Analysis of Cement Sheath Stress in Horizontal Well Fracturing

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Abstract. The research of cement sheath stress in horizontal well fracturing plays an important role in horizontal well fracturing analysis, and is also related to the work of horizontal wells to a certain extent. The core work of the shaft is also affected by its cement sheath, so we should pay attention to the actual control of the cement sheath pressure in the actual work process to ensure that the cement sheath analysis is more effective. In this paper, the stress distribution model of casing-cement sheath-formation system is established, which is of great significance to the subsequent wellbore integrity control.

Keywords: Horizontal well, fracturing, cement sheath, stress.

1. Introduction
In the process of oilfield exploitation, wellbore is a very important device and plays a very important role in oil exploitation. The effect of staged fracturing in wellbore and horizontal wells also has certain influence, which improves the fracturing effect of horizontal wells to the greatest extent and ensures more effective fracturing implementation. However, in the process of staged fracturing in horizontal wells, its casing and cement sheath device will be affected to some extent and will produce certain stress changes. In this study, in order to reasonably study the fracture cement sheath stress of horizontal wells, aiming at the stress field induced by casing, cement sheath and cement sheath failure, the stress distribution model of casing-cement sheath-formation system is established, and the actual stress is reasonably analyzed to ensure that the stress analysis is more effective and reasonable.

2. Analysis of staged fracturing technology for horizontal wells
The staged fracturing technology of horizontal wells is a very important technical application in the working process of horizontal wells, and plays a very important role in oil exploitation. When fracturing fluid enters reservoir through perforation hole at high speed, perforation friction will be produced and increase with the increase of pumping displacement, which will drive the increase of bottom hole pressure. Once the bottom hole pressure exceeds the fracture pressure of multiple fracturing intervals, i.e., cracks are cracked in each interval, which requires that the fracture pressure of each interval is basically close and can be adjusted by hole friction. In the implementation process of horizontal staged
fracturing technology of water turbine, the reasonable implementation of fracturing technology can play an important role in improving the oil recovery effect, and also improve the oil recovery effect to a certain extent. For example, in the actual oil production process, when encountering thin reservoirs, low permeability and thick oil and gas reservoirs, the traditional oil production technology will be affected to some extent, and its production efficiency will drop sharply. Therefore, in the actual oil exploitation process, we should pay attention to the reasonable application of cracking technology, which can improve the oil well output of a single well, and has the effective characteristics of large penetration and high reserve movement degree, and also plays a very important role in optimizing and upgrading the oil exploitation environment.

3. Establishment and analysis of casing-cement sheath-formation system model
In the current horizontal well fracturing process, casing-cement sheath-formation system is a very important system application, which has a very important impact on the whole fracturing process. In addition, in the current implementation process of fracturing technology, it is necessary to control the fracturing technology reasonably. During the whole process, the stress of the whole system will change, and it will also be affected by the stress change of crack spacing. For example, during the whole fracturing process, the stress of cement sheath inner wall, casing wall thickness, etc., has an impact on cementing and fracture spacing, and also has an impact on the implementation effect of the whole technology. In order to study its cementing technology and fracture spacing design, it is necessary to complete the stress distribution analysis in the actual system model analysis and application process. In the actual stress distribution analysis process of the model, the casing-cement sheath-formation system model is established to complete the work analysis of the whole fracturing technology system, to ensure that the subsequent work is carried out more reasonably, and to maximize the process effect.

4. The induced stress field is analyzed
In the fracturing process of casing-cement sheath-formation system, the core stress will cause the influence of induced stress field. Especially in the implementation process of hydraulic fracturing technology, it mainly completes the injection of fracturing fluid inside the fracture, which has a certain stress influence on the surrounding rock structure, thus forming the whole induced stress field. In the whole induced stress field, the high pressure of fracturing fluid is affected. In the process of realizing the induced stress field, it is mainly caused by the cooperation of stress surfaces of casing, wellbore, hydraulic fracture, cement sheath and stratum. Fig. 1 is a concrete calculation model of induced stress. In the actual stress analysis process of casing-cement sheath-formation system, it is also very critical to complete the analysis of induced stress, which is related to the effect of overall stress analysis to a certain extent.

