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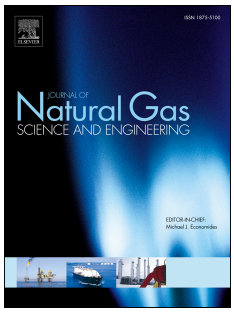

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Experimental Study and Mechanistic Modeling of Pressure Surging in Electrical Submersible Pump

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Abstract

Gas entrainment is frequently encountered in crude oil production with electrical submersible pumps (ESP). Previous studies revealed that the increase of gas entrainment rate in ESPs results in mild degradation of boosting pressure followed by a drastic drop. This critical condition, termed as pressure surging, significantly affects ESP's operational stability and run-life. In this paper, the pressure surging phenomenon in ESPs is studied through experimental measurements and mechanistic modeling. A 7.62-cm two-phase flow loop with a 14-stage radial-type ESP is used for testing pump performance under single- and two-phase flow conditions. The stage-by-stage boosting pressure with different gas entrainment rates is measured. Effects of intake pressure, gas volumetric fraction (GVF) and rotational speeds on the ESP two-phase pressure increment are investigated. Experimental results show that the boosting pressure of ESP under gassy flow conditions varies significantly with inlet GVFs and fluid properties. For low GVFs (<6%), the ESP pressure increment deteriorates gradually with the increase of gas flow rate. However, severe degradation of pump boosting pressure is observed if the inlet GVF exceeds a certain value (>7%), which triggers ESP's unstable operations. A mechanistic model based on the critical bubble diameter in rotating multiphase flow field is developed to predict the surging initiation in ESPs. Compared with experimental results, the model predictions demonstrate good agreement.

Key words: multiphase flow, gas entrainment, electrical submersible pump, pressure surging, bubble size

Introduction

As an efficient downhole equipment for converting the kinetic energy of fluids to hydraulic pressure potential, ESPs are widely used in crude oil production (Takacs, 2009; Zhu and Zhang, 2014). About 15 to 20 percent of almost one million wells worldwide produce crude oil with the help of ESPs (Gupta et al., 2016). ESP is a type of artificial lift methods, comprising of multistage centrifugal pumps, motor, seal, power cables, surface controls etc. Since invented, ESPs have excelled in lifting much greater liquid rates than most of the other types of artificial lift and have found their best use in high-rate on- and off-shore applications (Takacs, 2009). However, ESP's performance is affected by the downhole flow conditions such as multiphase flow (Zhu and Zhang, 2016), high-viscosity oil flow (Zhu et al., 2016) and flow assurance issues, i.e. asphaltene-stabilized emulsions (Correra et al., 2015). For gas-liquid multiphase flow, which is frequently encountered in on- and off-shore wells, ESPs may suffer from severe operational problems and production system failures (Barrios and Prado, 2011; Barrios et al., 2012). Previous studies revealed that the presence of gas inside ESP results in the degradation of hydraulic head, pressure surging and gas pocket formation, which are detrimental to its functionalities and in turn jeopardize the whole production system. Surging may also cause ESP vibrations and short field run-life, while the gas pockets reduces hydrocarbon fluid production rates severely (Zhou and Sachdeva, 2010). High vibrational stress and unexpected operation conditions may even cause serious damage to pumping devices (Neumann et al., 2016).

Pressure surging, first identified by Lea and Bearden (1982), is a significant phenomenon that affects ESP pressure-boosting abilities under gassy flow conditions, which coincides with the instability of ESP's operations (Gamboa, 2011). To extend ESP stable operation and its field service life, it is necessary to predict the critical gas volumetric fraction (GVF) accurately, at which the pressure surging inside ESPs initiates. Due to the complex pump geometries, associated with the compact multistage assembly of twistedly-channeled impellers and diffusers, the prediction of surging initiation is very difficult. Most of existing prediction correlations and models in literature are of empirical nature. The lack of a theoretical basis in these correlations restricts their field applications to a wider range of flow conditions and different pump models. Therefore, a more general and reliable mechanistic model for predicting the initiation of pressure surging in ESPs is needed so that necessary precautions can be taken before the inlet GVF approaches a certain value that causes drastic performance drop and further unstable operations of ESPs.

As a remedial tool to improve the ability of handling gas-liquid mixtures, a downhole separator can be