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ANALYSIS OF PIPELINE EROSION BY CFD SIMULATION UNDER THE EFFECT OF SAND PARTICLES OF WATER AND ETHYLENE GLYCOL

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Abstract

Sand productions include a variety of main essential difficulties for gas and oil productions, as sand managements are increasingly becoming crucial to manage wells with high rates of sand accumulation. Approximately 70 percent of the world's gas and oil reserves are found in sand deposits. Sand erosion over a pipe bend is studied in this research, which examines and analyses many aspects to determine the sand's severity and quantity of erosion. For this work, computational fluid dynamics (CFD) was employed to analyse the fluid flow phenomenon. The sand particle sizes of 160m and 370m will be compared in this experiment to see how different percentages of water and EG may affect the results. The three primary impacts that will be investigated further are erosive rate, skin friction coefficient, and swirl velocity. Through the investigation, it can be concluded that the character of the material and the flow velocity are the most important elements influencing the rate of sand erosion in pipelines.

Keywords: Ethylene Glycol, CFD, ANSYS, Erosion rate, Skin friction coefficientsand erosion.

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1. INTRODUCTION

In pipeline engineering, pipe fitting deterioration and associated problems are the most common problem. Various sand control frameworks have been established throughout time to limit sand at the bottom of the well's pit. In order to prevent sand from getting into the pipeline, these methods use gravel packing at the wellhead or a screen to keep sand out. Because of their effectiveness in significantly decreasing the flow of sand into pipeline lines, these sand exclusion systems are often found in gas and oil wells as well as improved sand observation and control systems. The combination of components generated by hydrocarbons wells will lead to pipeline erosion, which will result in pipeline damage.. Demolitions such as erosion-corrosions and cavitation are only a few examples of what might go wrong. Multi-phase particle modelling focuses on the oil and gas pipeline's transportation. Concerns such as transportation of sand, vibration induced of flow, corrosion, erosion, wax, hydrates and slugging have huge impacts over the assurance of the flow. The common cause of erosion is particulates (sand and prop pants). Particulate erosion is a function of density, viscosity and velocity. For modelling the process of erosion in the pipes of oil and gas, the use of ANSYS software is made in this experimental work; thus, estimating the mechanical and pitting strength estimation. The testing of the design and configuration of the pipe over flow assurance will be done and the effects of damages caused due to erosion will be observed.

1.1. Sand impact Erosion

Particularly in small, deposited sandstone reservoirs during oil and gas abstraction, sand production is a common problem. The sand particles can be extracted from the reservoir and are formed during oil, water or gas production. Sand output will occur at the very starting of the flow or afterwards when the pressure of the reservoir or water breakout has dropped. Based on its degree of magnitude, not all sand production needs intervention, or sometimes constant sand production is admitted. Sand development is regarded as one of the hardest challenges associated with oil and gas production, and is the primary cause of several flow assurance issues, including sand effect erosion. Erosion is characterized as the loss of material from the surface of the metal that is affected by a moving fluid that with a series of mechanical acts carries small solid particles. Erosion can cause significant damage to pipelines, crippling manufacturing and facilities on the surface. Many cases were earlier reported about sand impact erosion which becomes the cause of catastrophic accidents. Some examples are shown in figure given below:

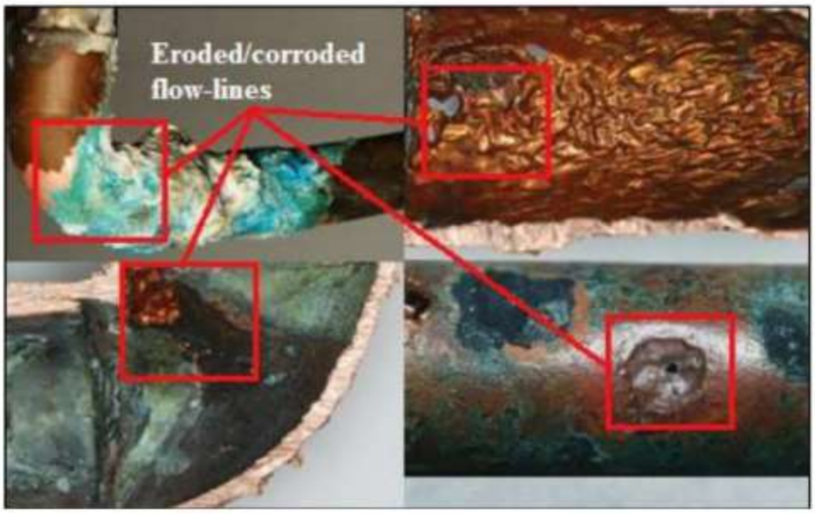

Figure 1: Illustration of severely damaged flow-lines caused by erosion

1.2. Ethylene Glycol and Deionized Water

The formula of Ethylene glycol is $(CH_2OH)_2$. The major use of ethylene glycol is for two purposes which are for antifreeze formulations as well as for the manufacturing of polyester fibers as a raw material. The properties of ethylene glycol are that it is sweet-tasting, colorless, viscous liquid and odorless.

