Discussion on casing damage situation and prevention methods in a block

Dandan Zhang
The second oil mine of the seventh oil production plant of Daqing Oilfield Co., Ltd, 163517, China
Dandan@petrochina.com.cn

Abstract. With the development of A oilfield and the constant adjustment of water injection scheme, affected by geological, engineering and development factors, the casing of oil and water wells will be damaged to varying degrees. Casing damage not only leads to the normal production of this well, but also needs to invest a lot of money for overhaul and renewal. At the same time, it will destroy the original injection-production system in this area and accelerate the production decline. Therefore, it is of great significance to study the causes of casing damage and its prevention technology for preventing casing damage and improving injection-production relationship. In this paper, a fault block in A oilfield is taken as the research object. By analyzing the present situation of casing damage in this block and the distribution law of casing damage wells in plane and longitudinal direction, combining with lithology and pressure conditions, the causes of casing damage are analyzed, and finally the countermeasures are put forward to improve the oilfield development effect and ensure the sustainable development of A oilfield.

Keywords: Casing damage; Distribution characteristics; Governance countermeasures.

1. Introduction
Since the northern part of A oilfield was put into development, 410 oil and water wells have been abandoned due to casing damage, and 581 wells have been produced with diseases after casing damage, and the number of wells with casing damage is still increasing at a rate of about 20 per year, which restricts the development effect of oil and water wells. By analyzing the distribution law of casing damage wells in a fault block in this oilfield, this paper discusses the casing damage mechanism, and puts forward the ways and means to prevent casing damage wells.

2. Present situation and distribution characteristics of block casing damage

2.1. Block status
The terrain of a fault block is flat and slightly undulating, and the sand body is distributed nearly in the north-south direction as a whole. During this period, there are 179 oil wells and 89 water wells. Up to now, this block has accumulated oil production of $4.484235 \times 10^4$ t, water production of $1.6348173 \times 10^5$ t.
10^4 m³, water injection of 2.777.8238 × 10^4 m³, comprehensive water cut of 95.2% and annual injection-production ratio of 1.1.

2.2. Distribution characteristics of casing damage wells

2.2.1. Distribution characteristics of casing damage well types. At present, there are 62 casing damage wells in a fault block. Among them, 43 cases were deformed, 12 cases were broken, 6 cases were broken and 1 case was leaked. A total of 104 casing damage points have been confirmed in 62 casing damage wells, including 50 casing damage wells in the oil layer, 5 casing damage wells below the oil layer and 7 casing damage wells above the oil layer.

2.2.2. Plane distribution characteristics of casing damage wells. Seen from the plane distribution, casing damage wells are mainly concentrated near faults, and gradually show a concentration trend in the middle and south of the block. According to the plane combination map of faults and the plane distribution statistics of casing damage wells in A oilfield, there are 33 casing damage wells near faults, accounting for 53.23% of the number of casing damage wells in a certain fault block, and they show a concentrated trend in the middle and south.

2.2.3. Longitudinal distribution characteristics of casing damage wells. According to the casing damage depth data of 104 casing damage points in 62 casing damage wells in this fault block, the casing damage mainly occurs above and inside the oil layer in the longitudinal direction. Casing damage points above oil layer are mainly distributed in A-1 formation, with 14 casing damage points, while internal casing damage points mainly occur in B-1 oil layer, with 58 casing damage points accounting for 72.5% of this group, followed by B-2 oil layer with 16 casing damage points accounting for 20.0% of this group, and B-3 oil layer with 6 casing damage points at least.

2.2.4. Lithology and well pattern distribution characteristics. The lithology of casing damage points is mainly mudstone. Among the 62 casing damage wells, the lithology of casing damage points in 50 wells is mudstone, accounting for 80.6% of the total number of casing damage wells, and the lithology of casing damage points in 12 wells is sandstone, accounting for 19.4% of the total number of casing damage wells.

Seen from the well pattern, the casing damage of the basic well pattern is serious. There are 30 casing damage wells in basic well pattern, with casing damage rate of 60%, 27 casing damage wells in primary well pattern, with casing damage rate of 27.8%, and 5 casing damage wells in secondary well pattern, with casing damage rate of 15.8%.

3. Cause analysis of block casing damage

Casing damage is the result of a variety of reasons. This paper focuses on analyzing the causes of casing damage of a fault block from the following three aspects:

3.1. Geological factors

3.1.1. Relationship between reservoir development and casing damage. Fine geological study shows that the general sedimentary characteristics of B-1 reservoir are the inner front and outer front and transitional facies of delta formed in lacustrine background. On the plane, there are intermittent banded rivers and unstable sheet sand distribution, and the poor connectivity and continuity of sand bodies cause local pressure suppression in water injection development, which leads to the largest proportion of casing damage points in this sandstone group.

B-2 oil layer is delta inner front facies deposit, and its sand body types are mainly inner front underwater distributary channel sand, inner front underwater distributary shoal sand and inner front
lenticular sand. In the process of waterflooding development, due to the development characteristics of stable banded sand bodies, the proportion of casing damage points is small.

