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Mathematical modelling of a hydrocyclone for the down-hole oil–water separation (DOWS)

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ABSTRACT

In this study, a mathematical model is developed to predict the efficiency of a down-hole oil–water separation hydrocyclone. In the proposed model, the separation efficiency is determined based on droplet trajectory of a single oil droplet through the continuous-phase. The droplet trajectory model is developed using a Lagrangian approach in which single droplets are traced in the continuous-phase. The droplet trajectory model uses the swirling flow of the continuous-phase to trace the oil droplets. By applying the droplet trajectory, a trial and error approach is used to determine the size of the oil droplet that reaches the reverse flow region, where they can be separated. The required input for the proposed model is hydrocyclone geometry, fluid properties, inlet droplet size distribution and operational conditions at the down hole. The model is capable of predicting the hydrocyclone hydrodynamic flow field, namely, the axial, tangential and radial velocity distributions of the continuous-phase. The model was then applied for some case studies from the field tested DOWS systems which exist in the literature. The results show that the proposed model can predict well the split ratio and separation efficiency of the hydrocyclone. Moreover, the results of the proposed model can be used as a preliminary evaluation for installing a down-hole oil–water separation hydrocyclone system in a producing well.

Keywords: Hydrocyclone; Swirl intensity; Down-hole separation

1. Introduction

The largest volume waste stream associated with oil and gas production is produced water. Treatment and disposal of produced water represent significant costs for operators. A new technology, down-hole oil/water separators (DOWS), has been developed to reduce the cost of handling produced water. DOWS may also be referred to as DHOWS or as dual injection and lifting systems (DIALS). DOWS separates oil and gas from produced water at the bottom of the well and re-inject some of the produced water into another formation or another horizon within the same formation, while the oil and gas are pumped to the surface. Since much of the produced water is not pumped to the surface, treated, and pumped from the surface back into a deep formation, the cost of handling produced water is greatly reduced. Hydrocyclones have no moving parts and separate substances of different density by centrifugal force. They could be used for solid–liquid or liquid–liquid separation. The liquid/liquid type of hydrocyclone is used in DOWS application. Fig. 1 shows a schematic drawing of a hydrocyclone. By application of DOWS, additional oil may be recovered as well. Shpiner et al. (2009) showed that the produced water (PW) can serve as an alternative water resource for restricted halo tolerant agricultural purposes if the main pollutants, hydrocarbons and heavy metals, can be removed to below the irrigation standards. In the present study, a mathematical model is proposed for a liquid–liquid hydrocyclone.

As it is shown in this figure, the produced water is pumped tangentially into the conical portion of the hydrocyclone. Water, the heavier fluid, spins to the outside of the hydrocyclone and moves towards the lower outlet. The lighter fluids, oil and gas, remain in the centre of the hydrocyclone where they are carried towards the upper outlet and produced to the surface. The separation of fluids in a hydrocyclone is not

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