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The reliability-based evaluation of casing collapsing strength and its application in marine gas reservoirs

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ABSTRACT

The casing serving in the marine gas reservoir is often squeezed by the collapse pressure from salt rock creeps. The combined action of acid corrosion media and high temperature result in necking deformation and even fracture. However, it is difficult the traditional design method of casing safety factor to deal with the randomness of the structural and load factors. The designed strength is either too high or too low. To face the challenges, the reliability evaluation method for the casing collapsing strength in marine gas reservoirs is developed based on the standard of collapsing strength and the load-strength interference model. The distribution of casing collapsing strength is firstly simulated by Monte Carlo sampling. The reliability calculation model of casing under different working conditions is obtained. Then, the quantitative relationship between the target reliability and the safety factor is explored by backward derivation. Four kinds of casing used in marine gas reservoir are evaluated. The result shows that the collapsing strength obeys a Gaussian distribution. The bigger the variation coefficient of casing parameters, the more dispersed the strength distribution. Based on the failure probability, the target reliability can be set and the safety factor can be calculated. The collapse pressure from creep is a key factor to control reliability. With the change of layer groups, the load distribution curve is gradually close to the intensity distribution curve until the interference failure occurs. The reliabilities of casings in some layer groups are < 50%. The corrosion defects and temperature are important factors to casing strength. The reliability and the life expectancy are greatly reduced with time, which leads to premature failure of some casings.

1. Introduction

With development of the engineering marine carbonate reservoir as a main target, the safety of the casing serving during the whole life period in gas wells becomes a challenge to face in long-term and efficient exploitation of marine gas resources. Because there is a large number of creep salt rock interlayers in the marine geological structure, the casing in the layers will be subjected to the radial collapse pressure from the creep of salt rock. The combined action of acid corrosion media such as H_2S, CO_2, and high temperature results in necking deformation, strength reduction and even fracture, as shown in Fig. 1. However, only safety factors are considered in the traditional design of casing strength. When facing the random variation of the casing size, mechanical property, corrosion defect and collapse pressure, the fixed safety factor makes the design strength either too high or too low, and cannot quantitatively measure the reliability of the casing, resulting in economical or security risk [1]. Therefore, it is important to develop reliability-based evaluation and design methods for casing strength.

Up to date, researches on the strength and reliability of casing collapse are mainly based on qualitative analysis, not on

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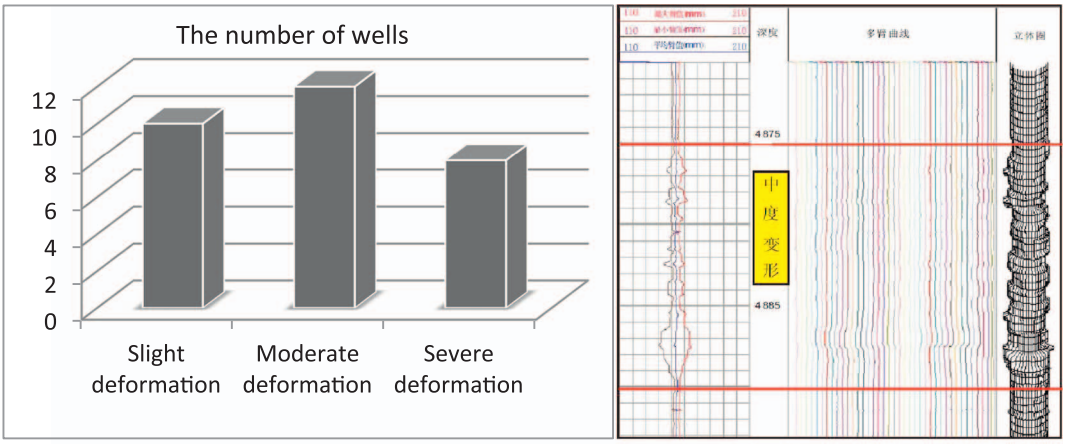

(a) Casing deformation of 30 production wells in Puguang gas field and interpretaion figure of borehole deformation section between 4875.0-4890.0 m

(b) Tubing and casing corrosion fracture pattern

Fig. 1. Casing deformation and corrosion fracture pattern in Puguang Gas Field [9,10].

quantitative conclusions. By the experiment examinations, Cheatham [2] suggested that it is uneconomical to use the maximum non-uniform external load acting on the casing in the salt rock formation as the design standard. Adams [3] and Gulati [4] proposed the design and risk analysis methods for oil and casing string based on the theory of structural reliability. Maes [5] and Keilty [6] explored application of the reliability theory and risk assessment in casing design, and calculated a few of practical cases. Liu Qingyou [7] investigated a calculation model to predict the reliable life through analysis to the fault tree of casing. Yan Xiangzhen [8] quantitatively analyzed the influence of various factors on casing strength, thereby developing a method of casing risk assessment under complex well conditions.

Most studies so far have used finite element analysis to calculate the strength or directly describe the probability distribution. However, case evaluation and process of reliability models for the collapsing strength under the conditions have not been reported. The design method based on the quantitative relationship between reliability and safety factors is also rarely reported. In this work, through analysis of casing failure reason and design method, a reliability-based method for evaluating the collapsing strength and designing safety factors of casing in marine gas reservoirs is developed on the basis of the standard of collapsing strength and the load-strength interference model. The model is fitted by Monte Carlo sampling, and the safety of some serving casings is evaluated and analyzed.

2. The standard for calculation collapsing strength, the parameters selection and the load distribution

2.1. The standard for calculation collapsing strength

2.1.1. API standard

Since the 1980s, a series of full-scale casing collapse experiments were carried out by American Petroleum Institute (API). According to the experimental data of thousands of casings, the collapse pressure of the casing can be described by four kinds of