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Study on the influence of temperature change on fracture pressure of oil wells

Wei Gao

Xi'an Shiyou University, Xi'an, Shaanxi 710065, China

Abstract

The fracturing pressure has great effect to many operations during oil well working like borehole stabilization, hydro fracture etc. Experience in the past shows that fracturing pressure was influenced by many factors. We hold a research about the influence of temperature to fracturing pressure in the high-temperature reservoir. Based on linear elastic mechanics we build a three-dimensional model using finite element methods, and the temperature change is under consideration. The result shows the fracturing pressure decreasing with decreasingly temperature, and have a linear relation, that is in average fracturing pressure decrease 3.6 MPa while borehole temperature decrease 50℃.

Keywords

Fracturing Pressure, High-temperature Reservoir, Temperature change, Finite Element Method.

1. Introduction

With the requirements of China's energy strategic deployment, the demand for deep-water high-temperature and high-pressure oil and gas resources is also increasing. During the development and utilization of such oil and gas resources, it is found that the temperature has a great impact on the fracture pressure of oil and gas wells. Field operation practice shows that when the equivalent density of drilling fluid exceeds the fracture pressure gradient, the wellbore will rupture, resulting in lost circulation, block falling and other phenomena [1-5]. If not handled in time, the continuous leakage of drilling fluid will induce blowout, which will bring huge losses to the safety of drilling operators and drilling construction property. Therefore, studying the stress distribution around the well under the influence of temperature is of great significance to accurately calculate the formation fracture pressure and ensure the safe and rapid operation of oil and gas wells. Many researches have been carried out on the calculation of formation fracture pressure at home and abroad, and a series of results have been obtained. In 1967, Matthew and Kelly thought that the overburden pressure was constant, which was not in line with the reality and was not popularized [6]. In 1969, Eaton proposed that the pressure gradient of overlying strata is a function of depth [7]. In 1986, considering that the in-situ stress is uneven, Huang rongzun deduced the calculation model of formation fracture pressure "sixth five year plan model" [8]. In 1997, Holbrook published a method suitable for predicting fracture propagation pressure in extensional basins [9]. In 2001, Ge Hongkui et al. Proposed a modified Holbrook bottom fracture pressure prediction model [10]. Fracture pressure refers to the liquid column pressure in the well when the liquid column pressure in the well is enough to fracture the formation, open and extend the original fractures or produce new fractures. In terms of mechanics, formation fracture is caused by the excessive density of drilling fluid in the well, which means that the circumferential stress of the rock reaches the tensile strength of the rock, that is:

$$\sigma_{\theta}=S_{t} \tag{0.1}$$

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If the formation containing oil and gas wells is simplified to a two-dimensional problem, the stress distribution has the following analytical formula:

$$\sigma_\theta = \frac{1}{2}(\sigma_H - \sigma_h)\left[1 + \frac{r^2}{R^2} - \left(1 + \frac{3r^4}{R^4}\right)\cos 2\theta\right] \tag{0.2}$$

Considering the pore pressure and pore connectivity, the fracture fracturing calculation formula can be obtained by substituting into the above formula (1.1) (1.2):

$$P_f = 3\sigma_h - \sigma_H - \alpha P_p + S_t \tag{0.3}$$

Where S_t is the tensile strength of rock, which depends on the physical properties of rock; P_p is pore pressure; α is the effective connection coefficient, between 0 and 1; σ_H and σ_h are plane horizontal principal stresses.

The above formula is the most widely used formula for calculating the fracture pressure at present, but after long-term on-site construction, it is found that the temperature has an obvious impact on the rock fracture pressure, so it is necessary to consider the impact of temperature on the fracture pressure. Based on the above formula (1.3), considering the influence of temperature on rock fracture pressure, we believe that temperature will produce an additional stress, establish a three-dimensional finite element model and numerically simulate the additional stress.

2. Finite Element Analysis

ABAQUS is a mature finite element commercial software with powerful functions and friendly interface. It has powerful pre-processing module and post-processing module, built-in standard solver, implicit solver, CFD hydrodynamics solver and electromagnetic solver. It is widely used in material mechanics, civil engineering, mechanical design, automobile manufacturing, geotechnical mechanics and other fields. In this paper, ABAQUS software is used to establish a three-dimensional finite element model to simulate the stress change caused by reservoir temperature change. The model is shown in Figure 1, and the model parameters are shown in Table 1 below.

