Reynolds Number and Geometry Configuration Effect on Secondary Flows in S-Shaped Circular Bends

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Abstract

What do some industrial pipe layouts, heat exchangers, and arteries have in common? They all have S-shaped bend configurations. The formation of secondary flows is well known in such bends. In many situations, those flows have been used to enhance mixing and heat transfer. However, if particles are present in the fluid, those secondary flows could bring the particles closer to the pipe walls enhancing erosion. Billions of dollars have been spent every year due to the negative effects of corrosion and erosion in the oil & gas and power generation industries. The understanding of the secondary flow development inside S-shaped circular bends is helpful for future studies in S-shaped arteries and industrial pipeline erosion phenomena.

Most of the studies in S-shaped bends have focused on laminar flows, as they were interested in arteries in human bodies (Hoogstraten et al., 1996; Johnston and Johnston, 2008; Niazmand and Jaghargh, 2010). Few have considered such configurations for a turbulent flow but they either have been for non-circular cross sections (Ng and Birk, 2013; Debnath et al. 2015), looked into the primary flow only (Mazhar et al., 2014), or were done for limited Reynolds number values (Taylor, 1984). In contrast to all previous studies, we propose to investigate how the secondary flow develops along the S-shaped 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).

Simulations were performed with COMSOL Multiphysics® software using the CFD Module to analyze the secondary flows and axial velocity profile along the bends. A model validation was created using a three-dimensional S-shaped bend with sweep angle of 90°, radius of curvature (r/D) of 6.5, and Reynolds number of 960 as presented by Niazmand and Jaghargh (2010). Close attention was given to the mesh and the straight pipes (connected to the S-shaped bend) lengths in order to minimize the numerical error in the domain of interest. For all of the cases in this study, we looked at the axial and transverse velocities, vorticity magnitude (maximum, minimum, and their locations), swirl intensity, and pressure field for different cut planes along the bends.

Reference

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Figures used in the abstract

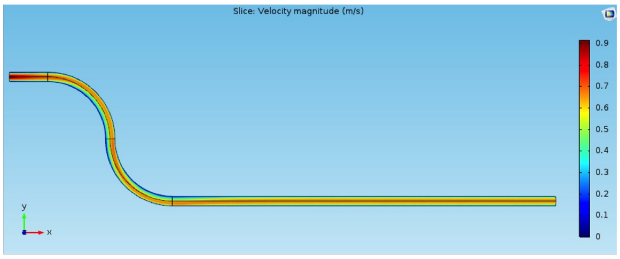

Figure 1: A S-shaped bend configuration showing the velocity profile on a central plane.