Numerical Study of Secondary Flows in a Sinusoidal Pipe

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Abstract

In many industrial settings, secondary flows have been induced to significantly enhance heat transfer and mixing (Yang et al., 2000). In contrast, in cases where the fluid contains particles, it could enhance undesired erosion phenomenon. To better understand secondary flows in industrial bends and their impact in such applications, a simplified geometrical model is desired to observe their development and behavior. A sinusoidal pipe whose centerline follows the equation $y = a \sin(kx)$ is proposed as such configuration.

This shape has been used previously by some authors in their studies but they either have focused on the axial flow of non-Newtonian fluids (Iemoto et al., 1985-1986; Gopalan, 1985), enhanced heat transfer coefficient (Yang et al., 2000; Yang and Chiang, 2000-2002;), pulsating flows (Inaba and Murata, 1978), or limited Reynolds number and curvatures (Murata et al., 1976). In this study the secondary flows are observed for: various Reynolds numbers for laminar and turbulent regimes (100; 1,000; 10,000; and 100,000), and six combinations of pipe amplitude (a) and period (1/k). The sinusoidal configuration affects the centrifugal force the fluid feels, which is related to the Dean number. This number along with Reynolds number have been widely recognized as the main parameters that influence secondary flows.

With that in mind, the goal of this paper is to observe how the flow behaves on a sinusoidal pipe using the CFD Module of the COMSOL Multiphysics® software. An example of the geometrical configuration is shown in figure 1. To validate our geometry and procedure, a model based on Yang et al. (2000) was developed to compare against their results. Close attention was given to the mesh and the straight pipes (connected to the sinusoidal pipe) 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 sinusoidal pipe.

Reference

1. S. Murata, et al., Laminar flow in a curved pipe with varying curvature, Journal of Fluid Mechanics, 73, 736-752 (1976).

2. T. Inaba, and S Murata, Pulsating Laminar-flow in a sinusoidally curved pipe, Bulletin of the JSME Japan Society Of Mechanical Engineers, 21, 832-839 (1978).

3. N.P. Gopalan, Laminar-flow of a suspension in a curved ppe with varying curvature, International Journal of engineering Science, 6, 621-632 (1985).

4. Y. Iemoto, et al, Steady Laminar-Flow of a power-law fluid in a curved pipe of circular cross-section with varying curvature, Journal of non-newtonian fluid mechanics, 19, 161-183 (1985).

5. Y. Iemoto, et al, Steady Laminar-Flow of viscoelastic fluid in a curved pipe of circular cross-section with varying curvature, Journal of non-newtonian fluid mechanics, 22, 101-114 (1986).

6. R. Yang, et al., Flow and Heat Transfer In A Curved Pipe With Periodically Varying Curvature, International Communications Heat Mass Transfer, 27, 133-143 (2000).

7. R. Yang, and F.P. Chiang, An experimental study of heat transfer in curved pupe with periodically varying curtvature for application in solar collectors and heat exchangers, 35th Intersociety energy conversion engineering conference and exhibit (IECEC), 1, 154-160 (2000).

8. R. Yang, and F.P. Chiang, An Experimental Heat transfer study for periodically varying-curvature curved-pipe, International Journal Of Heat and Mass transfer, 54, 3199-3204 (2002).

Figures used in the abstract

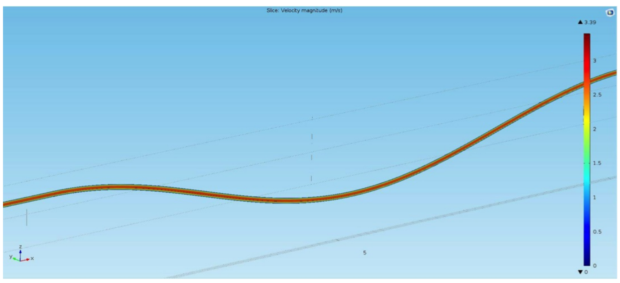

Figure 1: A sinusoidal bend configuration (a = 3; k = 0.1; Re=300) showing the velocity profile on a central plane