Study on the standard of well and layer selection for infill wells in L13 well area of medium and low permeability L Oilfield

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Abstract. L oilfield entered the stage of high water cut development, because the high water flooded zone in infill wells was not used in the early stage, the relationship between subsurface injection and production in some horizons was imperfect, and the remaining oil showed a distribution pattern of "overall dispersion and local relative enrichment", which affected the oilfield development effect. By filling holes in infill wells in time and perfecting the local injection-production relationship, the remaining oil in the imperfect injection-production parts can be effectively used and the oilfield development effect can be improved. In this paper, through the comprehensive analysis of previous hole-patching effects, the original well-selecting and layer-selecting standards are re-evaluated, the hole-patching and layer-selecting standards are further improved, and the oilfield hole-patching potential is implemented, which is of great significance for guiding the oilfield to tap the potential remaining oil.

Keywords: Encrypted well; Filling holes; Select well and layer.

1. The raising of questions
L13 well area of L oilfield is located in Longhupao, central depression area of Songliao Basin—North of Da'an terrace Longhupao anticline structure. In 1997, it was fully put into development, and in 2007, a total of 43 infill production wells were put into operation in the block. Due to the water injection development in the block for many years, the underground oil and water distribution was complex, and the flooding situation in some well areas was serious. In the early stage of infill wells in the well area, the low-risk thin and poor oil layers were mainly perforated, and the logging curves showed that the oil and water were in the same layer, with high flooding degree and high perforation risk, and no perforation was carried out (Figure 2). According to the statistics of new infill wells, the oil layers of 26 wells are not completely perforated, with a total of 112 layers not perforated. After the adjustment of injection-production system in 2010, the water flooding direction increased. By coordinating the water injection intensity of new and old wells, the water injection in the old water breakthrough direction was controlled, and the water injection in the new direction was strengthened. With the increase of comprehensive water cut in the well area, the medium-risk layer became the main potential layer for hole filling at present [1].

In recent years, after the adjustment of injection-production system in the well area, the preliminary standards for well and layer selection of infill wells have been formulated: 1. By coordinating the water
injection intensity of new and old wells, the injection wells in the old water breakthrough direction of the replenishment layers have stopped injecting for more than two years. 2. Strengthen water injection in water injection wells in the new direction, and the water injection intensity reaches more than 2 times of the effective intensity. According to this standard, a total of 53 sublayers of 10 wells were filled with infill wells, with a sandstone thickness of 77.8m and an effective thickness of 26.4m. After hole supplementation, the average daily oil increase of single well is 3.4t, and the average cumulative oil increase of single well is 163t. Among them, water appeared in 3 wells after hole repairing, which made the measures ineffective and made it more difficult to select wells and layers. Therefore, it is necessary to analyze the hole repairing effect and further optimize the standards for selecting wells and layers [2]-[4].

By analyzing and comparing the hole repairing effect of infill wells, the effective thickness of hole repairing layer, the number of main layers, the liquid production and water cut are analyzed. The stopping time of water injection wells from the old water breakthrough direction, the number of water injection wells in the new direction, and the continuous water injection intensity of the corresponding layers of the main layer of supplementary holes are analyzed to improve the standards for selecting wells and layers for supplementary holes.

2. Effect analysis and standard determination of supplementary hole well measures

2.1. The oil production wells with low liquid production before the measures have good effect after hole patching

According to the relationship between daily liquid production before measures and initial oil production after measures, it can be seen (Figure 3): When the daily liquid production before the oil well measures is less than 20.0t, the daily oil production in the initial stage of hole filling is higher and the hole filling has achieved good results. The average daily oil production of such wells is 2.2t in the initial stage of single well and the cumulative oil increase is 225 t; When the daily liquid production before the measures is higher than 20.0t, the perforated horizon has strong liquid production capacity and high water flooding degree, which causes interlayer interference to the newly opened horizon, and the effect of the measures is relatively poor. The average initial daily oil production of such wells is 0.8t, and the cumulative oil increase is 83 t. However, well L1 in the block produced 30.6t/d of liquid, 0.8t/d of oil and 97.3% of water before the measures for hole supplementation. At the same time of hole supplementation, the high water flooded zone with the ratio of liquid production accounting for more than 40% of the whole well was blocked in time (Figure 4), and the oil production increased by 3.2t at the initial stage after the measures, which also achieved good results. It shows that it is suggested to plug the main watered-out layers to reduce the interlayer interference and give full play to the role of the hole-patching layer in high-fluid wells.

