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ISSN : 2348 - 5612 | Volume : 09 , Issue : 01 | January - March 2022

CFD Analysis of Sand Erosion in a Pipeline: A Review

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ABSTRACT

Particulate erosion in the slurry handling unit of a thermal power plant is a major concern. Pipe bends are the most erosion-affected elements of a pipeline unit; hence, adopting a cost-effective method to reduce pipeline erosion is a necessity. Thus, it can cause highly priced potential eco-friendly 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. Pipe erosion due to sand transport can have an adverse effect on the production efficiency of pipe lines and other related flow systems. Proper knowledge of the flow characteristics, particle behaviour and geometric effects are the important factors for accurate prediction of erosion rates and location. The main focus of the present study is to review various literatures of the researchers and through them study the various factors for determining the severities and amount of the erosion of sand over the pipe bend.

Keywords: Sand erosion; Pipe erosion; Computational fluid dynamics.

I. INTRODUCTION

Pipelines are used inshore and offshore for the transportation of many fluids like water, oil and gas. Pipelines placed on the seabed are vulnerable for damage by fishing gear and scraping anchors. In some areas therefore it is required to protect the pipelines. This can be achieved, for instance, by covering the pipelines by trenching and subsequently backfilling of the pipeline or by using natural erosion and sedimentation processes. These natural processes can be amplified by placing a spoiler on top of the pipeline. The erosion and subsequently lowering down of the pipeline due to the natural processes can be subdivided into various stages. [1]

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. [2]

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. [3]

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.

Figure 1: Actual damaged pipelines (a) a failure of bend after repairing; (b) a failure of bend in a gas pipeline

II. LITERATURE REVIEW

(Ejeh et al., 2020) [4] Studied that flow dynamics in pipes get hugely impacted because of the available conditions of the flow. 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.

(Okafor & Ibeneme, 2019) [5] 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) [6] Evaluated that Pipeline degradation, along with the associated financial integrity and safety concern, remains a big problem for the petroleum industry. By using CFD, for investigating the sand erosion behaviour in diameter of 76.2mm is the primary objective of the researcher of this work. "Simulation of erosion through fine sand particles" (< 50 μm) appears to predict the erosion outcome according to literature; "transportation of sand particles" in the elbow is influenced by "fluid particles"; slightly changed geometries yield substantially different erosion's 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 final outcomes obtained in this study indicate that the

supposition of constant sizes for each sand particle resulted in a maximum wear rate prediction of more than 10 percent.

(Lospa et al., 2019) [7] To evaluate the erosion rate in bends of the pipe brought in use during the process of the technocal installation, which circulates the fluid with a small amount of solid particles. The researchers conducted an analysis with the help of CFD and presented it through this study. 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) [8] 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 enhancement in the rate of transfer of heat 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) [9] 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) [10] 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 motions by carrier fluids like mixed gasses, methane-oil, methane, and many more. The erosion mechanism is analyzed for both multi and single-phase flow with the help of CFD analysis conducted on ANSYS Fluent 6.0. The most prone areas having the maximum level of degradation of the material were suggested to investigate. By API recommended standards, erosion rate can be calculated which will use CFD for comparing the values numerically. Calculation of the forces striking over the bend section is performed along with the pressure drop.

(Hosseini & Hosseini, 2016) [11] stated the process of erosion among the amin threats to the integrity of assets in hydrocarbon transportation and production industry. Subsea flexible pipes and risers are

particularly susceptible to particulate erosion due to the complex geometry of inner metallic carcass. In this work, the sand erosion in a 2" flexible riser carrying a two-phase gas and liquid flow were numerically simulated using a computational fluid dynamic tool and E/CRC model. The erosion rates were estimated for commercial carbon steel, UNS S31600 and UNS S32750 at an angle which yields the minimum bend radius (MBR) in riser. As a reference, the simulation was also conducted on a rigid pipe with a similar geometry. It was found that both maximum and total erosion rates were considerably higher for all three materials in flexible riser.

(Pao et al., 2016) [12] reviewed that Sand production is an inevitable by-product in oil and gas industry. Transport infrastructure of the particles to the surface from the wellbore would cause the equipment and facilities to be affected. Pipeline erosion is one of the damage caused by extreme sand production and there are many factors influencing the severity of the erosion rate. The objectives of the project are, i) to evaluate the different sand erosion models, ii) to assess the effect of particles properties and fluid properties on the erosion rate in the pipeline, and iii) to develop Visual Basic Application (VBA) Toolkit for the computation of sand erosion rate based on different sand erosion models. The present study focuses on naturally produced sand and fine under isothermal condition where no change in temperature is assumed. The analysis on the erosion rate through VBA is conducted by referring to different sand erosion models. The parameters affecting erosion are categorized into three which are carrier fluid, sand particle and target material. Every factor is being analyzed throughout the study. It is observed that flow velocity and material character are the predominant factors that affect sand erosion rate in pipeline.

III. 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. The severity of the erosion rate depends on many factors such as impact angle, velocity, sand rate, particle properties, target wall properties and etc. Every factor has different significant and effect on the erosion rate depending on the situation.

Sand particle erosion remains one of the major bottlenecks for increased production in the oil and gas industry. Sand production results in the damage to the internal wall surfaces of pipelines and other line equipment in the oil and gas industry. It is therefore of paramount importance to predict the erosion rate of and identify the erosion location in the pipelines for possible leakage. After studying literature reviews, it was observed that to employ the right modeling technique and to capture the flow features and particle behaviour, all the characteristics must be properly captured.

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