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Using the curve moment and the PSO-SVM method to diagnose downhole conditions of a sucker rod pumping unit

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Abstract: Downhole working conditions of sucker rod pumping wells are automatically identified on a computer from the analysis of dynamometer cards. In this process, extraction of feature parameters and pattern classification are two key steps. The dynamometer card is firstly divided into four parts which include different production information according to the "four point method" used in actual oilfield production, and then the moment invariants for pattern recognition are extracted. An improved support vector machine (SVM) method is used for pattern classification whose error penalty parameter C and kernel function parameter g are optimally chosen by the particle swarm optimization (PSO) algorithm. The simulation results show the method proposed in this paper has good classification results.

Key words: Sucker rod pumping unit, diagnosis of downhole conditions, dynamometer card, curve moment, support vector machine, particle swarm optimization

1 Introduction

In actual oilfield production, it is difficult to know the real downhole working conditions of oil rod pumping systems working thousands of meters underground. The conventional methods rely on engineers to analyze the cards collected from the dynamometer measuring the force on the sucker rod pump. Traditional manual interpretation of the card shapes can encounter some problems, such as influence by subjective factors, no real-time analysis, and high cost. With the development of automation technology in petroleum production, many jobs relying on people have not yet met the actual production requirements. So, it is important to use the machine learning method to replace the manual task so as to increase the working efficiency. Many advanced analytical methods have been used in diagnosis of downhole conditions of sucker rod pumping units, such as expert systems (Derek et al, 1988; Martinez et al, 1993), artificial neural networks (Rogers et al, 1990; Xu et al, 2007; de Souza et al, 2009; Wu et al, 2011), rough set theory (Wang and Bao, 2008), filter techniques (Li et al, 2010) and frequency spectrum analysis (He et al, 2008). However, the expert system and the rough set have a single way of knowledge expression and reasoning strategy, the artificial neural network needs a large number of training samples and application of the filter technique and frequency spectrum analysis have some limitations. The support vector machine (SVM) technique is a good pattern recognition method as it only needs a small number of training samples and has good generalization ability, which is widely used in many research fields (Ganapathiraju et al, 2004; Campbell et al, 2006; Nath and Shevade, 2006; Widodo and Yang, 2007; Chowdhury et al, 2011; Mountrakis et al, 2011; Wang et al, 2011; Li et al, 2012). It has been used to solve diagnosis faults in sucker rod pumping units in many instances (Shi et al, 2004; Li et al, 2006; Tian et al, 2007a; 2007b). However, more in-depth work should be undertaken in selection of feature parameters and classification performance. So, this study firstly uses the moment curve method to extract the features of typical dynamometer cards, and then uses the improved SVM method for pattern classification which is combined with particle swarm optimization (PSO) algorithm to choose the best error penalty factor C and kernel function parameter g so as to improve classification efficiency. The final examples show that the proposed method has good classification results for fault diagnosis of sucker rod pumping units.

2 Downhole dynamometer card in sucker rod pumping wells

A one-dimensional wave equation with viscous damping which describes dynamic changes of a sucker rod string is used to calculate the downhole dynamometer card in a sucker rod pumping unit, which can truly reflect working conditions of the subsurface pump as it may eliminate effects of the deformation, viscous resistance, vibration and inertia of the sucker rod string (Gibbs and Neely, 1966). Our study uses

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