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An One-Dimensional Mathematical Model of Transient Oil-Water Two-Phase Emulsion Flows in Horizontal Pipes at High and Low Temperatures

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ABSTRACT

The paper presents one-dimensional transient mathematical model of thermal oil-water two-phase emulsion flows in pipes. The set of mass, momentum and enthalpy conservation equations are solved for the continuous fluid and droplet phases. Two correlations, which describe the friction between the continuous fluid phase and the wall, are tested in the paper. The interaction between droplets and the continuous fluid phase is modeled by using the aerodynamic drag force. The Beal, the Beggs and Robinson, and the Glaso empirical viscosity correlations are analyzed in the paper. Applicability of those correlations is tested for the case of medium oil at low temperatures. The proposed mathematical model is validated on the experimental measurements of pressure losses in water-in-oil emulsion flows in horizontal pipe. Numerical analysis on single- and two-phase oil-water flows in a pipe is presented in the paper. The continuous oil flow having water droplets is analyzed. Predictions show good agreement with the experimental data if the water fraction is less than 10%. Disagreement between simulations and measurements is increased if the water fraction is larger than 10%. The influence of the temperature on two-phase flow behavior is analyzed.

KEY WORDS: Mathematical modeling; oil-water; two-phase emulsion pipe flows.

NOMENCLATURE

C_D	aerodynamic drag coefficient
$d_{droplet}$	diameter of the droplet (m)
D_{pipe}	diameter of the pipe (m)
h_C	enthalpy of the continuous fluid phase (J/kg)
h_D	enthalpy of the droplet (J/kg)
P	total pressure (MPa)
R_{C-Wall}	continuous fluid phase to wall friction term
R_{C-D}	continuous fluid phase to droplet interaction term, friction
S	cross-sectional area of the pipe (m^2)
t	time (s)
T	continuous fluid phase temperature (K)
U_C	continuous fluid phase velocity (m/s)
U_D	droplet velocity (m/s)
z	axial co-ordinate of the decompression tube (m)
α_C	volume fraction of the continuous fluid phase
α_D	volume fraction of droplets
μ_C	continuous fluid phase viscosity ($Pa \cdot s$)
μ_{od}	“dead” oil viscosity ($Pa \cdot s$)
Π	perimeter of the pipe (m)
ρ_C	density of the continuous fluid phase (kg / m^3)
ρ_D	density of the droplet (kg / m^3)
ρ_{oil}	density of oil (kg / m^3)
ρ_{water}	density of water (kg / m^3)

INTRODUCTION

A development of new technologies on heavy oil production requires more intensive oil transmission from one place to another. The heavy oil is usually transported through the pipeline by mixing with the water in order to reduce the overall pressure losses. Multiphase oil-water flows in pipes is much more complex process compared to single phase flows due to phases interaction and re-distribution within the cross-sectional area of the pipeline. The overall pressure loss in pipelines at multiphase flow regime depends on many parameters such as the fluid density, viscosity, temperature, pipe inner diameter, water fraction and flow Reynolds number (i.e. flow regime). Experimental studies show that the pressure drop in oil-water two-phase emulsion flow is usually less comparing to single phase water or single phase oil flows. It is difficult to estimate the pressure drop at multiphase flow regime.

The information on the mathematical modeling and experimental study of oil and water two-phase transport in pipes is limited in the open source literature, especially if the viscosity of oil is much higher than the viscosity of water. Experimental studies on oil-water flows in vertical and horizontal pipes at different mixture velocities and water