Fluid Motion Between Rotating Concentric Cylinders Using COMSOL Multiphysics® Software

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Abstract

Introduction
Fluid flow patterns in research or process-scale equipment where a fluid is contained between concentric rotating cylinders in the absence of bulk axial flow has received notable attention in the field of fluid mechanics. Annular flows occur in many practical applications, such as in the production of oil and gas, fluid viscometers, centrifugally-driven separation processes, electrochemical cells, tribology, hydraulic equipment, and chemical reactors. Understanding the flow behavior in a vertically-oriented annular gap whose outer wall is stationary while the inner wall rotates is an important problem within the broader scope of fluid flows within annular regions. COMSOL Multiphysics® software provides a platform for investigating various non-ideal effects that can occur in this particular configuration under both transient and steady-state flow conditions. A knowledge of non-ideal effects is important for the design of equipment and interpretation of any derived parameters, such as fluid viscosity and fluid flow rates.

Objectives
The primary objective of this study is use COMSOL Multiphysics® software to determine the fluid velocity and pressure profiles between two concentric cylinders in which the inner cylinder is rotating and the outer cylinder is stationary for the case where non-ideal end effects are included. When end effects are neglected, an analytical solution to the equation of motion can be obtained for the fluid velocity and pressure profiles. Parameters that are varied include the radii of the inner and outer cylinders, rotational speed of the inner cylinder, and kinematic viscosity of the fluid. Conditions that lead to the onset fluid-flow instability are examined.

Results and Discussion
Figure 1 shows the fluid velocity profiles generated from a COMSOL Multiphysics solution of a 3-D model in which an inner cylinder is rotating inside a stationary outer cylinder. The non-deal fluid velocity profiles near each end are apparent. The flow becomes fully developed after traveling a distance that is several times the annular gap width. The analytical solution for the case where the fluid velocity profile depends only on the azimuthal component of the velocity vector in the radial direction is compared to the 3-D solution and shown to have good agreement in the fully-developed zone. It is also shown that the pressure gradient increases with increasing rotational speed. Results that illustrate the fluid flow stability and the behaviour of Newtonian and Non-Newtonian fluids are also examined and will be presented.

Reference

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Figures used in the abstract

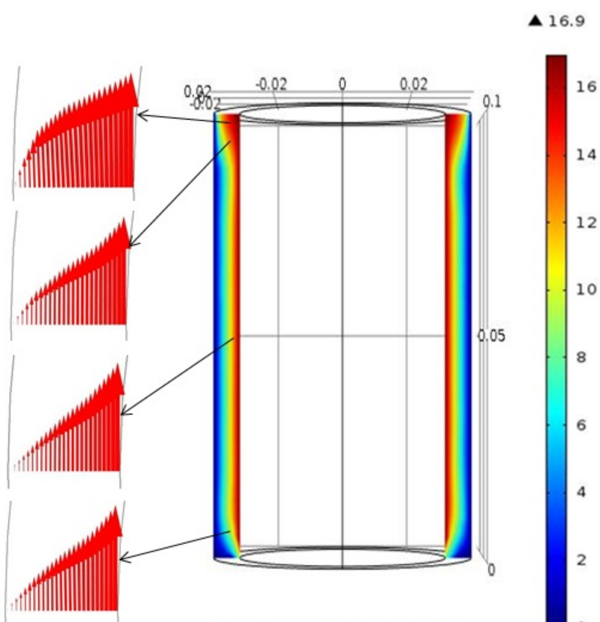

Fig1: Velocity Profile Distribution

Figure 1: Velocity Profile Distribution

Figure 2

Figure 3

Figure 4