Preliminary Study of Particle Trajectory and Secondary Flow in Bend Configurations to Reduce Erosion

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Abstract

Erosion is one important problem in many industrial and environmental applications and it is associated to the presence of particles carried by a fluid flow. In the industry, it may cause complete failure of the pipeline or malfunctioning of equipment attached to it. In 1994, it was estimated that erosion-corrosion problems (not including erosion itself) cost about $15 billion a year to the US industries. That amount is even larger in nowadays economy. Even though it is an important problem, we are far from having a full picture of the erosion phenomena in pipelines. Although it has been recognized that the fluid-particle interactions play an important role in understanding particle impact erosion, most of the studies on erosion has been focused almost exclusively in the material properties and particle-wall interaction right before collision.

To the best of our knowledge, only few researchers have made attempts to minimize the erosion in bends by modifying the bend configuration in order to alter the particle-laden flow pattern to reduce the erosion. Yao et. al. (2000) and Fan et. al. (2004) did experimental and numerical investigations of gas-particle flow erosion in a bend and in different specimens of ribbed bends in a square cross section duct. They concluded that the changes in the particle trajectory, particle impingement angle, and particle impact velocities found in their work make the erosion rate to drop in 66% to 91% in average. Edwards et. al. (2000) compared the erosion process in elbows and plugged tees and concluded that long-radius elbows and plugged tees geometries have smaller erosion rates than standard elbow. Wood et. al. (2001) studied the influence of swirl-induced flow in erosion damage from slurries in bends. They claimed that the use of a swirl pipe before the bend could reduce erosion. The results showed that inducing the swirl flow reduces the particle impact velocity, but increases the angle of particle impact.

In this work, using COMSOL Multiphysics® software with its CFD Module and Particle Tracing Module, we revisit those three bend configurations to reduce the erosion. In addition to those configurations, we also proposed two additional bend designs. First, we used a twisted blade located before the inlet of the bend, following Kadyirov (2013) who used a twisted tape model to simulate the swirl effect on a laminar flow. Second, we used a combination of plugged tee and a gradual expansion before such tee as it is known that an expansion in a flow decreases the

fluid velocity and particle impact wall velocities as a result. In the configurations shown in the figure, the particle trajectories were studied in order to observe their impact velocity, impact area, and angle of impact on the bend. Close attention was paid to the secondary flows in such bends, as they are an important piece on the particle-laden flow pattern alteration while looking at the overall pressure drop in the bend, which needs to be kept to a minimum.

Reference

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Figures used in the abstract

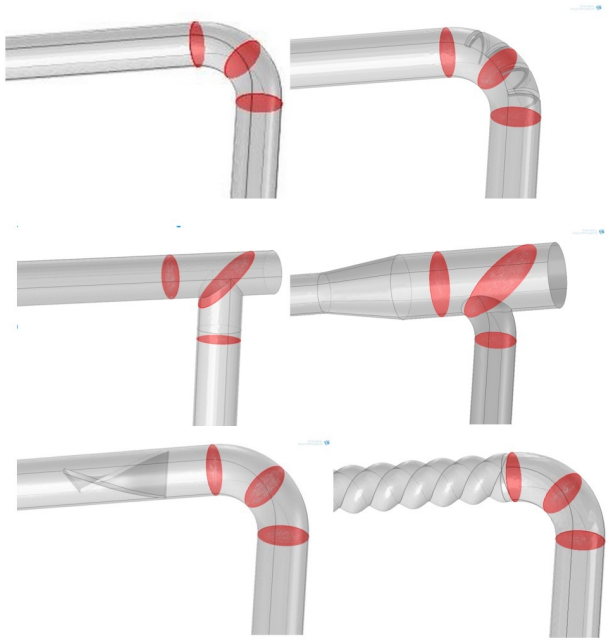

Figure 1: Bend configurations used to study the particle-laden flow pattern in COMSOL Multiphysics. In summary, we studied six different configurations, a regular elbow, a ribbed elbow, a plugged tee, an expansion-plugged tee, a twister blade in pipe, and a swirling pipe. The secondary flows were analyzed on the red cross-sectional planes shown.

Figure 2

Figure 3

Figure 4