Research on the Correlation between Injection and Production Speed and Casing Loss Trend

Jinfeng Cao
Geological Brigade of No.1 Oil Production Plant of PetroChina Daqing Oilfield Co., Ltd., Heilongjiang, 163000, China
CaoJinfeng@petrochina.com.cn

Abstract. When the oilfield enters the late stage of ultra-high water cut development, the number of wells with casing damage is increasing, which leads to the imperfect injection-production relationship, makes it difficult to effectively use geological reserves, and makes the treatment and repair of casing damaged wells difficult, long in cycle and high in cost, which seriously affects the oilfield development effect and economic benefits. There are many factors leading to casing damage, and injection-production rate, as an important development data, affects various production indexes of oilfield and casing damage rate. Based on the statistical analysis of the injection production rate and casing damage rate in the past 15 years, this paper summarizes the related laws between them and the number of casing damage wells, time distribution, change trend, etc., studies the inter area range of water injection speed and injection production speed difference when casing damage occurs with high probability by well spacing, and formulates reasonable limits of water injection speed and injection production speed difference, so as to provide reference for the benign development of oilfield For reference.

Keywords: Water injection rate, Poor injection-production rate, Casing damage rate.

1. Introduction
This research block is one of the earliest blocks in oilfield development, and it is also the development block with the earliest discovery of casing damage wells and the largest number of accumulated casing damage wells. In 1985, the first oil shale standard layer in Nenerdi oilfield appeared as a casing damage area. In 2013, there were nearly ten well areas with concentrated casing damage, which seriously affected the development adjustment and development effect of the block. Since 2017, the comprehensive prevention and control project of casing damage has been implemented, which makes the casing damage degree lighter. However, the casing damage rate is high and the casing damage situation is grim. For this reason, the deepening research on the causes of casing damage is carried out to provide technical support for systematic evaluation of casing damage prevention and control measures and improvement of prevention and control effect.

According to the statistics of casing damage wells since the development of the block, the proportion of casing damage in non-oil layers accounts for 43.2%, mainly concentrated in the second member of Nen. The proportion of casing damage in oil layer accounts for 56.8%, mainly concentrated in Sa 0-II4.
On the plane, Sa 0-II4 casing damage wells are distributed near the eastern transition zone and the western transition zone, while casing damage wells in other oil layers are scattered. Casing damage is mainly manifested by bending deformation and fault of oil layer.

Many scholars at home and abroad have studied the problem of casing damage in many aspects, with different viewpoints, which can be summarized as follows: 1. Under the condition of large difference in formation pressure between adjacent blocks, based on uplift theory, high pore pressure can relatively increase the shear force on the inclined plane of formation, resulting in rock mass displacement and casing damage. 2. The horizontal bedding of oil shale in standard bed is developed, which is characterized by hard lithology and weak surface. When the injected water enters the standard bed, it will diffuse along the bedding planes of fossil fossils such as ostracods and conchostracods, which are densely stacked, and form the immersion water area, which makes the mudstone easy to crack as a whole. When the rock is subjected to shear stress, the stress will be released along the fossil weak surface of the marker layer, resulting in a piece of casing damage. 3. According to the theory of tectonic stress, it is considered that the stress is concentrated near the structural axis and faults, which causes disturbance stress changes in the process of water injection and oil recovery, and easily damages the casing. 4. High-pressure water injection and super-fracture pressure water injection easily lead to casing damage. 5. Based on the principle of expansion with heat and contraction with cold: water injection reduces the temperature of rock, reduces the horizontal axial stress and easily damages casing. 6. Corrosion factors: there are mainly high salinity formation water, hydrogen sulfate radical, sulfuric acid reducing bacteria, hydrogen sulfide and electrochemical corrosion. 7. Other factors: engineering factors such as poor casing quality, improper perforation or fracturing technology, unstable operation during downhole operation and maintenance, etc. Under the influence of the above factors, many types of casing damage will occur, such as deformation, bending, rupture, perforation, wrong break and so on. Nowadays, more and more enhanced oil recovery measures are applied to oilfield production, such as high-pressure water injection, fracturing, large-scale acidification, steam injection and other engineering technical measures. On the one hand, these enhanced oil recovery measures improve the oil field production and achieve obvious economic benefits; on the other hand, they also make the working environment of oil and water wells casing deteriorate constantly, and induce various factors to destroy the casing. The external load on the casing increases continuously until the casing is damaged. It is of great practical significance to analyze and study various causes and mechanisms of casing damage in oil and water wells, and formulate and adopt effective maintenance and prevention methods according to the causes to meet the needs of long-term oil production in oil fields. In this paper, aiming at the factor of casing damage caused by disturbance stress change during water injection and oil recovery, the influence of water injection speed and injection-production speed difference on casing damage rate in recent years is statistically analyzed, and the related laws between them and the number of casing damage wells, time distribution and change trend are summarized. The interval range of water injection speed when casing damage occurs with high probability is studied by well pattern and block, and a reasonable boundary between water injection speed and injection-production speed difference is worked out, which provides a basis for benign oilfield production.

