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Numerical Simulation of Elbow Erosion with Circumferential Welding in Two-Phase Gas Flow

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1. Introduction

Sand produced with liquid oil and gas in oil wells, despite the filtration of transmission pipelines, is transported to the downstream points and for various reasons, including lack of proper cleaning, these particles get stuck inside the pipe and will be problematic. Because they will cause pressure drop, pipe blockage and erosion and will cause financial losses. When a particle hits the surface, it injures the surface. The shapes of these scratch depend on many parameters, including surface material, particle size, and impact angle. On the other hand, when the piping connections of the station like elbows have circumferential welds, the erosion-corrosion is created in the connections, so welding is very important for this system. When the internal pressure of a system is very high, it has higher welding, rating and reliability than other connections. The most common welding method in gas pressure reducing stations is butt welding, in which the ends of two joints are machined to form a gap at the joint. This gap is filled when the welding material is mixed together to form a desired joint. The joint edge is prepared for welding according to its thickness. For low thicknesses, welding is best done with square edges, and for larger thicknesses, proper welding is achieved when the connection edges are chamfered.

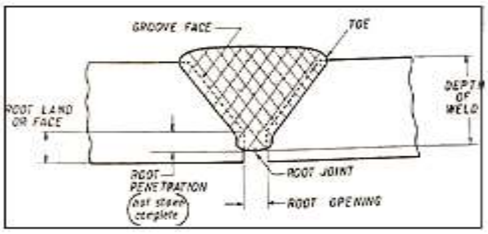

Figure 1. Details of butt groove welding

Calculation of erosion-corrosion rate of welded joints is based on the internal geometry of the weld. The geometry of the weld determines the strength of the weld against corrosion. In this study, the first case, i.e., the presence of solid particles in the gas fluid was explored. Erosion seems to be dependent on the following nine basic parameters:

1) Type of material: For brittle materials, the mechanism of cracking is due to surface fatigue and the formation of microcracks, and for soft materials, the wear mechanism is due to the impact. (According Figure 2).

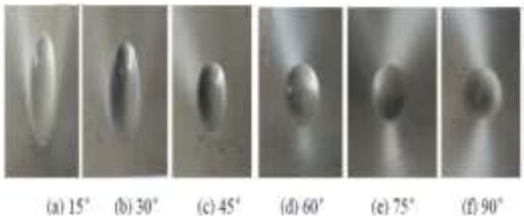

Figure 2. Macrograph of corrosion scars caused by different angles of contact of solid particles

2) Particle impact angle: The critical angle is about 90 degrees for brittle materials and about 15 to 30 degrees for soft materials (as shown in Figure 5).
3) Items related to design: such as the amount of elbow radius - headers and splits
4) The amount of accompanying sand in the fluid: based on the percentage of weight of associated sand / total fluid weight;
5) Particle collision speed;
6) Fluid velocity;
7) Fluid corrosion rate;
8) Fluid viscosity;
9) Fluid density.

2. Simulation Modeling

The CFD-based erosion modeling includes three main steps:

- the continuous phase
- flow field
- simulation, particle tracking and erosion calculation.

The gas is treated as a continuous phase and solved by Navier-Stokes equations. The particles are treated as a discrete phase and solved by Newton′s second law. Additional two- way coupling is applied between the continuous phase and discreate phase.

3. CFD Modeling

The commercial software ANSYS FLUENT is adopted to conduct the numerical simulations. A database of the Zamany (2017) is employed in this work to investigate the preformed erosion model. Zamany (2017) studied the erosion of long redius elbows without any welding part. The test piece was a 90°elbow with a diameter of 3 inch. Figure 3 shows the 3-D computation mesh used in the simulation. Meshing consist of two parts: surface meshing and volume meshing. The surface mesh was carefully generated due to its important effect on the

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quality of resulting volume mesh. Gradual refinement is necessary for the near-wall region where high velocity gradients and boundary layer are present. A structured grid is used to

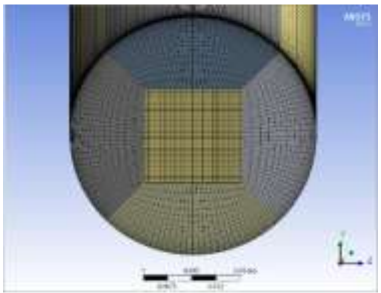


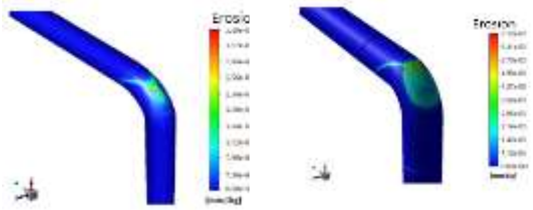
Figure 3. Elbow cross-section meshing

mesh the surface of the cross-section. Finally, the hexahedral structured mesh is adopted to mesh the whole volume.

4. Finite Element Analysis of Elbow

First, the erosion-corrosion contour in non-welded Conditions is examined for an elbow with a diameter of 3 inch (Figure 4).

As can be seen, the highest amount of corrosion is related to the elbow part of the pipe. The maximum amount of corrosion in the whole pipe in this case is equal to 0.00345 mm/kg. When under the same conditions the amount of elbow corrosion is taken into account, considering 3 mm of overflow penetration, this amount increases to 0.00712 mm/kg according to the simulation results in this study.



a: Contour of Erosion-corrosion distribution without welding

b- Contour of Erosion-Corrosion distribution with peripheral welding

Figure 4. Contour of Erosion-Corrosion in two modes without welding and considering the circumferential welding

In addition, the rate of particles would increase when elbow is studied with circumferential welding. When the solid particles hit the wall of the pipe at angles of 47-degrees and 58 degrees, the most erosion-corrosion occurs in the elbow when exposed to the welding. This rate has an upward trend between angles 0 to 60 and decreases sharply between 60 and 90. Meanwhile, the speed of movement of solid particles and, of course, the amount of their impact on the wall of pipes and fittings significantly reduced

According to Figure 5, the accumulation of particles in the weld state compared to without welding for the elbow indicates a zigzag motion in which the particles hit the elbow wall and continue on their way. The difference in this case is only the volume of particles moving along this path.

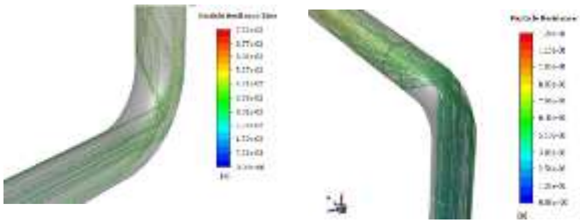


Figure 5. The path of particles in two modes without welding and considering the circumferential welding

5. Conclusion

According to the results, the amount of corrosion in the elbow with peripheral welding to study the standard welding amount of 3 mm is a natural problem in Iran and according to the type of gas, the penetration of welding must be above the standard to be acceptable. Due to the pollution of natural gas in Iran with solid particles and considering that the analysis of gas according to previous researches shows the presence of water in the gas fluid, the same amount of corrosion in the presence of water exposes the pipe material which is carbon steel to corrosion. In addition, due to the acceleration of gravity, the amount of corrosion in the case of peripheral welding is shown at two points, one is welding the lower part of the joint and the other is the elbow of the joint, while in previous welding studies erosion of the upper elbow curve is not well predicted.