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A Review on CFD Analysis for Erosion Effects on Elbows Containing Water Particles

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***Abstract*-Erosion due to particulate impingement is the key factor responsible for damage of industrial pipeline. Sulfur particles carried by high-speed flow impact pipelines, which may cause equipment malfunctions and even failure. In recent years, Computational Fluid Dynamics (CFD) technology has been widely used in many industrial fields. Afterwards, multiphase flow simulation with the discrete phase model of CFD software had been extensively explored in various fields, including the effects of parameters of the continuous phase on erosion scars, simulation of erosion rate, and modification of the erosion model. In this study, a review work has been performed in the context of erosion effects on elbows containing water particles.**

***Keywords*-Erosion, Elbows, R/D ratio, Taguchi method, 90-degree bend pipe.**

I.INTRODUCTION

Erosion can be defined as the mechanical loss of material by the impact of solid particles (e.g. sand, certain hard scales, catalysts) and / or liquid droplets. Erosion caused failures are not new. The oil and gas industry has suffered and continues to face many failures that can be attributed to erosion. Under aggressive operating conditions, flow velocity limits and thus the production limits are set to avoid erosion. If the velocity limits are overly conservative (lower values) then an oil company can suffer production losses and if they are too optimistic (high velocities) there is a serious risk of erosion damage and the loss of system integrity. Piping failures are often the first sign of a corrosion problem. Yet in many examples, signs of an impending pipe failure have been clearly evident for months or years and ignored. Failures can be minor, in the form of a pinhole leak, or catastrophic, with significant losses due to water damage as well as the cost of pipe replacement. When detected, the problem can be arrested easily with pipe leak repair kits readily in the market.

Erosion commonly occurs in elbows and turns within piping systems. Damage often occurs when the pipe line is carrying solid particulates, slurries, or two phase flow, such as wet steam. In a plain elbow, the flow is accelerated and directed toward the outer wall of the elbow, which focuses high speed particulates or droplets on a restricted region. Severe wear begins to occur at that point. The 90 reducing elbow is designed to change direction as well as reduce the size of the pipe within a piping system. The reducing elbow eliminates one pipe fitting and reduces the welding by more than one-third. Also, the gradual reduction in diameter throughout the arc of the reducing elbow provides lower resistance to flow and reduces the effect of stream turbulence and potential internal erosion. These features prevent sizeable pressure drops in the line.

II. LITERATURE REVIEW

Erosion does not only depend on particle property, fluid that flow along with sand is another important factor. Different fluid may exhibit different erosion behaviour. In gas solid flow, sand particle tends to cross the fluid streamline upon subjected to changes in fluid flow direction; while in liquid solid flow, sand particle will flow the streamline closely (Mansouri et al., 2015).

The particle trajectories and distribution in fluid are dependent on the relationship between particle inertia and fluid drag force. The liquid drag force will cause the lateral movement of particle prior to impact leading to comparative less impact frequency on the target surface which yield lower erosion rate. Moreover, different carrier fluids will not have the same erosion pattern. In gas solid flow, vee-shaped erosion is often reported by researchers with flow through elbow (Solnordal et al., 2015; Vieira et al., 2016; Peng and Cao, 2016a) while in liquid solid flow, the erosion profile is not fixed. Therefore, a detailed study on the particle trajectories and particle liquid interaction are needed to characterise the liquid solid flow.

A few mathematical models had been proposed to describe the distribution of particle size which utilised power law, hyperbolic, logarithm or exponential power equations. Rosin and Rammler expression had been regarded as the most suitable model as it is proven to be applicable at wide range of materials (Rodriguez et al., 2016); contained relatively less number of model parameters but high fitting accuracy over range of particle size as compared to other models (Bayat et al., 2016).

The complexity of flow geometry greatly affects the flow condition hence the erosion severity. Flow in straight pipeline required extreme turbulent flow to cause significant mass loss due to low contact frequency between particle and the wall. Geometries such as valves, elbow, tees experience severe erosion as compared to straight pipeline due to the direct impingement and recirculation of sand particle. A slight differ in the geometry may heavily affect the severity of erosion. An experimental and numerical investigation had been carried out to investigate the relative erosion severity between plugged tees and elbows (Chen et al., 2006). Flow streamline redirection is more drastic in plugged tees than in elbows. Some particles recirculate repeating almost identical paths more than one hundred times. These repeating impingements at the same location cause highly localized erosion in the plugged tee. Thus, different geometries have their own particular flow field that may increase or decrease erosion rate which requires numerous investigation on these effects of geometries towards the erosion behaviour.