Table.1 Model parameters

Parameters	Value
Borehole diameter (cm)	16
Model size(m)	0.8*0.8
Reservoir thickness (m)	5
Young's modulus(Gpa)	7
Poisson's ratio	0.2
In-situ temperature(℃)	120
Coefficient of thermal expansion(℃$^{-1}$)	1.35×10^{-5}
Reservoir depth(m)	3000
Overburden pressure(MPa)	67.6
Maximum horizontal in-situ stress(MPa)	56
Minimum horizontal in-situ stress(MPa)	50
Tensile strength(MPa)	3

The temperature when the formation is not opened is 120 ℃, respectively simulating the circumferential stress distribution of the horizontal plane when the borehole wall temperature drops to 110 ℃, 100 ℃, 90 ℃, 80 ℃, 70 ℃ and the temperature remains unchanged after the formation is opened. The boundary conditions of the model are shown in Figure 1 below.

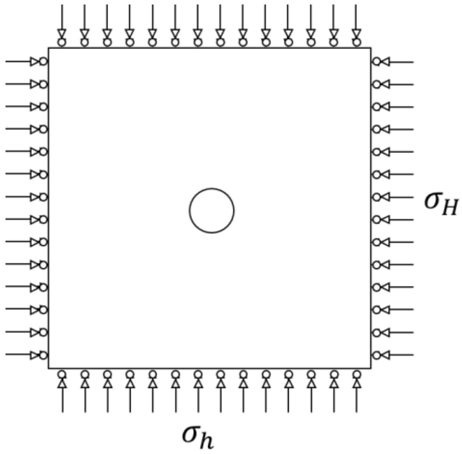

Fig.1 Schematic diagram of boundary conditions on model plane

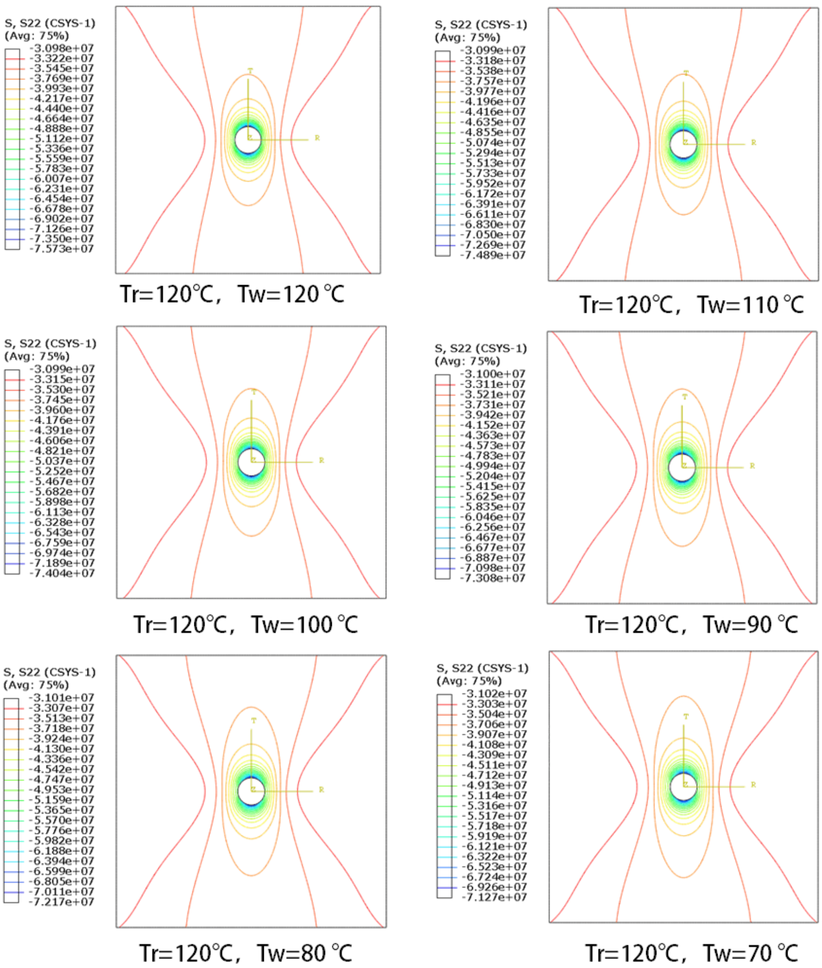

Fig. 2 circumferential stress distribution of water plane at different wellbore temperatures, In this figure, TR is the reservoir temperature and TW is the barrel temperature

It can be seen from the above figure that the change of wellbore temperature has a significant impact on the distribution law of wellbore circumferential stress, which is shown as an additional stress without changing the original distribution law. The variation law of circumferential stress of wellbore under different wellbore temperature drop is shown in Figure 3 below. It is found that the average temperature difference of every 50 ℃ will reduce the circumferential stress of the wellbore by 3.6MPa. Without considering the influence of temperature on fluid, the fracture pressure can be reduced by 3.6MPa according to formula 1.3. The fracture pressure distribution is shown in Figure 4. The minimum fracture pressure appears in the direction of the maximum horizontal in-situ stress and is perpendicular to the minimum horizontal in-situ stress.

