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CFD simulation of Taylor–Couette flow in scraped surface heat exchanger

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ABSTRACT

The flow between two concentric cylinders which is termed as Taylor–Couette flow has been studied in scraped surface heat exchanger with and without blades. Shear rate in annular flow with and without blades was measured by Dumont et al. (2000a) using electrochemical method and determined the onset of Taylor vortices at specific Taylor number in both cases for Newtonian flow. CFD simulations have been carried out to determine the transition zone from laminar Couette flow to Taylor vortex flow using the same geometry for which Dumont et al. (2000a) had carried out the experiments. The Reynolds stress model (RSM) and k–ε model are used for Taylor vortex flow ($Ta > 300$) to characterize the flow pattern in annular flow and SSHE respectively. The aim of the present work is to analyze the effect of rotating scraper on the existing flow patterns in simple annular flow using CFD simulations.

Keywords: Taylor vortex flow; Annular flow; Shear rate; Turbulence

1. Introduction

The flow in the annular region between two concentric cylinders, when inner one is rotating and outer one is stationary, is known as Taylor–Couette flow. Couette flow can be described as the simple shear flow in which the axial and radial velocity components are zero whereas in Taylor vortex flow the large secondary toroidal vortices are formed which occur in pairs with opposite rotation. Beyond a certain critical speed of the rotating cylinder, Couette flow results in the formation of a vortex flow. This flow is generally expressed by a dimensionless number called the Taylor number (*Ta*), which is a ratio of the centrifugal force to the viscous force (Taylor, 1923). Taylor number is given by the following equation

$$Ta = \sqrt{\frac{R_s - R_r}{R_r}}\frac{\rho d_h \Omega R_r}{2\mu} \qquad (1)$$

When a small amount of axial flow is added to the Taylor–Couette flow, axial motion of the Taylor vortices results in toroidal motion of fluid elements. The flow in annulus is circumferential because of the shearing action of the rotating cylinder. The overall path of the fluid can be considered as helical or spiral along the length when the axial flow is added to the system.

The aim of the present work is to analyze the effect of blade on the existing flow patterns in simple annular flow. The flow in scraped surface heat exchanger (SSHE) can be considered as the flow through annulus wherein inner rotor was equipped with blades along the length. There are two or three rows of blades on the rotor which scrap the heat transfer surface to reduce the fouling and to improve the heat transfer especially for viscous products. Scraped surface heat exchangers (SSHEs) are commonly used in the food, chemical and pharmaceutical industries for heat transfer, crystallization and other continuous processes of viscous Newtonian and non-Newtonian products and hence understanding the flow pattern is must. The extensive reviews of flow patterns and heat transfer in SSHE can be found elsewhere (Harrod, 1986; Abichandani et al., 1987; Rao and Hartel, 2006).

In the present work, an attempt has been made to simulate the flow pattern in scraped surface heat exchanger using 3D simulations. The Dumont and co-worker's research is considered here to find out the effect of blades on flow pattern in SSHE using CFD simulation. The two dimensional CFD simulation of the same geometry was carried out by Yataghene et al. (2009) to determine the local shear rate for Newtonian and

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