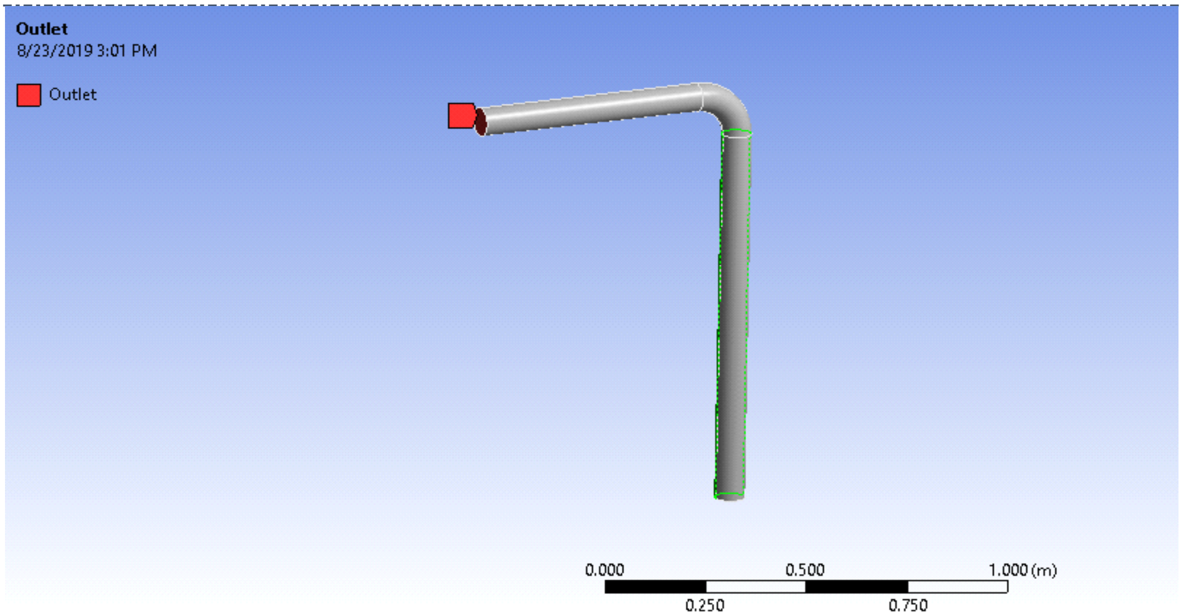

Figure 3.9 Outlet

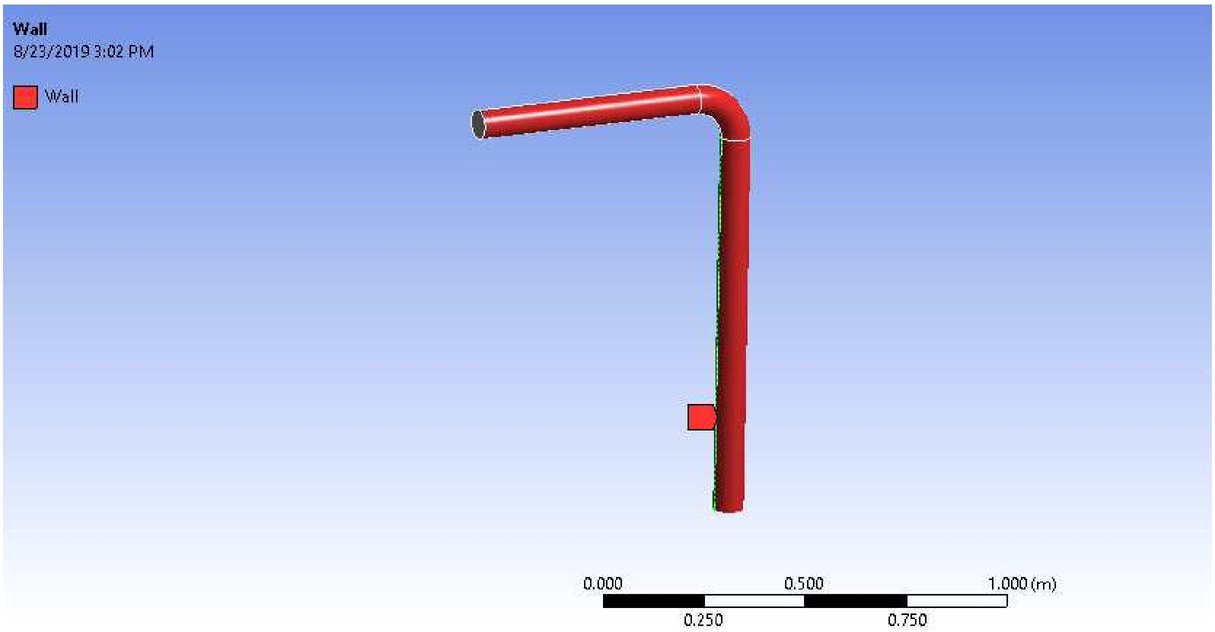

Figure 3.10 Wall

7. Material Properties

In table 4.2, materials and its properties which are used in this simulation are listed. For comparing the effect of carrier fluid, water and air are used.

