Research on the Forecast Means of Large-Scale Multi-Branch Fracturing Capacity

Liu Jiandong
Research Institute of Exploration and Development of Daqing Oilfield Company Ltd., Daqing 163712, Heilongjiang, China
liujian321@petrochina.com.cn

Abstract. In order to effectively improve the economic benefits of large-scale fracturing of the single well in tight reservoirs, avoid investment risks and raise development effects, research on the forecast means of large-scale multi-branch fracturing capacity is carried out. Large-scale fracturing has high costs and high investment risks, it is necessary to conduct relatively accurate forecast for the capacity after fracturing to reduce investment risks. On the basis of the single-well capacity data of 78 large-scale fracturing wells that have been put into production in the Hailar Basin, the geological, development and engineering factors affecting capacity were deeply analyzed and summarized. According to different applicable conditions, the theoretical derivation and polynomial linear regression methods are used; two different capacity forecast models of tight reservoir are given. These two forecast models are used, the error of capacity forecast results after fracturing is less than 15%, and the accuracy can meet the actual application requirements of the mine, therefore, this forecast method provides a powerful technical support for the promotion of large-scale fracturing technology and reducing economic risks.

Keywords: tight reservoir; multi-branch fracturing; capacity forecast model; polynomial regression.

1. Introduction
The Hailar Oilfield is an important part of the peripheral oilfields of Daqing, it belongs to complex fault-block reservoir with low-extra-low permeability, due to its tight reservoir, low reservoir mobility, poor reservoir distribution regularity, and low natural capacity. Reservoir must undergo transformation of fracturing increase in production before they can produce industrial oil; therefore, fracturing technique and post-fracturing capacity forecast means are key technologies for realizing effective development of the Hailar Oilfield.

The low-porosity, low-permeability complex fault block reservoir is affected by ultra-low permeability non-Darcy flow; it is difficult for oil droplets near single artificial plane fracture to overcome the starting pressure and flow into the fracture, reservoir substrate is poor in supplying oil to fractures, resulting in short effective period of conventional fracturing measures and rapid decline in oil well capacity, which restricts the development effect of oilfield. In order to ensure the economic and effective development of the oilfield and improve the development effect, in recent years, large-scale
fracturing test of difficult-to-recover branch fractures of vertical wells in Hailar complex fault block reservoir was carried out, change from the original conventional fracturing to the multi-branch fracturing which aims at increasing the contact range of the fracture and the reservoir, which realize the matching of fracture and sand bodies, expand the control volume, and ensure the continuous supply of oil flow. The forecast means of large-scale multi-branch fracturing capacity was formed in large-scale fracturing practice; it can more accurately forecast the capacity of a single well after fracturing, thereby providing an effective means for promoting large-scale fracturing technology and reducing economic risks.

2. Large-scale Branch Fracturing Technique

2.1. Technical principle
In the process of hydraulic fracturing, the net pressure in the fracture exceeds the maximum and minimum horizontal stress difference and the tensile strength of rock via the construction of large liquid volume and large displacement, when form a main fracture, at the same time, bridge blocking is generated in the main fracture of artificial fracture via the degradable fiber network sanding technique, secondary fracture is generated in the lateral direction of the main fracture, two-level secondary fracture is continuously generated in the secondary fracture, eventually the multi-fracture system combining main fracture and branch fracture is formed, the fracture swept volume is enlarged, the permeability of the reservoir is effectively improved, thereby increasing the capacity of a single well.

2.2. Formation conditions
When the net pressure in the fracture exceeds the sum of the horizontal principal stress difference and the tensile strength of rock during construction, new fracture can be formed based on the original fractures to form the fracture network. Therefore, in order to realize fracture network fracturing in vertical fracturing reservoirs, the size of the horizontal stress difference coefficient should be considered [1]:

\[ \sigma_h = \frac{S_{H_{\text{max}}} - S_{H_{\text{min}}}}{S_{H_{\text{min}}}} \]  

In the formula: \( \sigma_h \) — is the horizontal stress difference coefficient, dimensionless; \( S_{H_{\text{max}}} \) — is the minimum horizontal principal stress, MPa; \( S_{H_{\text{min}}} \) — is the maximum horizontal principal stress, MPa.

Laboratory physical model tests and numerical simulations confirm that the reservoir \( \sigma_h \) is <0.13, and the fracture network is directly formed via clear water fracturing; when 0.13<\( \sigma_h <0.25 \), the value \( \sigma_h \) needs to be reduced by process control to produce the fracture network.