![Induced stress calculation model](image)

**Figure 1.** Induced stress calculation model
5. Stress analysis of fractured cement sheath in horizontal well

In this paper, during the stress analysis of horizontal fracturing cement sheath, the initial stress distribution is mainly analyzed, and the stress during fracturing is also analyzed. Through reasonable analysis, the optimal control of fracturing technology is completed, and the fracturing implementation effect is improved to the greatest extent.

(1) Initial stress analysis

Initial stress analysis is an important content in horizontal well fracturing analysis, and plays a very important role in horizontal well analysis. When cement is formed and solidified, the reticular module inside itself will conduct pressure transmission to the pores in the formation and transmit the pressure to the casing device, thus forming a certain stress system between the cement sheath structure and the formation. In the stress analysis of cement sheath and casing, formation pore pressure is the force between formation and cement sheath, and this force is within the range of greater than or equal to formation pore pressure. Suppose the formation pore pressure is \( P_p \), the cementing well pressure is \( P_{wc} \), and the cementing casing has radial internal force \( \sigma_{r1} \) and hoop stress \( \sigma_{r2} \), where \( r_1 \) and \( r_2 \) are the inner radius of the casing and the outer radius of the casing device, respectively. In the process of calculating the stress, the radial stress \( \sigma_{r1} = \frac{r_2^2}{r_2^2 - r_1^2} \cdot \{1 - \frac{r_1^2}{r_2}\} P_p - \frac{r_1^2}{r_2^2} \cdot \frac{1}{2} \cdot \{1 - \frac{r_2^2}{r_2}\} P_{wc} \). The formula for calculating the hoop stress of the casing device is \( \sigma_{a1} = \frac{r_2^2}{r_2^2 - r_1^2} \cdot \{1 - \frac{r_1^2}{r_2}\} P_p - \frac{r_1^2}{r_2^2} \cdot \frac{1}{2} \cdot \{1 + \frac{r_2^2}{r_2}\} P_{wc} \). This formula is that the cement sheath is the stress after curing, which has a very important influence on the stress analysis of cement sheath, and in the actual analysis process. At this time, the cement sheath is in a state of constant stress, and its inward stress and outward stress do not exist. The values of circumferential stress and radial internal force are 0 [2].

When hydraulic fracturing occurs, hydraulic fracturing begins to exert pressure on the whole ground layer, and because of its irregular movement in the fracturing process, the direction of fracturing force is also inconsistent. Its core is the stress at the longitudinal hydraulic cracks, and gradually approaches the stress direction. During the formation of the borehole, the surrounding rocks are gradually squeezed out, and the formation surface is also affected by new pressure. At this time, the stress of the cement ring-stratum and the surrounding rock of the horizontal well changes badly. The starting formula is \( \sigma_{r3} = 1 / 2 \cdot (\sigma_H + \sigma_V - 2P_p) \cdot \{1 - \frac{r_3^2}{r_2^2}\} + \sigma_H - \sigma_V / 2 \cdot \{1 - 4\frac{r_3^2}{r_2^2} + 3\frac{r_3^4}{r_2^4}\} \). Table 1 shows the specific content in this formula [1].

| Formula letter | Express |
|----------------|---------|
| \( \sigma_H \) | Maximum horizontal in-situ stress |
| \( \sigma_V \) | Vertical geostress |
| \( \sigma_{r3} \) | Radial stress in formation during cementing |
| \( r_3 \) | Open hole wellbore radius |
| \( r \) | Radial distance |

Table 1. Shows the specific content in this formula

The above two types are the main stress analysis in horizontal well fracturing, which play a very important role in fracturing implementation, and are also related to fracturing implementation effect to a certain extent [3].