B-3 oil layer is a lacustrine delta outer front subfacies deposit, which is characterized by transition between inner and outer front, and mainly consists of sheet sand deposits. Sandstone is thin in thickness, stable in horizon and continuously distributed in a large area on the plane. Because of its good connectivity and uniform water injection effect, it is difficult to form a pressure-out zone, so the proportion of casing damage points is relatively small.

3.1.2. Relationship between fault and casing damage

The stress concentration zone is near the fault zone, and the damage degree of well casing near the fault is relatively serious. On the one hand, there is pressure difference on both sides of the fault, coupled with the lubrication of water, which makes the fault revive and slip along the fault plane, which is easy to crush the casing; on the other hand, the injection of water near the fault is greater than the exploitation, which makes the injected water penetrate into the fracture zone of the stratum interface, which promotes the argillaceous rock fragments and hard lenses to slip along the water flow direction, thus crushing the casing and aggravating the casing damage caused by the fault. According to the statistics of 16 oil and water wells on both sides of faults in this block, it is found that 7 wells have casing damage in different degrees. According to the pressure measurement data of 23 oil wells on the fault side, the formation pressure difference on both sides of the fault increases year by year.

3.2. Development factors

High pressure water injection and its relationship with casing damage.

High-pressure water injection cracks the primary fractures and cracks in mudstone, and the volume of clay minerals in mudstone expands rapidly after absorbing water, and the rock structure and mechanical properties change, resulting in lateral deformation and flow of mudstone. Transverse shear force is generated to act on the casing, which may cause deformation of the casing, and may cause dislocation of the casing.

With the increase of liquid production, the scheme adjustment is intensified continuously, the water injection intensity of thin and poor layers is improved, and the water injection pressure is continuously increased to keep the injection-production balance, which indirectly accelerates the occurrence of casing damage. In recent years, an average of 3.75 wells have been lost in casing in a fault block every year. Figure 1 shows the relationship between the number of top-pressure water injection wells and the number of casing damage wells. It can be seen from Figure 1 that the number of casing damage wells increases with the high proportion of top-pressure water injection.

![Figure 1. Relationship between the number of casing damage wells and the number of top pressure water injection wells in a fault block](image-url)
3.3. Engineering factors

Relationship between cementing quality and casing damage.

The injected water flows into shale through the well section with poor cementing quality, and the rock mechanical properties change after the shale enters water. With the increase of water cut in shale, the cohesion and internal friction angle of rock will also decrease. According to Coulomb-Moore formula, with the decrease of cohesion and internal friction angle of shale, the shear strength of rock decreases greatly.

Coulomb-Moore formula:
\[ \tau = C + (\delta - p) \tan \varphi \]

In the above formula
- \(\tau\) —— Rock shear strength, MPa;
- \(C\) —— Cohesion of mudstone;
- \(\varphi\) —— Internal friction angle, (°);
- \(\delta\) —— Normal stress, MPa;
- \(P\) —— Pore pressure, MPa.

Therefore, after mud shale is immersed in water, it is easy to form a large area of immersion water area, which causes large area casing damage in non-oil layer parts and induces casing damage.

4. Prevention measures of casing damage

4.1. Aiming at the problem of high water injection pressure, carry out pressure reduction treatment measures

The injection pressure of water injection wells is relatively high, which tends to suppress the pressure at the parts with poor lithology, causing mudstone creep and damage to the extruded casing. Therefore, it is necessary to reasonably control the injection pressure and strictly control it below the maximum allowable pressure. For water injection wells that exceed or approach the maximum allowable pressure, the scheme should be adjusted in time. At the same time, combined with fracturing, acidizing and other reform measures, the injection pressure should be reduced to prevent in-situ stress changes and casing body deformation caused by excessive injection pressure, and reduce the occurrence rate of casing damage.

Since 2013, acidizing 46 water injection intervals of 17 wells and fracturing 44 intervals of 14 wells have been adopted for some wells with high pressure and poor injection condition in this block, and good treatment results have been achieved. After the reform measures are implemented, the average water injection pressure drops from 14.3 MPa to 11.9 MPa (Table 1).

Table 1. Statistical table of reform effect of high pressure water injection wells from 2013 to 2019