According to the rock mechanics data of oil reservoir samples, the principal stress direction of Hailar Oilfield is 65°-85°, the maximum horizontal principal stress is 24.4MPa-48.0MPa, the average is 37.2MPa, and the minimum horizontal principal stress is 20.7MPa-42.2MPa, the average is 32.5MPa. After calculation, the stress difference coefficient is 0.12-0.19, the average is 0.15, and some blocks require technique control to form the conditions of fracture network.

2.3. Analysis of influencing factors of fracturing effect

2.3.1. Implementation condition and production increase effect. According to the actual geological parameters of the fracturing reservoir, the fracturing construction aims at the best dimensionless oil production index and the engineering matching the formation sand body, the design method of "propping agent optimization" is applied, and 0.425-0.85mm/52MPa ceramsite and coated sand constitute propping agent, concentration of propping agent is 40%-20%, fiber use concentration is 0.3-1.4%, single layer is 52MPa, ceramsite upper limit is 130m³, coated sand is used for the part that exceeds the sand amount, pad fluid use emulsion, sand-carrying fluid uses guanidine gum fracturing fluid, adopt what can meet the needs of high pressure, long time and large amount of sand construction, the maximum
compression of the pipe column is 100MPa, the fracturing pipe column whose sand amount is more than 200m³. The fracture volume is optimized and transformed, fracture extension feature under different fracture net pressure conditions are simulated and analyzed, and the construction time is determined to be 5-10min.

According to the above fracturing technology, the Hailar Oilfield selects 78 oil wells in the developed areas of different fault blocks to carry out large-scale re-fracturing, which has achieved a good oil increase effect.

(1) The transformation scale of large-scale fracturing is several times that of conventional fracturing

The large-scale fracturing effect is significant, the swept volume increases, and the capacity increases. The monitoring showed that: the fracturing well forms 3-4 branch fractures, the fracture length is 271-399m, and the fracture width is 80-101m. The average construction fluid volume is 1704m³; the average construction sand volume is 115m³, the construction fluid volume is 6.8 times that of the initial fracturing, the construction sand volume is 2.9 times that of the initial fracturing, the fracture length is increased by 2.5 times, and the swept volume is increased by 3 to 5 times.

(2) Large-scale fracturing can greatly increase the capacity of oil wells, and the staged oil increase effect is significant

The average daily oil production before fracturing is 0.86t, the initial daily oil production after the average fracturing is 3.82t, the average annual oil increase of a single well is 645t, and the cumulative oil production is 8.60×10⁴t. The profit and loss even point of accumulative oil increase of a single well is determined by pressing the fracturing cost, there are 58 wells with economic benefits, and the proportion is 74.3% (Table.1).

Table 1. Capacity comparison of large-scale fracturing wells before and after fracturing

| reservoir classification | number of fracturing wells | number of wells with economic benefits | fracturing fluids (m³) | amount of sand increase (m³) | effective fracturing thickness (m) | daily oil production before fracturing (t) | daily oil production after fracturing (t) | annual production increase of single well (t) |
|--------------------------|---------------------------|---------------------------------------|------------------------|-------------------------------|-------------------------------------|----------------------------------------|------------------------------------------|--------------------------------------------|
| thick sandstone with medium permeability | 12 | 10 | 1917 | 75.4 | 15.2 | 0.72 | 4.20 | 757 |
| thick sandstone with ultra-low permeability | 26 | 23 | 1702 | 136 | 16.5 | 0.86 | 4.17 | 779 |
| thick sandstone with ultra-low permeability | 40 | 25 | 1643 | 114 | 14.5 | 1.01 | 3.10 | 402 |
| average/total | 78 | 58 | 1754 | 108 | 15.4 | 0.86 | 3.82 | 645 |

(3) The use condition of the oil layer is significantly improved after large-scale fracturing

According to the graded statistics of the fluid production section of 25 large-scale fracturing wells, compared to conventional fracturing, the effective thickness use ratio of oil layers less than 0.5m, 0.5-1.0m, 1.0-2.0m, and greater than 2m is increased by 15%, 22%, 22% and 30%, respectively, increase by 32% average.