2. Overspeed water injection induced reservoir pressure loss and casing damage
Improper water injection rate in oilfield is closely related to casing damage. Generally speaking, due to various reasons, the injection volume is greater than the production volume, resulting in pressure loss in small layers. If this situation exists, the stress balance of the original layer will be destroyed to a great extent, and finally the casing stress will be uneven, resulting in serious deformation of the casing.

2.1. Serious pressure loss in small layers leads to casing damage in oil layers
The research shows that the vertical principal stress of the block is the smallest, and the elastic deformation caused by the change of reservoir pore pressure has the greatest influence on the deformation of the overlying strata. The upper stratum is prone to overpressure deformation, and the closer the distance is, the more obvious it is.
When the formation pore water pressure changes, the formation deformation mode depends on the contrast relationship of triaxial stress (Figure 1). The in-situ stress relationship within 1200m of Sazhong Development Zone (triaxial stress relationship) is: maximum horizontal principal stress > minimum horizontal principal stress > vertical principal stress. When the pore pressure changes, the equivalent stress and elastic deformation of rock skeleton are opposite, and the equivalent stress changes vertically > minimum horizontal stress direction > maximum horizontal stress direction. Elastic deformation of stratum: vertical > minimum horizontal stress direction > maximum horizontal stress direction. The larger the injection rate, the higher the formation pressure and the more casing damage wells. The water injection rate is positively correlated with the number of casing damage wells: the higher the water injection rate, the greater the contradiction of reservoir pressure suppression and the more casing damage wells. The casing damage rate is higher when water is injected at top pressure or overpressure. Due to various reasons, the injection volume is greater than the production volume, resulting in pressure loss in small layers → energy accumulation → sand deformation → interlayer sliding → casing damage. This leads to the value of injection-production rate, and this paper will further study the influence of injection-production rate on casing damage.

2.2. Law understanding of the influence of injection-production rate on casing damage

From 2005 to 2019, there were 4,401 casing damage wells in the reservoir area, with an average water injection rate of 16.2% and an oil production rate of 13.9%. By analyzing the contrast curve of water injection speed between the block and Placantline since 2008 (Figure 2), it is found that the water injection speed of the block started to be higher than the average level of Placantline in 2010, and the difference between the two is getting bigger and bigger, and the difference reaches the maximum in 2015. Since 2012, the casing damage rate began to rise, and reached the peak in 2017. We believe that there is a strong correlation between the water injection rate and the casing damage rate, and the rise of the casing damage rate occurs two years after the water injection rate rises.

![Figure 1. Comparison curve of injection speed between block and Changyuan](image)

Further analyze the change of injection-production rate and injection-production rate difference and annual casing damage rate in the block (Figure 3, 4, 5 and 6), and translate the annual casing damage rate data corresponding to X time axis forward for two years. The casing damage rate increases with the increase of water injection rate and injection-production rate difference. By analyzing the reasons why the peak number of casing damage wells appears two years after the peak value of the difference between the water injection speed and the injection production speed, it is considered that the average operation cycle of the movable string of oil and water wells in the block is generally about two years, and the operation frequency leads to the lag in the detection of casing damage wells.
According to the well pattern data of block development, the block where casing damage wells are located is divided into conventional well spacing block and small well spacing block. There are 11,859 wells in the conventional well spacing block and 3,042 casing damage wells, accounting for 20% of the total number of wells. There are 6,689 wells in the small well spacing block and 1,359 casing damage wells, accounting for 20% of the total number of wells. After moving forward for 2 years, it can be
found that the annual casing loss rate is positively correlated with the difference between water injection rate and injection-production rate in both conventional well spacing blocks and small well spacing blocks: the greater the value, the greater the contradiction of reservoir pressure suppression, and the more casing loss wells, and vice versa.

