COMSOL CONFERENCE 2015 BOSTON

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

ODU IDEA FUSION

O. Ayala[1], A. Arruda[2], L. Calembo[2], E. Enes[2], D. Monteiro[2]
R. Paizante[2], A. Rocha[2], M. Simões[2], J. Michaeli[1]
1. Old Dominion University, Department of Engineering Technology, Norfolk, VA, USA
2. Brazil Scientific Mobility Program, CAPES, Brasilia, DF, Brazil

Introduction: In the industry, erosion 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. 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; Fan *et. al.*, 2004; Edwards *et. al.* 2000; Wood *et. al.*, 2001). In this work, we revisited previously proposed bend configurations to reduce erosion, in additional to two of our own design.

Computational Methods: For this particle laden problem, the carrier fluid was water flowing in a pipeline for which a stationary RANS equation (Reynolds-averaged Navier Stokes) was solved with a k-ε turbulence model. The particles were tracked by the one-way coupled Lagrangian approach with only drag acting upon each particle. Two particle sizes were analyzed 250 μm and 500 μm with density of 2,200 kg/m^3.

Using COMSOL Multiphysics with its CFD and Particle Tracing modules, we studied the six bend configurations shown in figure 1. A Reynolds number was fixed to 75,000. After performing a mesh sensitivity analysis, we used a "Fine" mesh as it gave a reasonable compromised between accuracy and computational requirements. We also monitored the y+ value of the region with boundary element type to keep it between 50 and 100.

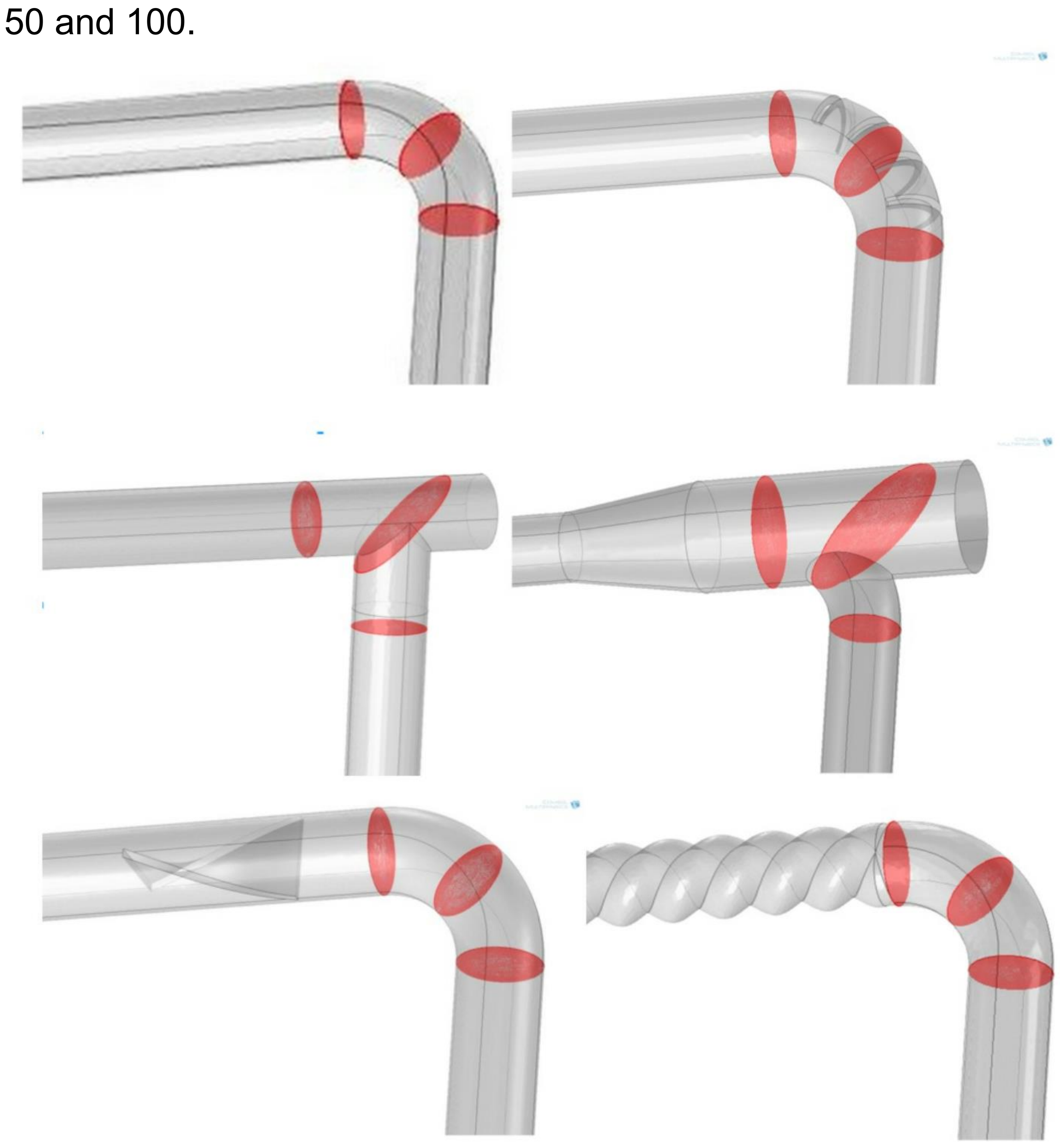

Figure 1. Bend configurations used to study the particle-laden flow pattern in COMSOL Multiphysics. In summary, we studied six different configurations, a regular elbow, a ribbed elbow, a plugged tee, an expanded-plugged tee, a twister blade in pipe (Kadyirov, 2013), and a swirling pipe. The secondary flows were analyzed on the red cross-sectional planes shown.