![Figure 1. Relationship between daily liquid production before measures and initial daily oil production](image)
According to the relationship between water cut before measures and oil increase at the initial stage after measures, there is no necessary connection between water cut before measures and oil increase after measures. With the increase of water cut level, the comprehensive water cut of single well before replenishment and the oil increase after measures still have the oil increase effect. Even if the water cut is 100%, the initial oil increase can still reach over 1t, which shows that the comprehensive water cut of single well before replenishment is not the influencing factor that limits the hole replenishment effect (Figure 5).

2.2. The hole repairing effect of oil production wells with large effective thickness and many main layers is good

32.4% of the main layers of infill wells have not been perforated due to high water cut, and the injection-production well pattern is irregular. With the change of the main water drive direction of new and old wells, the remaining oil is enriched to unperforated well points. It can also be confirmed from the schematic diagram (Figure 6) and remaining oil saturation diagram (Figure 7) of the water drive status of the main layer in the well area that the remaining oil of the main layer is mainly concentrated in the unused well points [5].
Figure 4. Remaining oil saturation map

It can be seen from the relation diagram between the effective thickness of communication and the initial oil increase (Figure 8) that the patch layer is in good communication condition, and when the effective thickness of communication is greater than 1.3m, the measures are effective, with an average daily oil increase of 2.0t and a cumulative oil increase of 212t for a single well. For wells with poor connectivity in the patch layer, the average daily oil increase of a single well is 1.2t, and the cumulative oil increase is 66t; It can be seen from the relationship diagram between the number of main layers and initial increasing oil production (Figure 9) that the more main layers are opened, the better the effect of the measures, and the higher the initial increasing oil production after hole filling. After the measures are explained, the main hole filling layer still contributes a lot to increasing oil production. It is suggested that there should be at least three main horizons in the later stage of hole patching and layer selection.

Figure 5. Relationship between effective thickness of communication and initial daily oil increase

Figure 6. Relationship between the number of main layers of hole patching and initial daily oil increase
2.3. When the injection stop time of the old direction risk layer is more than 24 months and the continuous injection intensity of the water layer is less than 3500m$^3$/m, the hole filling effect is good. Since the hole filling of infill wells is mainly due to the increase of water flooding direction after the adjustment of injection-production system, the water injection intensity of new and old wells is coordinated, the water injection in the old water breakthrough direction is controlled, the water injection in the new direction is strengthened, and the hole filling is carried out after the underground oil and water are redistributed. Therefore, the cumulative water injection rate is higher, and the corresponding layers in the old water breakthrough direction are stopped, but the injection stopping time is different. In the analysis, the wells with increasing oil production by more than 1t and increasing accumulated oil production by more than 150t at the initial stage after the measures are defined as effective wells, and the boundary of infill wells is analyzed from the stopping time of water layer and the continuous water injection intensity of water layer in the old direction. It can be seen from the figure that the plugging effect is good when the stopping time of water layer in the old direction is more than 24 months and the continuous water injection intensity of water layer is below 3500m$^3$/m (Figure 10). It can be seen from the relationship diagram between it and initial daily oil increase that the longer the injection stop time of water-seeing risk layer (Figure 11), the better the effect; It is not seen that the effect is best when the continuous water injection intensity of water layer is about 2000m$^3$/m (Figure 12). Due to the large water absorption of the old direction risk layer and the high water storage rate of the formation, the longer the injection stop time of the water injection wells in the old water breakthrough direction, the water injection is strengthened in the new direction, and the remaining oil around the new hole filling layer is fully enriched with good results; Although the risk of no water layer is small, the water flow channel has been formed due to the long water injection time, and the high continuous water injection intensity will lead to rapid water breakthrough after the new hole filling layer measures.

![Figure 7. Intersection diagram of injection stop time of risk layer and continuous water injection intensity of unseen water layer](image)

![Figure 8. Relationship between injection stop time and initial daily oil increase in risk zone](image)
Figure 9. There is no relationship between continuous water injection intensity and initial daily oil increase in water layer.

2.4. When the number of new directions of injection diversion is two or more and the water injection intensity is between 2500-4500m³/m, the hole filling effect is better.

After the adjustment of the injection-production system in the well area, the injection in the old flooded direction was stopped, and the transfer of injection wells became the main factor to promote the redistribution of oil and water. The injection time in the new direction was shorter and the intensity was smaller. Therefore, in the aspect of transfer injection wells, the plugging limit of infill wells is mainly analyzed from the new direction number and water injection intensity. It can be seen from the figure that when the number of new directions is two or more and the water injection intensity is between 2500-4500m³/m, the hole patching effect is better (Figure 13). It can be seen from the graph of its relationship with the initial daily oil increase that the more injection wells are transferred in the new direction (Figure 14), the more liquid is supplied and the better the effect is; When the water injection intensity is between 2500-4500m³/m, the hole filling effect is better. If the water injection intensity in the new direction is higher, it will lead to the communication between the new and old water injection wells, which will lead to the rapid water breakthrough of oil wells after the measures, and the effect will become worse. It can be seen from the figure that when the water injection intensity is about 4000m³/m, the oil increase effect is most obvious (Figure 15).