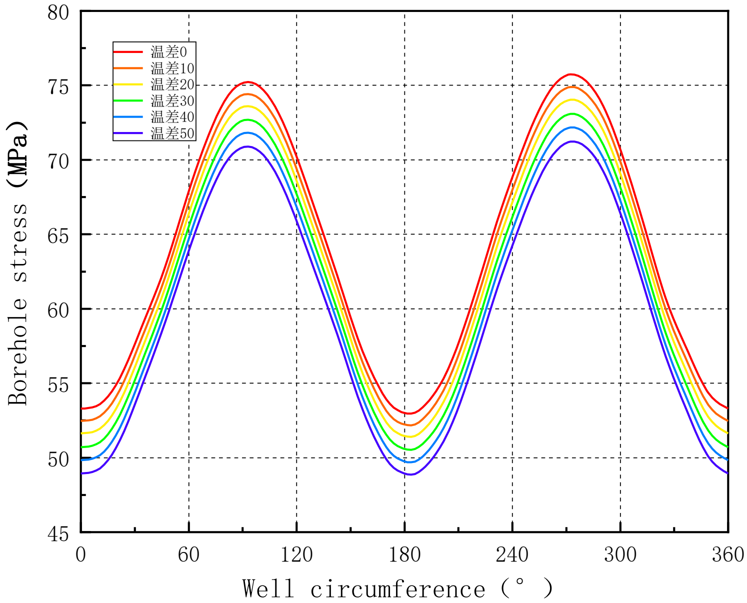

Fig. 3 circumferential stress distribution of shaft wall at different temperatures

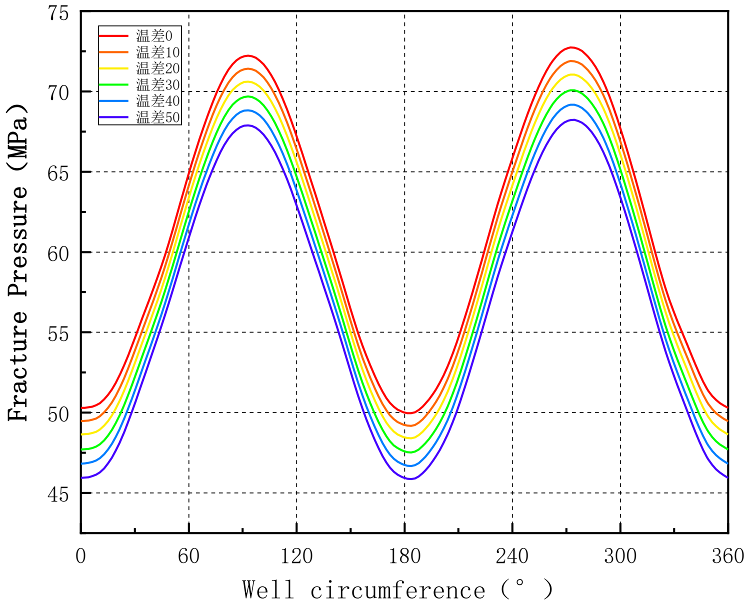

Fig. 4 distribution of well fracture pressure under different temperatures

3. Conclusion

By establishing the finite element numerical simulation model, we discuss the influence of temperature drop on fracture pressure after formation opening, and draw the following conclusions: (1)As the temperature in the wellbore decreases, the stress around the well decreases. If the temperature drops too much, the borehole wall rock will change from compression state to tension state.

(2)If the temperature in the well is too low, the stress around the well will be reduced. If the change of tensile strength with temperature is not considered, the fracture pressure will be reduced. (3)The temperature of drilling fluid shall be reasonably controlled during drilling operation. When the drilling fluid temperature is lower than the formation temperature, the

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long-term circulation of drilling fluid will lead to excessive wellbore temperature drop, resulting in wellbore instability.

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