The freezing point of EG is -36.8 °C and is mixed 50:50 by the volume with water. It should be kept in mind that fluid temperature is less cold than the evaporator surface where the cooling takes place. It might be at or below the liquid's freezing temperature. The decrease of glycol/water temperature also increases the viscosity, decreasing the flow rate inside a bath from the pump and/or the mixture. A boundary layer that holds to the much colder evaporator and protects it from the rest of the fluid could also create this higher viscosity, restricting how low a temperature can be reached and decreasing cooling power. [1]

Distilled water and deionized water both are the forms of pure water but still they are not same. As mineral ions are removed in the deionization process for producing high purity water; however, those organic molecules, which are uncharged, will not be removed because of it. The fact that it is being used in cooling has been one of the applications. Dissolved impurities like minerals are contained in varying level in the normal tap water. This contributes to electrical conductivity in it which will not be preferred for various cooling applications. The build-up of size, corrosion and erosion would also lead to these dissolved minerals. Consequently, in these applications, deionized water is favored as it has very low level of electrical conductivity and also, it won't lead to building up of unwanted scale. [2]

1.3. Objective

Pipeline is one of the most common methods of transporting fluids from one location to another in the industrial sector. From the study article, it can be observed that water is one of the most prevalent substances that flow and transfer via pipelines. Due to the presence of sand particles in the water, the pipeline deteriorates at a higher pace than normal.

- Pipeline erosion is increased when it is in continual and continuous contact with water. Further, it can be observed by employing two additional common materials that go through pipelines, ethylene glycol and water, to achieve this effect.
- As part of the CFD analysis, sand particles from Water and Ethylene Glycol are being used to simulate pipeline erosion (Used in Different Percent ratio). Comparing the rate of pipeline deterioration under various fluids, an analysis was made.
- Viscosity of the fluid has a significant impact on pipeline erosion. Consequently, the influence of viscosity on pipeline erosion rate is examined and compared.
- Elbow bending angle, flow direction and particle size will also be examined.

2. LITERATURE REVIEW

(Ejeh et al., 2020) [3] For the sake of the aforementioned investigation, this research examines crude oil dynamics in pipeline flow and identifies erosion hotspots for different pipe elbow curvatures. As part of this research, “PTM and Reynolds Averaging Navier–Stokes (RANS)” were used. Fluid dynamics and particle tracking are the primary goals of this research project. The fluid velocity magnitude was much larger in the region with the smallest curvature radius, according to post-processing results. The maximum static pressures and turbulence dissipation levels were found in low-velocity severity zones. At the elbow, erosive wear was substantially more common, and the curvature of the pipe varied with the hotspot.

(Okafor & Ibeneme, 2019) [4] Engineers working with gas and oil pipelines face a big problem: the deterioration of pipe fittings and other concerns. Various sand control frameworks have been established throughout time to limit sand at the bottom of the well's pit. Sand exclusion methods like gravel packing at wellheads and screens are used to keep sand out of pipelines. Aside from increasing visibility and control over sand, these sand exclusion systems are widely employed in oil and gas well production since they reduce sand output in the pipelines by a significant amount. In this work, the results are based on simulations done using a well-known proprietary CFD model. The degree of bending, diameter, and radius of the pipe all have an effect on the rate of erosion, which increases with fluid velocity and decreases with sand particle size. It is also possible to determine the parameter's threshold magnitude from the results.

(Wee & Yap, 2019) [5] Considered the fact that pipeline deterioration, with its safety and financial integrity problems, remains a major issue for the petroleum business The primary goal of this study work is to analyse the sand erosion behaviour in diameters of 76.2mm using CFD. Sand particles smaller than

50 micrometres seem to predict the erosion result, according to the literature; fluid particles affect sand particle movement; even little geometrical changes may have a significant impact on erosion. The Navier-Stokes equations may be solved using CFD analysis using the Eulerian-Lagrangian technique and the particle force balance secondary phase. Together with low “Reynolds number modification”, the Reynolds Stress Model depicts the continuous nature of viscous boundary effects and secondary elbow flows in the near wall area for more accurate performance.. According to the study's evidence, assuming that each sand particle has a constant size leads in a wear rate forecast of more than 10%.