Figure 10. Intersection diagram of number of new directions and water injection intensity in new directions.
Figure 11. Relationship between the number of new injection directions and the initial daily oil increase

Figure 12. Relationship between water injection intensity in new direction and initial daily oil increase

From the above analysis of the main factors affecting the hole replenishment of oil wells, it can be seen that the old direction water injection wells are mainly controlled in the process of hole replenishment well culture because of the high underground water storage rate; In the new direction, the overall water injection rate is insufficient, and lifting is the main factor. At the same time, in terms of protection of the effect of measures after hole repairing, the injection allocation intensity of corresponding intervals of new and old water injection wells should be treated differently, referring to the pre-measures training standard. After the measures, water injection should not be resumed in the risk layer of the old direction water injection wells within the effective period of hole repairing, and the new direction water injection wells should absorb water normally to ensure adequate liquid supply. To sum up, the standard of well and layer selection for infill wells has been further improved.
Table 1. Standard table for well and layer selection of infill wells

| Type                                           | Characteristics of potential well layers and water injection culture methods | Selection of wells, layers and training standards |
|------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------|
| High water flooded zone without perforation in infill well | Strengthen water injection in new direction Old direction control water injection | 1. The daily liquid production before oil well measures is less than 20t. If the daily liquid production is higher than 20t, it is recommended to plug the main watered-out layer when repairing holes to reduce interlayer interference; 2. The communicated effective thickness of the patch layer is greater than 1.3m; 3. There are at least three main horizons in the patching layer. |
| Oil well                                       | Old direction injection well Transfer injection to new wells             | 1. There are at least 2 injection transfer wells in the new direction; 2. The continuous water injection intensity of the layer corresponding to the new direction patching layer is more than 2 times of the effective intensity: 2500 m³/m - 4500 m³/m (it is recommended to be around 4000 m³/m); 4. After the measures, the water injection wells in the new direction absorb water normally, so as to ensure adequate liquid supply in the new direction. |

3. Application effect

Table 2. Table of well selection and layer selection for hole repairing measures

| Well No. | Daily liquid production before measures (t) | Communication effective thickness of patching layer (m) | Number of main layers in patching layer (pieces) | Old direction injection well Stop injection time of risk layer (month) | No continuous injection strength of water layer is found (m³/m) | Number of surrounding injection wells (ports) | Water injection intensity corresponding to the new direction in the supplementary hole layer (m³/m) | Measure mode |
|----------|--------------------------------------------|--------------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-----------------------------------|-------------------------------------------------|----------------|
| Long No.1| 28.4                                       | 5.4                                                   | 4                                               | 47                                              | 3224                                           | 4                                | 4333                                           | Plug-up: plugging high water flooded layer |
| Long No.2| 31.6                                       | 2.3                                                   | 5                                               | 42                                              | 2042                                           | 3                                | 3896                                           | Plug-up: plugging high water flooded layer |
| Long No.3| 15.2                                       | 2.2                                                   | 4                                               | 35                                              | 2846                                           | 3                                | 3698                                           |                                             |
| Long No.4| 14.3                                       | 2.9                                                   | 3                                               | 29                                              | 2653                                           | 4                                | 4156                                           |                                             |
| Long No.5| 16.2                                       | 5.5                                                   | 5                                               | 25                                              | 3142                                           | 3                                | 3927                                           |                                             |
| Average  | 21.1                                       | 3.7                                                   | 4                                               | 36                                              | 2781                                           | 3                                | 4002                                           |                                             |
There are 18 wells and 59 sublayers in the well area, which have the potential of reperforating. According to this standard, 5 wells are selected in the well area for reperforating. The effect of increasing oil after hole-mending measures is good, the average initial oil increase of single well reaches 3.4t, the comprehensive water cut decreases by 15.1 percentage points, and the cumulative oil increase of single well is 212t. Good results have been achieved.

4. Conclusions
First, in the early stage of infill well, the risk layer was not perforated and the hole was replenished in time, which can achieve better oil increase effect;
Second, the main layer with low daily liquid production, large effective thickness and good sand body development is preferred to make up the hole better;
Third, the influencing factors of surrounding new and old water injection wells should be fully considered in formulating the standard of hole supplementation and well selection;
Fourth, the standard of well selection and layer selection should be suitable for oilfield development, which needs to be continuously improved and updated.

5. References
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