CHAPTER 2

COMPUTATIONAL FLUID DYNAMICS MODELING FOR PIPE-FITTINGS EROSION

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2.1 INTRODUCTION

Fluid transportation with entrained solid (sand) particles in a pipeline system typically leads to erosion problems of liquid-solid impacts encountered by various sectors, including hydrocarbons (oil and gas-O&G) and power production. The sand's existence in the said system was reported to be the main contributor to erosion failure, particularly on the downstream complex pipeline fittings (Araoye et al., 2017; Liu et al., 2019). For example, in upstream activities, the hydrocarbon products (O&G) produced from the production well are often contaminated with sand, which is the origin of the problems of flow assurance in the pipeline, as in practice, these pipelines size are in the ranges of 0.1016m (4 inch) to 0.3048m (12 inch) (Canadian Association of Petroleum Producers (CAPP), 2018). The flow involving this sand-liquid could affect the material integrity of pipeline fittings such as reducers, elbows, flanges, tee-junctions, and related equipment, for instance, boilers, heaters, pumps, and compressors, which typically can be found at the processing plant because of erosion phenomenon. Improper handling of this erosion may cause an unplanned shutdown for the whole production system and malfunction of equipment for a prolonged period. Consequently, the plant uptime will be severely affected, reducing the reliability of the asset (equipment/system) and the profit.

Accurate prediction of erosion phenomenon caused by various factors, for example, the characteristics of fluid flow and particle, the details of particle impingement, and the properties of the target surface, etc. can assist in design processes for practical applications as well as assist in future planning for predictive (when failure will occur) and reactive/corrective (fittings replacement) maintenance. Several scholars have investigated the erosion phenomenon of elbows and tee-junctions using the experimental approach, and their works are extended by the development of models (mechanistic) and correlations (empirical) to forecast the erosion rate. In the meantime, current advancements in the simulation approach of computational fluid dynamics (CFD) have greatly helped scholars to comprehensively assess the parameters affecting erosion rate and forecast the erosion rate for pipeline fittings in different flow conditions.

Chen et al. have investigated the particle trajectories and erosion pattern of 90° elbow for the air flow system via both the experimental and simulation (CFD) approaches (Chen et al., 2004). In their works, they claimed that the velocity of the stream possesses remarkable influences on the erosion rate, and the maximum erosion rate observed at the centre area of the elbow is due to the multiple impingement effects produced by a single particle. Additionally, they found that the maximum erosion rate was situated almost at the centre area of the elbow for the tested range of elbows diameter (0.0254m–0.2032m) and size of particles (50 μm–300 μm) (Chen et al., 2006). However, a different location for maximum erosion rate occurred when they substituted the flow system from the air to the water, whereby it shifted to the exit area. The reason for this occurrence is the higher drag and inertia forces of particles produced under the flowing media of water. On top of that, for the water-solid particles flow, they concluded that the velocity of the stream, the diameter of elbows, and the size of particles weakly influence the location of the maximum erosion rate. These conclusions are congruent with previously reported works (Blanchard et al., 1984).

In other published works, they claimed that the stream velocity is directly proportional to the momentum of particles and higher particles momentum caused a higher erosion rate (Shamshirband et al., 2015; Verma et al., 2018; Vieira et al., 2016; Ya et al., 2018). Besides that, high particle volume concentration results in erosion reduction in elbows owing to the strong interactions between the particle (Chen et al., 2006; Duarte et al., 2015). Smaller particles size cause lesser erosion severity (Nguyen et al., 2016; Pei et al., 2018; Wee & Yap, 2019), and different erosion effects could occur depending on the types of fluid flow. For the geometry of elbows, the severity of erosion decreased with increasing elbows' diameter. The reason for that is a larger stagnation area that the impinging particles must pass through, permitting a longer duration for particles to decelerate (McLaury et al., 1997).

On the other side, Lospa et al. (Lospa et al., 2019) investigated the elbows with variations of angles (30°, 45°, and 90°) and diameters (76.1, 88.9, and 114.3 mm) in a liquid-solid flow system via the CFD approach. For the 90° elbows, they found that the maximum erosion rate is inversely proportional to the diameter of the elbow. Meanwhile, the erosion rate is directly proportional to the elbow angles. In addition, all the maximum erosion rate was observed at the exit area of the elbows regardless of angles and diameter. Other scholars (Ejeh et al., 2020) deduced that the increment of elbow angle from 45° to 180° resulted in an increased erosion rate. For their works, they also revealed that the increment in particle flow rate, mass, and density causes the erosion rate to increase.

In similar works, Chen et al. discovered the maximum erosion rate of tee geometry forecasted by a stochastic particle rebound model has occurred at the end surface of the tee (Chen et al., 2004). In addition, both the simulations and experimental results displayed notable erosion for the tees occurred at the end, side, and corner areas using the air flow of 45.72 m/s and the tee diameter of 0.0254m (Chen et al., 2004; Chen