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Review

Equations to calculate collapse strength of defective casing for steam injection wells

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ABSTRACT

Casings represent a very high proportion in OCTG (Oil Country Tubular Goods) and also influence the productive life of the wells. Studying the collapse strength of defective casing for steam injection wells can prevent casing collapse failure in advance, as well as improve life of defective casing and increase well production. Based on finite element analysis, the effect of pit shape, pit depth, pit circumferential spread, number of pit and circumferential spacing of pit on collapse strength is conducted, through which pit depth and pit circumferential spread are proven as the main controlling factors which affect the collapse strength of defective casing. A formula to calculate collapse strength of defective casing is obtained for steam injection wells by including the effect of temperature on the degradation of yield strength and compression stress function of a cylinder in the existing collapse strength formula. The formula is amended with results from numerical calculation and proven to be in good agreement with experimental data of collapse strength for defective casing. Therefore collapse strength can be accurately predicted using the proposed collapse strength formula for thermal recovery steam injection wells.

Contents

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1. Introduction

Casing, tubing and drill string (drill pipe, drill collar, etc.) are generally referred to as OCTG. With the development in the oil industry, there is more need for OCTG. According to statistics about 62 kg of the OCTG is required per meter drilled, of which 48 kg is casing, 10 kg is tubing. Casing accounts for about 77.4% of the total OCTG. The casing is fixed with cement in the wells and cannot be reused, thus rendering it is a one-time consumption material. In recent years, annual consumption of OCTG is more than 2 million tons in China. In the oil industry casing is not only used in large amounts and at high cost, but its quality and performance is also plays an important role in the development of the industry [1,2].

The service life of oil well is directly determined by the life of casing which consequently determines oil field life. Hence, as for the oil industry, there exists significant importance of casing reliability, service life and economy. The casing, along with the casing string endure hundreds of tons of tensile load, the collapse pressure of formation is usually used in high pressure, high temperature and high H_2S (HPHTHS) environments. Under the influence of the above working conditions, the main failure form of casing is the casing body rupture, collapse, thread tripping and corrosion wear. Oil companies have realized that economic losses incurred from stopping production or even abandoning oil and gas wells because of the casing failure is increasing. For instance, the cost of oil well in oil fields in western China is tens of millions or even hundreds of millions RMB [3–5].

Casing occurs structural instability or damage failure under collapse pressure, this critical pressure is called the collapse strength of casing. Specifically, when the external pressure reaches a critical pressure, casing appears serious deformation. The section of casing usually turns into oval or completely flat after collapse failure. Scholars have done a lot of research in view of the severe casing damage problem. Refs. [4,6,7] describe comparative study indicating some deficiencies on the currently commonly used API and ISO standard for collapse strength. Some scholars amended these formulas, of which Jianzeng Han's formula has been accepted by the API group. Literatures [6,8] investigate through theoretical calculation and experimental research the effect of wearing of casing by drill string on the casing strength. It is concluded that the influence of the wear on strength of casing is large. It is also noticed that casing is easily corroded failure with poor cementing between casing and cement ring or defective cement ring [9,10]. Refs. [11,12] analyze the effect of the manufacturing defect of casing on strength. It is concluded that manufacturing process is a very important factor which affects the property of casing. In order to meet the need of high temperature and high pressure steam injection wells, special casing has been developed for steam injection wells [13,14]. However, not much theoretical study has been conducted on casing collapse strength for thermal recovery steam injection wells and even less work on the study of defective casing. Moreover, there is no formula to accurately predict collapse strength of defective casing under high temperature and collapse pressure. In this paper, to obtain the formula of collapse strength for defective casing, a numerical model is established and verified. The effect of pit parameters, such as pit shape, pit depth, pit circumferential spread, number of pit and circumferential spacing of pit, is investigated using finite element method (FEM). The mathematical model of collapse strength is derived for defective casing from the pressure stress function of a cylindrical body. The feasibility of this model is verified using lab experimental data.

2. Common collapse strength formula of casing

Collapse strength of casing is an important indicator for casing design. In order to calculate the collapse strength of casing, API5C3 standards and ISO10400 are currently used.

2.1. API collapse strength formula

Applicable conditions of API formula are no internal pressure and axial force. Depending on the ratio D/t of diameter to thickness, API collapse strength formula is divided into the following four formulas: collapse pressure formula of yield strength, plastic collapse pressure formula, elastic–plastic collapse pressure formula and elastic collapse pressure formula [15,16].

(1) Collapse pressure of yield strength

where $D/t \leqslant (D/t)_{YP}$

$$P_{YP} = 2\sigma_y \left[\frac{(D/t) - 1}{(D/t)^2} \right] \tag{1}$$

$$(D/t)_{YP} = \frac{\sqrt{(A-2)^2 + 8(B + 6.894757C/\sigma_y)} + (A-2)}{2(B + 6.894757C/\sigma_y)} \tag{2}$$