(2) Change of fracturing stress

Hydraulic fracturing has a very important influence on the implementation effect of the whole process, and it is also related to the implementation of fracturing process to a certain extent. During the implementation of hydraulic fracture, the induced stress will also change to some extent. Therefore, in the actual fracturing analysis process, pore pressure is also affected to a certain extent, and in the actual influence process, it needs to assume that linear elastic materials such as cement casing and formation rock will also cause certain pressure. At this time, the fracturing stress calculation of peach casing, cement sheath and concentric ring of formation is very critical. In the implementation of its fracturing process, mainly \( \varphi = A \cdot r \ln r + B\cdot r + C\ln r + D + (F\cdot r^4 + H\cdot r^2 + K + M\cdot r^2) \cdot \cos 2\theta \). In the actual formula calculation process, \( A, B, C, D, F, H, K \) and \( M \) are all stress coefficients in the stress analysis process, and \( R \) is the radius of cement sheath. In the actual stress analysis process, the stress mainly includes the stress...
analysis of the following casing, bottom layer and cement sheath. Through reasonable stress analysis, the actual analysis of hydraulic fracturing can also be improved to the greatest extent. In the whole stress analysis process, the stress of cement sheath section should meet various objective forms such as equal stress increment and stress change, which plays a very important role in the overall stress analysis. The stress of casing and cement sheath is constantly changing, which plays a very important role in the overall mechanical analysis. During the fracturing process, the fracturing radial stress $\sigma_r = \sigma_i + \Delta \sigma_r$ and $\sigma_\theta = \sigma_i + \Delta \sigma_\theta$ should be considered. It is the circumferential stress during fracturing, which plays a very important role in the implementation of fracturing technology. In the process of horizontal well fracturing, it is also affected by fracturing technology, which also causes analysis for the overall horizontal fracturing. And in the process of tensile stress, its internal pressure is also affected to some extent. Therefore, the analysis of its fracturing process is also very important [4].

6. Case analysis

In this fracturing process, the horizontal well fracturing is more effective, and in the actual fracturing control process, it is necessary to drill in the direction of in-situ stress. In this state, the stress on the casing and the inner wall of the casing changes, which affects the pressure change in the well to a certain extent. In this test and analysis process, it is assumed that the pressure received in the horizontal section is 30MPa during cementing and weighing, while the pressure in the well can reach 85 MPa during the hydraulic pressure expansion, which is affected by the domestic pressure. In addition, it is necessary to judge and analyze the pressure vertically during the analysis of the actual borehole pressure. In the pressure analysis, it is found that the stress at the casing position has also changed to a certain extent, and its circumferential tensile stress is gradually distributed as tensile stress. Table 2 is a description of the analysis data parameters during the test development.

![Table 2. Description of the analysis data parameters during the test development](image)

In this study, in order to analyze the stress variation of cement sheath, the relationship between the wall thickness of cement sheath and the stress variation of cement sheath inner wall with distance was analyzed. Fig. 1 and fig. 2 are stress comparison diagrams in this experiment [5].

![Figure 2. The relationship between the stress of the inner wall of the cement ring and the distance](image)
Figure 3. The relationship between the stress of the inner wall of the cement ring and the thickness of the casing

Through the analysis of Figure 1 and Figure 2, it can be known that: ① The stress on the inner wall of cement sheath gradually decreases with the increase of distance, and its variation range is relatively small. ② During the analysis of the relationship between the stress on the inner wall of cement sheath and the casing wall thickness, it can be seen from Figure 2 that the greater the casing wall thickness, the greater the stress.

7. Conclusions

In this paper, the fracturing technology of horizontal wells is analyzed reasonably, the stress calculation is analyzed, and the main factors of stress change are also summarized, which plays a very important role in stress analysis.

References

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