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Table 3.1: Fluid Material Properties

Material	Properties	
	Viscosity (kg/ms)	Density (kg/m^3)
Water	1.003 x 10^{-3}	998.2
Air	1.8 x 10^{-5}	1.125

Following are the properties of the sand used to study the effect of particle size distribution are:

In Rosin Rammler Equation, the sand from the experiment is fitted on the basis of size distribution of the Oklahoma No. 1 sand. The parameters like mean, min, max and spread diameter as well as cumulative size distribution of particles is obtained. Therefore, The amount of simulated particles was calculated to be more than 50,000, which is enough to provide an adequate representation of the measurement of erosion.

Table 3.2: Sand Properties

Sand name	**Oklahoma No.1**
Shape Factor	0.53 (Semi Rounded)
D_{min}	65 µm
D_{max}	360 µm
D_{mean}	177 µm
Spread diameter (n)	4.10

8. Solution Method

The pressure dependent steady state solver will be the simulation solver that would be used to discretize the Discrete Phase Model as well as Reynolds Stress turbulence model. In table 4.4, the scheme of the solution and solver are summarized. To address the momentum as well as continuity equation sequentially before continuing to update mass flux, strain, speed, and turbulence and some other scalar equations, the segregated SIMPLE algorithm solution was being used. For getting accurate results, second order upwind was also selected. 10^{-4} is the residual convergence criteria used in this study.

Table 3.3 Solver and discretization summary

Solver	Pressure-Based Steady State Solver
Solution Scheme	SIMPLE algorithm (Segregated)
Spatial Discretization	Gradient: Least Squares Cell Based
	Pressure: Second Order
	Momentum: Second Order Upwind
	Specific Dissipation Rate: Second Order Upwind
	Reynolds Stresses: Second Order Upwind

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Impact Factor: 5.164
CODEN: IJESS7

6. CONCLUSION AND FUTURE SCOPE

Conclusion

Sand production is one of the major problems in oil and gas industry as it can cause severe damage towards the equipment. Pipeline erosion due to sand particle transportation is one of the negative implications of sand production. In this work, a proprietary CFD based simulation model is used to study the effects of some parametric factors on erosion rate in pipe bends. The effects of three parameters were studied, namely, erosion rate, skin friction coefficient and swirl velocity. Following are the conclusions from the above study:

- Results are analyzed on the basis of maximum erosion rate. On comparing different particle sizes, the results are obtained. Here, various cases of particle size 160µm and 370µm have been observed.
- By varying the percentage of water and EG, various cases of sand particle (size 160µm) are compared. From this, it can be concluded that:
  Erosion rate decreases with increasing the percentage of EG; but after Case 4, Case 5 shows the different results. When water is 60% and EG is 40% in Case 5 erosion rate increases with increasing the percentage of EG.
  On increasing the percentage of EG, it is observed that skin friction coefficient also increases.
  Negligible variations have been observed in swirl velocity of the particles when sand particle size is 160µm.
- By varying the percentage of water and EG, various cases of sand particle (size 370µm) are compared. From this, it can be concluded that:
  Erosion rate decreases with increasing the percentage of EG; from Case 6 to Case 10 it is observed that with increasing the quantity of EG and decreasing the quantity of water, erosion rate decreases.
  On increasing the percentage of EG, it is observed that skin friction coefficient also increases.
  Negligible variations have been observed in swirl velocity of the particles when sand particle size is 370µm.

Future Scope

- In this work, a proprietary CFD based simulation model is used to study the effects of some parametric factors on erosion rate in pipe bends. In future this CFD analysis can be performed experimentally.
- In this study, diesel industry is used for the research. Different industries like Power plants, Chemical industry, etc. can be used in future for the research.
- Various other fluids can be used in future as Ethylene Glycol is used as fluid in the present study.
- This study is performed for only to analyse the erosion rate of sand particles. In future, various other metallic particles can be used in further studies.

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