The up-to-date researches on erosion mainly focus on standard elbow geometries as elbow is the most common application in the process industry as well as in the petroleum production facilities (Parsi, 2015; Karimi et al., 2016). Hence, elbow with different flow orientation and angle required further study to investigate on the erosion pattern. Pereira, de Souza, and de Moro Martins (2014) showed that using the Oka model is an accurate and robust approach, as the model is based on measurable properties of both eroded and erodent materials. Duarte, de Souza, and dos Santos (2015) found that the erosion rate does not increase with the mass loading, because the particles protect the eroded surface in regions of high concentration. In an attempt to better predict elbow erosion due to fine sand particles,

Mansouri, Arabnejad, Karimi, Shirazi, and McLaury (2015) proposed a new model based on computational fluid dynamics (CFD) simulations. Zhou, Liu, Liu, Du, and Li (2017) studied the effects of particle and swirl intensity for the same geometry. Duarte, de Souza, de Vasconcelos Salvo, and dos Santos (2017) provided a comprehensive analysis of the effects of various parameters on the prediction of elbow erosion. They also demonstrated the importance of interparticle collision modeling when dealing with cases of high mass loading. Wang and Shirazi (2003) predicted the elbow erosion for different elbow radii and showed that increasing the elbow curvature is an effective way of reducing the overall damage due to erosion. This result was corroborated by experimental measurements made by Bourgoyne (1989). Parsi et al. (2014) gave a detailed review of solid-particle erosion modeling. Owing to operating conditions and space considerations, it may be unfeasible to use a long radius elbow to reduce erosion. Plugged tees and vortex-chamber elbows are thus interesting candidates. Erosion experiments using plugged tees are generally difficult to find in the literature, with only preliminary discussions having been published (Chen, McLaury, & Shirazi, 2004; Salama, 2000). Salama (2000) provided empirical relationships with which to predict/limit erosion in a number of piping devices, including tees. Chen et al.(2004) presented possibly the first predictions of the erosion rate by CFD analysis for the plugged tee. Qualitative agreement was found between numerical and experimental results, although rates were considerably overpredicted. A more elaborate experiment was conducted for a plugged tee by Chen, McLaury, and Shirazi (2006). They measured the local thickness loss of an aluminium specimen using a profilometer. The local thickness loss profile was extracted from the plugged tee end surface. Additionally, they predicted the erosion patterns for different particle diameters and compared the results against the standard elbow. The results reveal that the penetration ratio of the plugged tee is about half that of the elbow.

Additionally, no detailed experimental data on vortex-chamber elbow erosion have been presented in the literature. In a previous publication, the authors of the present study numerically investigated the use of a vortex chamber as an alternative to the standard elbow (Duarte, de Souza, & dos Santos, 2016). The nature of the multiphase flow inside the chamber provides a so-called cushioning effect that considerably reduces erosion. Both pipeline fittings are clearly advantageous in the sense that the erosion magnitude is mitigated but no systematic research has been performed to quantify the relative erosion under the same operating conditions. The main goal of the present work is thus to quantitatively investigate the relative erosion rates of the plugged tee and vortex chamber elbow for different mass loadings. The standard elbow is used as a reference. The CFD erosion model is first validated for the plugged tee on the basis of experimental measurements made by Chen et al. (2006).

The standard and vortex-chamber elbows designs follow the plugged tee geometry, preserving the main constructive characteristics (e.g., diameter) and simulation parameters (e.g., inlet velocity and physical properties for both phases). On the basis of four-way coupled simulations, all configurations are prepared and a detailed analysis of the effect of the mass loading on the relative erosion is carried out. The particle impact velocity, impact angle, and impact frequency patterns for each design are presented and erosion mechanisms are further explained.

III. METHODOLOGY

The erosion prediction model based on Computational Fluid Dynamics has become an effective approach to investigate the erosion problems. It consists of a 90 degree bend pipe in which R/D ratio were set to be 10 mm and 1.5, respectively. Considering the influence of inlet flow field on simulation, a 100-mm (10D) vertical downstream straight pipeline and a 100-mm (10D) horizontal upstream straight pipeline of elbow were used. The water as a flow material is enter from inlet. Simulations were run utilizing one flow conditions. The water particles enter from inlet and exit from outlet.

IV. CONCLUSION

In this study, a parametric study is performed to investigate the effects of velocity and R/D ratio on the erosion rate in the pipe elbow. It is optimized for the best performance using Taguchi method. A multiphase-flow hydrodynamic model of the 90○ elbow has been employed to predict erosion effect on an elbow for water-particle. A series of simulations were conducted to investigate erosion scars . It was concluded that most of the studies were focussed on bend or elbow erosion and were lacked in terms of fluid behaviour and magnitude of erosion wear. In the present work, simulation deals with analysis of erosion wear in elbow caused by turbulent flow of multiphase fluid and also the study of flow behaviour. The pipe is subjected to boundary conditions on wall, inlet and outlet. Water is allowed to flow from the pipe elbow. The pipe material is considered as mild steel.

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