| Measure category | Age | Number of wells | Number of intervals | Measure thickness | Before taking measures, Pressure (MPa) | Actual note(m³) | After the treatment, Pressure (MPa) | Actual note(m³) | Differential value |
|------------------|-----|----------------|--------------------|-----------------|--------------------------------------|----------------|-----------------------------------|----------------|------------------|
| Acidulate        |     |                |                    |                 |                                      |                |                                   |                |                  |
| 2013             | 9   | 22             | 7.6                | 5               | 14.2                                 | 17             | 10.8                              | 34             | -3.5             |
| 2014             | 1   | 3              | 11.3               | 4.4             | 14                                    | 10             | 14                                | 10             | 0                |
| 2015             | 1   | 2              | 10                 | 3.9             | 14.8                                 | 21             | 14.8                              | 30             | 0                |
| 2017             | 2   | 6              | 10.7               | 4.5             | 14.7                                 | 18             | 14.7                              | 24             | 0                |
| 2018             | 2   | 7              | 7.3                | 3.4             | 14.8                                 | 13             | 11.5                              | 27             | -3.3             |
| 2019             | 2   | 6              | 7.5                | 4.1             | 14.8                                 | 15             | 14.0                              | 30             | -0.8             |
| Average          | 17  | 46             | 8.3                | 4.5             | 14.4                                 | 16             | 12.1                              | 30             | -2.3             |
| Fracture         |     |                |                    |                 |                                      |                |                                   |                |                  |
| 2013             | 8   | 25             | 8.8                | 4.9             | 14.5                                 | 16             | 11.4                              | 41             | -3.1             |
| 2014             | 5   | 16             | 7.6                | 4.9             | 14.22                                | 14             | 11.4                              | 32             | -2.9             |
| 2018             | 1   | 3              | 12                 | 5.4             | 12.3                                 | 7              | 13.9                              | 43             | 1.9              |
| Average          | 14  | 44             | 8.6                | 4.9             | 14.2                                 | 15             | 11.6                              | 38             | -2.7             |
| Average          | 31  | 90             | 8.4                | 4.7             | 14.3                                 | 16             | 11.9                              | 34             | -2.5             |
4.2. Actively take oil and water well measures to improve the pressure imbalance on both sides of the fault
First, at the injection end, raise the level and control the level, and properly adjust the water injection well plan. According to the distribution of formation pressure on both sides of the fault, combined with the production, water cut and sand body development of surrounding oil wells, the water injection wells in high-pressure area should be appropriately lowered, and the water injection wells in low-pressure area should be appropriately raised to reduce the water injection pressure difference on both sides of the fault.

Second, at the production end, appropriate measures such as fracturing and changing pumps are taken for oil production wells with higher pressure near faults to reduce injection-production ratio, and appropriate measures such as lowering production parameters to restore formation pressure are taken for wells with lower pressure, so as to reduce the pressure difference between the two sides of faults and achieve the purpose of pressure balance.

4.3. Timely adjustment of oil and water wells in well areas with concentrated casing damage, and strengthening risk prevention and control in well areas with hidden casing damage
Adjust the scheme of casing damaged wells in a timely manner, control the water injection in the casing damaged interval, stop the water injection in the casing damaged interval, and take the measures of full entry and stop injection when necessary to prevent the flooding area from expanding. At the same time, after taking measures such as overhaul, renewal and sidetracking for casing damaged wells, the surrounding water injection wells will resume the normal injection allocation scheme for water injection to keep the injection-production balance of the system. Preventive adjustment shall be carried out for water injection wells in areas with hidden casing damage, so as to reduce water injection pressure and injection-production intensity and prevent casing damage.

4.4. Strengthen daily casing protection management
For wells to be overhauled and abandoned without taking measures, it is necessary to speed up the progress of measures such as overhaul, side inclination and renewal; Strictly implement the four-level alarm system of abnormal wells and the reporting process of abnormal wells, and stop injection of abnormal wells in time to prevent casing damage; Investigate the operation life of oil and water wells, and gradually arrange pipe inspection and casing inspection for wells that have not been operated for more than 8 years; After timely adjusting measures such as water shutoff, liquid reduction and liquid extraction from high-yield wells, the water injection quantity of corresponding horizons of water injection wells will be connected, so as to prevent the imbalance of injection and production in local well groups and reduce the occurrence probability of casing damage.

5. Summary
(1) Casing damage wells are mainly distributed near faults in the plane and in A-1 and B-1 oil layers in the longitudinal direction. The lithology of casing damage points is mainly mudstone, and the well pattern is mainly the basic well pattern.

(2) Poor connectivity and continuity of sand body, unbalanced pressure on both sides of fault, high water injection pressure and poor cementing quality are the main causes of casing damaged wells.

(3) The probability of casing damage can be effectively reduced by measures to reduce water injection pressure, corresponding adjustment of oil and water wells and strengthening daily casing protection management.

References
[1] Xu jiamei. applicability analysis of several injection profile logging methods in Hailar oilfield. petroleum tubing and instruments [J], 2015,1 (1): 65-69.
[2] Jiang Chenggang. Oil-water distribution and reservoir-forming model of Putahua oil layer in the west wing of Aobaota Oilfield [J]. Journal of Northeast Petroleum University, 2013, (05): 42-49.
[3] Liu Zongbao, Yan Li, Yu Jing, et al. Oil-water distribution law and main controlling factors of Putaohua reservoir in Taidong slope area of Songliao Basin [J]. Journal of Northeast Petroleum University, 2012, (06): 14-21.

[4] Du yuanqing. Analysis of main control factors and interpretation methods for fluid identification in complex fault-block reservoirs [j]. Journal of Yangtze University, 2014, (07): 18-22.