Quantitative Assessment of Secondary Flows of Single-phase Fluid Through Pipe Bends

Z. Kaldy[1], O. Ayala[1]

[1]Department of Engineering Technology, Old Dominion University, Norfolk, VA, USA

Abstract

There are hundreds of processes within the industry where a fluid is required to pass through a pipeline system. Due to particle contamination within these fluids, erosion in the piping system is a concern. Replacement of eroded pipes is one of the major costs of maintenance, which is an obvious pitfall in the overall cost of operation in industries. The highest erosion rate is most commonly found in bends, as particles are dragged towards the wall due to the streamwise and secondary flows. A better understanding of the secondary flows is required to gauge their impact in the particle trajectories.

Most of the studies concerning secondary flows have focused on a more qualitative assessment through visualization of their streamlines, velocity contours, and velocity vectors (e.g., Sudo et al., 1997; Timité et al, 2009; Röhrig et al. 2015). In this research, we will focus on a more quantitative assessment of the secondary flows by measuring the flow intensity, swirl intensity, location of core vortices, vorticity magnitude (minimum, maximum, and their locations), maximum secondary velocity module, and mean secondary flow velocity. Some of these parameters have been previously used in studies with settings different to the ones considered here. Kim et al. (2014) and Wang et al. (2015) looked into the swirl intensity and secondary flow intensity for small curvature radius bend and a straight pipe after a 90o elbow respectively. Boiron et al. (2007) looked at the maximum secondary flow velocity when analyzing an oscillatory flow in a U-bend. Vorticity magnitudes and location of core vortex were observed by Sudo et al. (1992), Vester et al. (2015), and Hellström et al. (2013) to study oscillatory flow in a curved pipe and a flow downstream of a 90o bend.

We propose to analyze how all those parameters of the secondary flows evolve along the bends for: four different Reynolds numbers (100; 1,000; 10,000; and 100,000), three radius of curvature ratio (r/D: 1.5, 6.5, and 10), and three sweep angles (22.5, 45, and 90 degrees). The computational fluid dynamics software used was COMSOL Multiphysics® through its CFD Module. Water was the working fluid in the simulations. A model validation was created to compare against the results by Homicz (2004) who have also studied secondary flow in pipe elbows. Close attention was given to the mesh and the straight pipes (connected to the bend) lengths in order to minimize the numerical error in the domain of interest.

Reference

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Figures used in the abstract

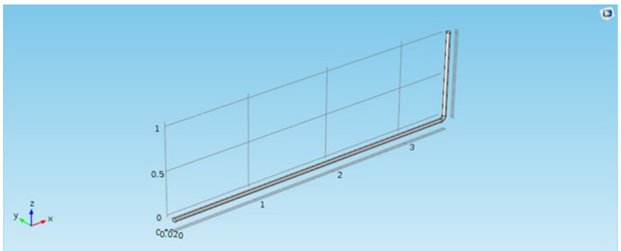

Figure 1: Bend configuration used to study the flow pattern in COMSOL Multiphysics. The secondary flows were analyzed on various cross-sectional planes.