(Lospa et al., 2019) [6] For the purpose of determining how quickly the bends of the pipe used in the installation of the technological installation are eroded by solid particles. CFD was used to perform an investigation by the researchers, who reported their findings in this paper. The CFD analysis is used to identify the region where erosion occurred and the rate of erosion. Erosion is concentrated in the extrados of the pipe. As the curvature of the curve increases, the total erosion rate increases, causing the observed differences. The project will continue to construct an experimental test framework for erosion analysis in order to compare CFD and experimental programme results.

(Xian & Che Sidik, 2019) [7] Ethylene glycol and water are the most often utilised coolants in car cooling systems, according to our research. In nano fluids, the thermal conductivity of traditional heat transfer fluids is improved by dispersing solid particles. Using nano fluid as a coolant improves heat transfer in vehicle cooling systems, according to earlier study. After 100 hours of continuous testing, every pump space profile was examined using a 3D imaging microscope. Before and after the testing, exact weight measurements were made to determine the overall amount of material lost. According to the research, the corrosion effect currently seems to be the same whether using a basic coolant or a nano coolant. The “erosion-corrosion effect” has enhanced material loss due to the usage of nano coolant instead of base coolant. Based on the ASTM 2809-09 standard, the impact of corrosion on the impeller was found to be minimal and received a high grade. As a result, it is feasible to consider the use of all coolants in the cooling system as an option.

(N. H. Saeid, 2018) [8] The quantity of sand in the choke valve and the two-phase turbulent flow of crude oil have both been studied using 3D CFD modelling. A discrete phase mathematical model is employed to simulate sand flow and its interaction with the oil flow in the system. Using parametric analysis, the controlling factors for decreasing sand erosion in the given system are uncovered. Measurements and valve geometry may be taken from the industrial oil production project. The study's parameters include the pressure differential between the pipe's intake and output, sand flow rate, and valve opening percentage. The erosion rate fluctuation is shown in the simulation results with regard to sand flow rate, valve opening, and pressure differential. The erosion rate is found to be high for both big and small valve openings. Every instance with a wide range of pressure variations has a minimum erosion rate between 20% and 30% of the valve opening. Areas with the greatest erosion rates are predicted in the models.

3. RESEARCH METHODOLOGY

3.1. Step of working

- For the purpose of creating a pipe elbow, CatiaV5 is used to extract dimensions from a reference document.
- Converting this STP design file to ANSYS fluent workbench for meshing is done.
- The process of selecting a mesh name begins once meshing has been produced.
- With the selection of a name, a set of parameters are established.
- Work is done using a variety of fluids.
- Setting up the CFD analysis technique in the correct manner.
- After completing the simulation task, it is important to evaluate the outcomes.

3.2. Erosion Modeling

Erosion modelling is the ratio of the loss of the inner wall to the particle mass hitting on the wall that was produced by erosion. The vast majorities of erosion prediction equations are based on experimental data and are empirically derived. "Particle impact angle and impact velocity" are two of the most important factors that govern the erosion process. A 90-degree elbow is used to choose the Oka and E/CRC models for the erosion rate analysis. Due to the fact that after the data have been gathered, they will be compared to CFD and experiment results from past work, the findings of the experiment are compared to those of E/CRC and CFD once the experiment is completed.

3.3. Material Properties

This simulation's materials and attributes are detailed in table 1. Water and air are used to compare the effects of different carriers.

Table 1: Fluid Material Properties

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

The sand used to investigate the impact of particle size distribution has the following properties:

Size distribution of Oklahoma No. 1 sand is used as a foundation for the Rosin Rammler Equation. Mean, minimum, maximum and spread diameters as well as the cumulative size distribution of particles are measured. There were 50,000 particles in all, which is enough to accurately portray the erosion of the surface of the earth.

4. RESULTS AND DISCUSSION

Results may be examined based on their maximum degradation rate. The simulated erosion results are derived from a range of particle sizes between 160 and 370 micrometers.

4.1. Particle size 160 µm

The study of the distribution of particle size is used to identify the increases in erosion prediction, since various sized particles have varied effects. This sand particle measures 160 m in diameter. By altering the amount of water and EG, several instances have been explored.

Table 2: Case design Particle size 160µm

Cases for particle size 160µm	Percentage of WATER	Percentage of EG
Case 1	100%	0%
Case 2	90%	10%
Case 3	80%	20%
Case 4	70%	30%
Case 5	60%	40%

To accurately anticipate the pace of erosion and identify the most vulnerable pipe places, a detailed knowledge of erosion's nature and brittleness is required. Bends are particularly vulnerable to sand damage.

