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ORIGINAL PAPER - EXPLORATION ENGINEERING

Numerical study of parameters affecting pressure drop of power-law fluid in horizontal annulus for laminar and turbulent flows

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Abstract

Efficient hydraulics program of oil and gas wells has a crucial role for the optimization of drilling process. In the present paper, a numerical study of power-law fluid flow through concentric (E = 0.0) and eccentric annulus (E = 0.3, E = 0.6 and E = 0.9) was performed for both laminar and turbulent flow regimes utilizing a finite volume method. The effects of inner pipe rotation, flow behavior index and diameter ratio on the pressure drop were studied; furthermore, the appearance and development of secondary flow as well as its impact on the pressure drop gradient were evaluated. Results indicated that the increment of the inner pipe rotation from 0 to 400 rpm is found to decrease pressure drop gradient for laminar flow in concentric annulus while a negligible effect is observed for turbulent flow. The beginning of secondary flow formation in the wide region part of the eccentric annulus (E = 0.6) induces an increase of 9% and a slight increase in pressure drop gradient for laminar and turbulent flow, respectively. On the other hand, the variation of the flow behavior index and diameter ratio from low to high values caused a dramatic increase in the pressure drop. Streamlines in the annulus showed that the secondary flow is mainly induced by eccentricity of the inner pipe where both high values of diameter ratio and low values of flow behavior index tend to prevent the secondary flow to appear.

Keywords Computational fluid dynamics (CFD) · Power-law fluid · Pressure drop · Secondary flow

List of symbols

D_o Diameter of the outer cylinder (m)
D_i Diameter of the inner cylinder (m)
D_h Hydraulic diameter (m)
L_h Length of the hydrodynamic entry (m)
E Eccentricity of the inner cylinder (−)
κ Diameter ratio (−)
K Flow consistency index (Pa s^n)
n Flow behavior index (−)
u Bulk flow velocity (m/s)
Re Reynolds number
ρ Fluid density (kg/m^3)
$\dot{\gamma}$ Shear rate (s^{-1})

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Introduction

The flow of non-Newtonian fluids through annular area has received much attention due to its wide practical applications. This flow is studied to provide solutions for industry challenges, particularly in oil and gas wells drilling like cuttings transport in deviated wells, coiled tubing return flow and cementing. Among problems that can be caused by poor hydraulics design are the insufficient hole cleaning, stuck pipe and lost circulation which causes slow penetration rates (Prassl and Dipl 2003), and produce many costly problems.

Guckes (1975) conducted an earlier study of non-Newtonian fluid in eccentric annuli using a finite difference technique to solve the equations of motion for laminar flow

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