(4) The water absorption of water injection wells is improved after large-scale fracturing, and the water injection volume of water wells increases

Large-scale fracturing improved the seepage conditions in the near-well zone of the oil well, shortened the spacing among injection-production wells in disguised form, and can establish effective displacement by enhancing water injection in some well zones. According to statistics of 33 water injection wells in a large-scale fracturing well group, the daily water injection volume of a single well
increased from 12.0 m$^3$ before fracturing to 31 m$^3$ after fracturing, and the cumulative injection increased by 47.14×10$^4$ m$^3$.

**Table 2. Comparison of injection increase of large-scale fracturing wells**

| Fracturing batch | Number of wells | Injection pressure before fracturing (MPa) | Daily water injection before fracturing (m$^3$/d) | Injection pressure after fracturing (MPa) | Daily water injection after fracturing (m$^3$/d) | Cumulative injection increase (10$^4$m$^3$) |
|------------------|-----------------|-------------------------------------------|-----------------------------------------------|-------------------------------------------|-----------------------------------------------|------------------------------------------|
| the first batch  | 6               | 16.3                                      | 44                                            | 18.1                                      | 220                                           | 15.92                                    |
| the second batch | 5               | 15.8                                      | 158                                           | 21.1                                      | 216                                           | 13.33                                    |
| the third batch  | 6               | 23.5                                      | 35                                            | 18.9                                      | 184                                           | 12.94                                    |
| the fourth batch | 6               | 17                                        | 16                                            | 27.6                                      | 103                                           | 2.68                                     |
| the fifth batch  | 10              | 19.1                                      | 142                                           | 19.6                                      | 297                                           | 2.27                                     |
| Total            | 33              | 18.5                                      | 395                                           | 20.9                                      | 1020                                          | 47.14                                   |

2.3.2. **Analysis of influencing factors of fracturing effect.** The factors that affect the development effect of large-scale fracturing wells include the development condition of the reservoir, the distribution of fluid in the reservoir, the maintenance degree of formation pressure, the water injection condition and the fracturing technique.

1. The impact of fracturing measure scale
   As the amount of sand increase, the strength of sand increase and fluid increase, the oil increase has the increase tendency (Fig.1, Fig.2).

2. Influence of reservoir development condition
   According to statistics of fracturing well data, as the formation coefficient ($K_h$) increases, the daily oil production tends to increase, and the correlation increases as time extends; the higher the oil saturation and porosity, the higher the daily oil production after fracturing (Fig.3, Fig.4, Fig.5).

3. Well-control reserves in the fracturing layer
   According to statistics data of 78 fracturing wells, as the single well control reserve in the fracturing layer increases, there is an increasing trend of oil increase, the initial correlation is poor, and the correlation increases as time extends (Fig.6).

4. Maintenance condition of formation pressure
   The maintenance condition of formation pressure has a significant impact on the oil increase after fracturing, the Beizhongxi X1 well area is affected by the physical properties of the reservoir, it is difficult to inject water in well, it is difficult to establish effective displacement among injection-production wells, the cumulative injection-production ratio is 0.39, the formation shortfall reaches 3.34×10$^4$m$^3$, and the maintenance level of formation energy is low. There are seven large-scale fracturing wells on this well area, and the annual oil increase of the five fracturing wells is 0-463t, the average is 228t. Two new infilling oil wells located at the edge increases by 837-1008t oil production, the average oil increase is 923t, and the oil increase effect is significantly better than that of fracturing oil wells inside the well pattern.

![Fig. 1](image.png) the relationship between fracturing sand increase amount and capacity
Fig. 2 the relationship between fracturing fluid increase amount and capacity

Fig. 3 the relationship between formation coefficient and capacity

Fig. 4 the relationship between oil saturation and capacity
3. Research on Capacity Forecast Means

3.1. Theoretical formula means

According to the actual situation of Hailar Oilfield, considering that there is certain fracturing ratio in the oil layer, the pseudo-steady flow formula is adopted; establish a prediction model for the oil increase of large-scale repeated fracturing wells: the forecast model of oil increase in large-scale repeated fracturing wells is established:

(1) Fluid capacity of conventional production at the initial stage

Fluid capacity of conventional fracturing layer at the initial stage:

\[ Q_{uf} = \frac{2\pi K_1 H_1 \Delta P}{\mu \ln \frac{2R_e}{X_1}} \]

Fluid capacity of un-fracturing layer at the initial stage:

\[ Q_{nf} = \frac{2\pi K_2 H_2 \Delta P}{\mu \ln \frac{R_e}{r_w}} \]

