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A new diagnostic method for identifying working conditions of submersible reciprocating pumping systems

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Abstract: The submersible pumping unit is a new type of pumping system for lifting formation fluids from onshore oil wells, and the identification of its working condition has an important influence on oil production. In this paper we proposed a diagnostic method for identifying the working condition of the submersible pumping system. Based on analyzing the working principle of the pumping unit and the pump structure, different characteristics in loading and unloading processes of the submersible linear motor were obtained at different working conditions. The characteristic quantities were extracted from operation data of the submersible linear motor. A diagnostic model based on the support vector machine (SVM) method was proposed for identifying the working condition of the submersible pumping unit, where the inputs of the SVM classifier were the characteristic quantities. The performance and the misjudgment rate of this method were analyzed and validated by the data acquired from an experimental simulation platform. The model proposed had an excellent performance in failure diagnosis of the submersible pumping system. The SVM classifier had higher diagnostic accuracy than the learning vector quantization (LVQ) classifier.

Key words: Submersible reciprocating pump, working condition, failure diagnosis, linear motor, characteristic quantity, support vector machine, misjudgment rate

1 Introduction

The submersible reciprocating pumping system is a new type of pumping unit used in oil fields. The submersible reciprocating pump is driven by a linear motor to lift formation liquids to the surface directly through oil tubing. A control device at the surface regulates the linear motor, which is powered by a submersible cable, to control the working conditions of the pumping unit through changing the operating time, stroke and the rate of the linear motor stator.

Different from conventional pumping systems, in this pumping system a submersible plunger pump is directly connected to a linear permanent magnet synchronous motor at the well bottom to lift crude oil (Yu et al, 2011a; 2011b). Since the output power of the linear motor acts directly on the pump for lifting crude oil, the submersible pump has high energy conversion efficiency (Rossini et al, 2008). Furthermore, no sucker rod and other equipment are introduced into the submersible pumping system compared with conventional pumping units, thus completely avoiding eccentric wear between a sucker rod and oil tubing. However, the linear submersible motor and the plunger pump are exposed to severe well bottom conditions, failures such as linear motor damage may occur, which seriously shortens the work period of the pump (Fu et al, 2006; Yu et al, 2011b). Therefore, it is important to find an effective way to detect early abnormal working conditions before serious breakdown of the submersible pumping system. With more and more oilfields becoming maturing fields, the submersible pumping units have been widely used for this type of pumping system. This has major significance for energy saving and efficient production (Yu et al, 2011a; 2011b).

The abnormal working conditions of a pumping system, such as paraffin deposits in oil tubing, sand production, leakage, liquid shortage in the pump and gas obstruction, may increase the work load of the linear motor. If the linear motor works under abnormal conditions for a long period of time, its in-service life, as well as the continuous running time, will be shortened. Therefore, it is necessary to seek a way to dynamically process the abnormal conditions of the pumping system and to perform online diagnosis, thus providing early

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