4.2. Result Comparison of cases with Sand particle size 160 µm

A graph is used to compare the results of all instances. Sand particles have a diameter of 160 nm. The attributes of six examples, including erosion, skin friction coefficient, and swirl velocity, are examined here.

Table 3: Result Comparison of Five cases

Case No.	Erosion (Kg/m^2s)	Skin friction coefficient	Swirl velocity (m/s)
1.	$1.43x10^{-5}$	**$4.75x10^3$**	-41.7m/s
2.	$1.22x10^{-5}$	**$5.36x10^3$**	-41.7m/s
3.	$1.00x10^{-5}$	**$5.78x10^3$**	-41.7m/s
4.	$9.57x10^{-6}$	**$6.13x10^3$**	-41.7m/s
5.	$1.06x10^{-5}$	**$6.42x10^3$**	-41.6m/s

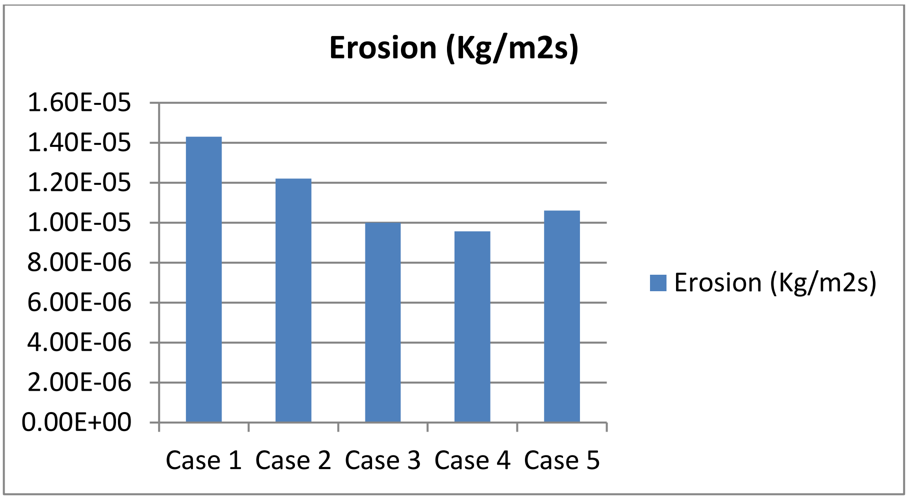

Figure 2: Graph showing the results of Erosion in different cases

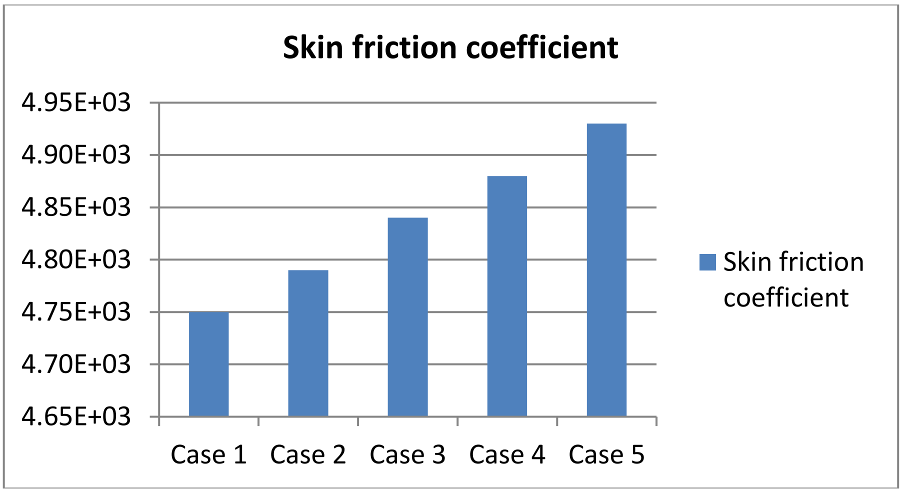

Figure 3: Graph showing the results of Skin friction coefficient in different cases

4.3. Particle size 370 µm

As a result of the examination of particle size distribution, erosion prediction is improved since the effect of particles of different sizes is varied. Here, a sand particle of 370 m in diameter is used. By altering the amount of water and EG, several instances have been explored.

Table 4: Case design for particle size 160 µm

Cases for particle size 160 µm	Percentage of WATER	Percentage of EG
Case 6	100%	0%
Case 7	90%	10%
Case 8	80%	20%
Case 9	70%	30%
Case 10	60%	40%

In order to accurately anticipate erosion rates and identify pipe areas most vulnerable to erosion, it is vital to have a full grasp of erosion's nature and severity. Bends are particularly vulnerable to sand damage.