The outlet was modeled with a constant pressure boundary condition and it was located 6 pipe diameters downstream of the bend. For the inlet a power law velocity profile was used. Such profile was obtained from data collected from a straight pipe simulation. The inlet was located 16 pipe diameters upstream from the bend to minimize any possible entrance length effect. For the turbulence intensity and turbulence length scale we utilized I=0.16Re$^{-1/8}$ and L=0.07D.

Results: 250 μm particles only

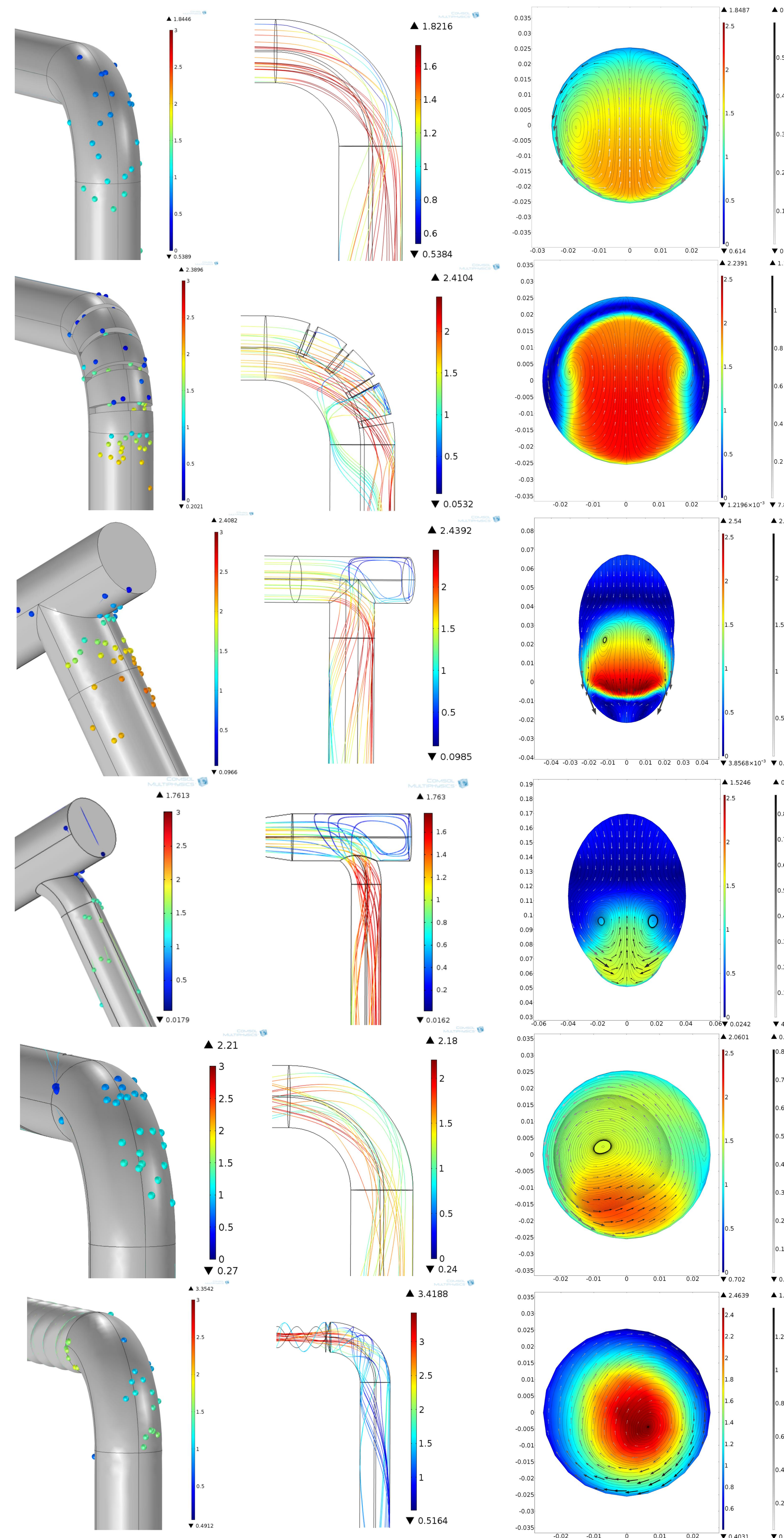

Figure 2. Particle contact location at the bend (1st column), particle trajectories in the bend (2nd column, from which impact angle can be observed), and secondary flows at the 45° plane (3rd column). On the 3rd column, rainbow color scale show the fluid velocity magnitude perpendicular to the plane, and the gray color scale show the fluid velocity magnitude on the plane.

Conclusions: We found that secondary flows play an important role on the erosion pattern (impact location and impact angle). The secondary flows depend on the pipe configuration. More work has to be done in this direction. We might be able to minimize erosion with bend configuration. However, this also depends on particle and fluid characteristics. In the near future, we will also include erosion in our models.

References:

1. J. Yao *et. al.*, An experimental investigation of a new method for protecting bends from erosion in gas-particle flows, Journal of Thermal Sciences, 9, 158-162 (2000).
2. J.R. Fan *et. al.*, Antierosion in a 90° bend by particle impaction, AIChE Journal, 48, 1401-1412 (2004).
3. J.K. Edwards *et. al.*, Evaluation of alternative pipe bend fittings in erosive service, FEDSM2000-11245, Proc of ASME FEDSM2000, 11-15 (2000).
4. R.J.K. Wood *et. al.*, Upstream swirl-induction for reduction of erosion damage from slurries in pipeline bends, Wear, 250, 770-778 (2001).
5. A. Kadyirov, Numerical investigation of swirl flow in curved tube with various curvature ratio, Proceedings of the 2013 COMSOL Conference in Rotterdam (2013).