Excluding individual abnormal points is due to the large number of casing damage wells found in the large-area moving string operation measures in this block in that year. The change trend of casing damage rate is very consistent with the change trend of water injection rate and injection-production rate difference. The higher the water injection rate, the higher the casing damage rate. The larger the injection-production velocity difference, the higher the casing damage rate.

2.3. Determine the correlation limit between water injection rate and casing damage trend

By dividing the water injection rate and annual casing damage rate of each small block into conventional well spacing block and small well spacing block, the scatter distribution diagram is made, and the linear regression equation of annual casing damage rate and water injection rate is obtained: conventional well spacing annual casing damage rate = 0.1523 * water injection rate - 0.3368; small well spacing block annual casing damage rate = 0.1248 * water injection rate -0.8706 (Figure 7, 8).

![Figure 6. The relationship between water injection rate and annual casing loss rate in conventional well spacing blocks](image1)

![Figure 7. Relationship between water injection rate and annual casing damage rate in small well spacing block](image2)

According to the formula, the water injection rate of conventional well spacing block is controlled below 15%, and that of small well spacing block is controlled below 23%, which can achieve the prevention and control goal of annual casing damage rate below 2.0% and annual casing damage well number around 400.

Then, the injection-production velocity difference and annual casing loss rate of each subblock in the block are divided into conventional blocks and small well spacing blocks, and it can be seen that when the annual casing loss rate of conventional blocks is lower than 2.0%, the injection-production velocity difference data is concentrated below 0.9 percentage points. When the annual casing loss rate of the small well spacing block is lower than 2.0%, the data of injection-production velocity difference is concentrated below 2.5 percentage points (Figures 9 and 10). Therefore, while controlling the water injection rate, we should also consider the change of injection-production rate difference, so as to effectively control the increase of casing damage wells and achieve the expected value of casing damage rate control.

![Figure 8. The relationship between the difference in injection-production speed and annual casing loss rate in conventional well spacing blocks](image3)
Proceeding from the actual situation of casing damage prevention and control in oilfield, aiming at the casing damage situation in oil layer, the inter-regional formation pressure balance was adjusted to control the sudden change of formation pore pressure, and the prevention and control measures of "reducing speed, relieving pressure and reducing pressure difference" were adopted for the whole Sazhong Development Zone to prevent the casing damage from spreading. The key measures to prevent casing damage are to control the water injection speed and reduce the difference between injection and production speed, to control the formation pressure change speed and range within the safety limit, to minimize the reservoir deformation and to maintain the relative stability of the overlying formation.

In recent years, a large number of casing damage prevention and control measures have been taken to control the water injection rate and reduce the injection-production rate difference, and the prevention and control effect of oil layer in the block is obvious. The number of casing damage wells decreased year by year, the casing damage rate decreased greatly, and the casing damage trend gradually improved.

3. Conclusions
(1) There is a positive correlation between water injection speed and injection-production speed difference and casing damage rate, and if the value is too large, it is easy to cause casing damage in oil layer.

(2) The water injection rate of conventional blocks is controlled below 15%, and the injection-production rate difference is controlled below 0.9%. The water injection and injection-production rate difference in the block with small well spacing are controlled below 23% and 2.5%, which is expected to control the number of casing damage wells below 400 and the annual casing damage rate within 2.0%.

(3) Macroscopically, the injection-production balance should be maintained, so that the pore pressure of each block is basically balanced, and the problem of reservoir pressure loss and casing damage can be reduced by controlling the water injection rate and reducing the injection-production speed difference.

References
[1] Hu Bozhong, Xu Zhiliang. Casing damage mechanism and protective measures for oil and water wells in Daqing Oilfield. Petroleum Drilling and Production Technology. 1998 (5), 95-96.
[2] Study on geological conditions of casing damage in Daqing Oilfield (internal data). Exploration and Development Research Institute of Daqing Petroleum Administration, etc. 1988.
[3] Zhang Gende, etc., Oil Well Casing Deformation and Damage Mechanism, Petroleum Industry Press, 2015.7, ISBN7-5021-4911-2, 76-85.
[4] Liu Jianzhong. The combined action mechanism of pressure and pressure difference in oilfield casing damage [J]. Petroleum Exploration and Development, Vol.28, 2001, No2: 97-99.