4.4. Result Comparison of cases with Sand particle size 370 µm

A graph is used to compare the results of all instances. Sand has a particle size of 370 nm. The attributes of six examples, including erosion, skin friction coefficient, and swirl velocity, are examined here.

Table 5: Result Comparisons for particle size 160 µm

Case No.	Erosion (Kg/m^{2}s)	Skin friction coefficient
6.	$1.53x10^{-5}$	**$4.75x10^{3}$**
7.	$1.44x10^{-5}$	**$5.36x10^{3}$**
8.	$1.47x10^{-5}$	**$5.78x10^{3}$**
9.	$1.46x10^{-5}$	**$6.12x10^{3}$**
10.	$1.19x10^{-5}$	**$6.42x10^{3}$**

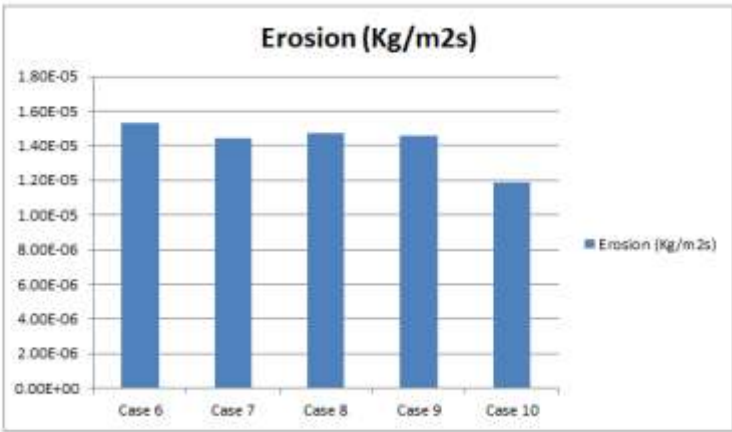

Figure 4: Erosion comparison for particle size 160 µm

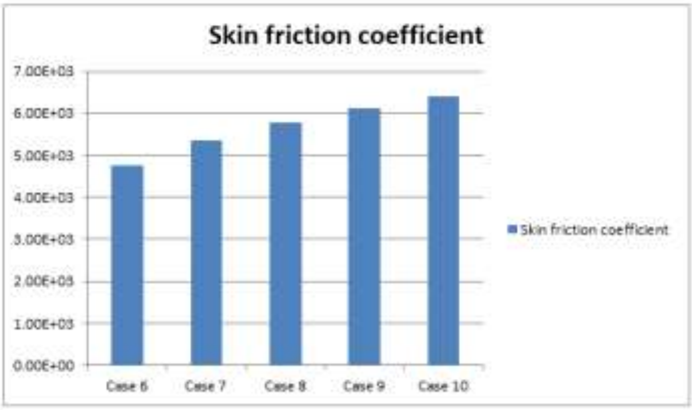

Figure 5: Skin Friction coefficient for particle size 160 µm

5. CONCLUSION

A key challenge in the oil and gas business is that of sand production since it may cause serious damage to the equipment. One of the drawbacks of sand extraction is the erosion of pipelines caused by sand particles. There are certain parametric elements that affect the erosion rate in pipe bends in this research, and the results are studied using a proprietary CFD simulation model. Erosion, skin friction coefficient and swirl velocity were all examined in this study. From this investigation, the following are the findings that emerged:

The highest erosion rate is used to evaluate the results. According to this comparison, the findings are found to be consistent. Particles with a diameter of 160 micrometres and 370 micrometres have been detected in this study. Sand particles (size 160 m) are compared by altering the percentages of water and EG. It may be argued from this that:

- Erosion reduces as EG % increases, however after Case 4, the findings are different in the fifth case. Erosion rates rise as the proportion of EG increases in Case 5 when water is 60 percent and the EG content is 40%.
- It has been shown that when EG concentration rises, so does the skin friction coefficient.
- When the sand particle size is 160 micrometres, there are no noticeable differences in the swirl velocity of the particles.
- Different types of sand particles (with a diameter of 370 microns) may be compared by altering the water and EG content. It may be argued from this that:
- Increasing the EG content reduces erosion rates; from Case 6 through Case 10, erosion rates drop as EG content rises and water content falls.
- It has been shown that when EG concentration rises, so does the skin friction coefficient. When the sand particle size is 370 micrometers, there are no noticeable differences in the swirl velocity of the particles.

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