DOI 10.1007/s12182-013-0283-4

Multiple fault diagnosis of down-hole conditions of sucker-rod pumping wells based on Freeman chain code and DCA

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Abstract: It is important to achieve continuous, stable and efficient pumping well operation in actual oilfield operation. Down-hole pumping well working conditions can be monitored in real-time and a reasonable production scheme can be designed when computer diagnosis is used. However, it is difficult to make a comprehensive analysis to supply efficient technical guidance for operation of the pumping well with multiple faults of down-hole conditions, which cannot be effectively dealt with by the common methods. To solve this problem, a method based on designated component analysis (DCA) is used in this paper. Freeman chain code is used to represent the down-hole dynamometer card whose important characteristics are extracted to construct a designated mode set. A control chart is used as a basis for fault detection. The upper and lower control lines on the control chart are determined from standard samples in normal working conditions. In an incompletely orthogonal mode, the designated mode set could be divided into some subsets in which the modes are completely orthogonal. The observed data is projected into each designated mode to realize fault detection according to the upper and lower control lines. The examples show that the proposed method can effectively diagnose multiple faults of down-hole conditions.

Key words: Sucker-rod pumping wells, multiple faults, designated component analysis, control chart, Freeman chain code, dynamometer card

1 Introduction

With the development of computer and artificial intelligence technology, down-hole working conditions of sucker-rod pumping wells can be monitored quickly and accurately by computer diagnosis. Reasonable technical measures can be developed to make the pumping wells achieve continuous and stable operation to improve working efficiency and oil production, which has very important significance to oilfield enterprises.

Many advanced analytical methods have been used in diagnosis of down-hole conditions in sucker-rod pumping wells. These include expert systems (Derek et al, 1988; Martinez et al, 1993), rough set theory (Wang and Bao, 2008), artificial neural networks (Rogers et al, 1990; Xu et al, 2007; De Souza et al, 2009; Wu et al, 2011), supported vector machines (Shi et al, 2004; Tian et al, 2007a; 2007b; Li et al, 2006; Li et al, 2013), spectrum analysis (He et al, 2008) and filter techniques (Li et al, 2010). However, in practical oilfield production, rational production programs are harder to develop as two or more abnormal down-hole conditions can occur at the same time. This problem cannot be adequately solved by the existing methods. So, it of important scientific significance and practical value to develop an approach to diagnose down-hole conditions in sucker-rod pumping wells with multiple faults.

Feature extraction and the pattern classification are two important factors for the intelligent diagnosis of sucker-rod pumping wells based on dynamometer cards. In this paper, a dynamometer card is first represented by Freeman chain code (Freeman, 1961) and twelve important features of it are then extracted. Freeman chain code is a good method of compact representation of the contour of the curves and has been used in many research fields (Lu et al, 2007; Hasan et al, 2009a; 2009b; Li et al, 2009; Sanchez-Cruz and Bribiesca, 2009; Sanchez-Cruz, 2010; SiddiqiI and Vincent, 2010; Jusoh and Zain, 2011; Li et al, 2011; Brlek et al, 2011; Lu and Dai, 2011; Nawab and Hassan, 2012; Li et al, 2012). Then designated component analysis (DCA) (Liu, 2002; Camelio and Hu, 2004; Liu and Hu, 2005) is introduced to diagnose multiple faults of down-hole conditions in sucker-rod pumping wells. The observed data is projected into the designated fault modes which are defined according to the analysis of the typical dynamometer card. The upper and lower control limits can be determined from the statistical

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Received August 8, 2012