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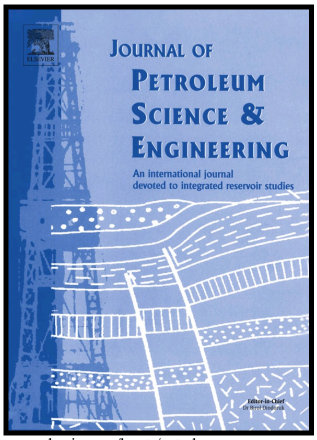

www.elsevier.com/locate/petrol

PII: S0920-4105(16)30422-3
DOI: http://dx.doi.org/10.1016/j.petrol.2016.09.033
Reference: PETROL3640

To appear in: *Journal of Petroleum Science and Engineering*

Received date: 21 June 2016
Revised date: 14 September 2016
Accepted date: 19 September 2016

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Abstract

Downhole oil-water separator is the most important component of downhole oil-water separation system. Its structure has great effects on oil concentration of underflow (OCU) thus requiring further optimization. This work aims to propose an optimization method for the structural optimization of downhole oil-water separator that consists of two series de-oiling hydrocyclones. Firstly, the significant factors influencing OCU are identified by two-level Plackett-Burman Design (PBD) with twelve factors. Then the central levels of the five significant factors identified from PBD are determined by steepest ascent design. Secondly, response surface methodology (RSM) is used to establish the second order model between the OCU and five significant factors for the implementation of particle swarm optimization (PSO). Finally, the optimal structural parameters are obtained by PSO algorithm. Computational fluid dynamics (CFD) is employed to calculate the OCU for each particular case and analyze the separation performance variations before and after optimization. The simulation results show that compared with the original geometry and the best geometry in CCF design, the OCU of the optimized decreases. And the separation performance of the optimized geometry is remarkably improved for the oil droplets whose particle sizes are smaller than 35.78μm. Furthermore, laboratory experiments have been conducted to validate the proposed optimization method. The experimental results confirm that the OCU also reduces following the proposed optimization method. It can be summarized that PSO algorithm combined with PBD, steepest ascent design and RSM can be an effective method for the structural optimization of the downhole oil-water separator.

Keywords

Downhole oil-water separator Response surface methodology Particle swarm optimization Numerical simulation Structural Optimization

1. Introduction

Downhole oil-water separation is an efficient, environmental-friendly and energy-saving technology, which can realize a complete production process including oil-water recovery, separation, oil lift and water injection in the same wellbore (Ogunsina and Wiggins, 2005; Amini et al., 2012). Downhole oil-water separator is the most important device of downhole oil-water separation system, and can determine the oil-water separation effect. In order to preventing the injection layer (waste layer or formations with high permeability) from being blocked, the oil concentration of the liquid injected to the injection layer should be as small as possible (Scaramuzza et al., 2001). In other words, the higher the separation efficiency of downhole oil-water separator, the smaller the OCU. To improve the separation performance, the scheme of two de-oiling hydrocyclones in series is often adopted in the design of downhole oil-water separator. Typically, a de-oiling hydrocyclone (DOHC) is composed of one inlet stream (tangential inlet in the cylindrical section) and two outlet streams, that is overflow stream with higher oil concentration and underflow stream with higher water concentration (Amini et al., 2012). Compared with the solid-liquid hydrocyclone (SLHC), it is more difficult to improve the separation efficiency of DOHC due to low density differences between two liquids in the DOHC. The DOHC generally follow a conventional design and