Fluid capacity of the oil well of conventional production at the initial stage:

\[ Q_{ut} = Q_{uf} + Q_{nf} \]

(2) Fluid capacity of large-scale fracturing at the initial stage

Fluid capacity of remaining conventional fracturing after large-scale fracturing:

\[ Q_{raf} = \frac{2\pi K_2 (H_1 - H_d) \Delta P'}{\mu \ln \frac{2R_e}{X_1}} \]

Fluid capacity of remaining un-fracturing layer after large-scale fracturing:
\[ Q_{\text{rf}} = \frac{2\pi K_2 (H_2 - H_d') \Delta P'}{\mu \ln \frac{R_e}{r_w}} \]

Fluid capacity of the large-scale fracturing part:

\[ Q_{\text{mf}} = \frac{2\pi K_3 (H_d + H_d' + H_3) \Delta P'}{\mu \ln \frac{2R_e}{x_d}} \]

Total fluid capacity after large-scale fracturing:

\[ Q_{\text{mf}} = Q_{\text{rf}} + Q_{\text{rf}} + Q_{\text{mf}} \]

Increase in production multiple of large-scale fracturing:

\[ c = \frac{Q_{\text{mf}}}{Q_{\text{ut}}} = \frac{\ln \frac{R_e}{r_w} + \frac{K_1 H_1}{\ln \frac{R_e}{r_w}} + \frac{K_2 H_2}{\ln \frac{R_e}{r_w}}}{\ln \frac{R_e}{x_1}} \Delta P' \]

Initial oil capacity after large-scale fracturing:

\[ Q_{\text{mf}} = cQ_{\text{ut}} \cdot \omega \]

After verified by 5 large-scale fracturing wells, the error between the theoretical calculation value of the initial oil capacity and the actual production after large-scale fracturing is small; it is less than 25% (Table.3).

| Table.3 comparison statistics table of theoretical forecast and actual capacity of oil well production after large-scale fracturing at the initial stage |
|---|---|---|---|---|---|---|---|---|
| well number | conventional fracturing | | | large-scale fracturing | | | | |
| thickness (m) | permeability (mD) | fracture length (m) | fracture width (m) | capacity (t/d) | thickness (m) | permeability (mD) | fracture length (m) | fracture width (m) | capacity (t/d) | forecast capacity (t/d) | error (%) |
| Bei28-X58-54 | 30.9 | 0.45 | 170 | 70 | 10.7 | 23.1 | 0.46 | 420 | 90 | 7.4 | 7.4 | -0.41 |
| Bei28-X58-56 | 16.8 | 0.66 | 140 | 70 | 17.6 | 19.1 | 0.63 | 350 | 90 | 7.9 | 6.8 | 13.92 |
| Bei28-X62-54 | 27.6 | 3.04 | 150 | 101 | 28 | 27.2 | 3.04 | 277 | 101 | 4.7 | 4.2 | 9.15 |
| Bei28-X62-58 | 36.3 | 8.87 | 170 | 87 | 8.2 | 15.7 | 8.7 | 399 | 97 | 8.5 | 10.6 | -24.71 |
| Bei28-X62-60 | 23.9 | 0.78 | 160 | 70 | 9.3 | 23.9 | 0.78 | 370 | 90 | 10 | 10.2 | -2.2 |

3.2. Multiple linear regression formula method

Considering that in large-scale fracturing, the fracture length and width of fracturing are generally monitored by micro-seismic method, which is costly, and it is impossible to monitor every well, many parameters cannot be obtained by theoretical formula method, and the application of formula is limited. Therefore, on the basis of the fracturing data of 78 wells with a long development time, the multiple linear regression method is used for forecast. In order to ensure the independence of regression parameters, effective fracturing thickness, fracturing sandstone thickness, permeability, crude oil viscosity, oil saturation, fluid increase strength, and sand increase strength, a total of 8 parameters are selected for fitting (Fig.7).

Multiple linear regression formula of large-scale fracturing capacity:

\[ Q_{\text{mf}} = 0.0319 \frac{kh}{\mu} + 3.6711s_o + 0.0070 \frac{v_l}{h_s} + 0.1478 \frac{v_t}{h_s} \]

According to the regression formula, the large-scale fracturing capacity of 13 wells in the Ta 19 block is calculated and compared (Table 4), compared to the capacity in stable period after fracturing, the calculation value of the multiple linear regression formula method is relatively close, the capacity of 13
wells in actual stable period is 7.8t average, and the formula forecasts 8.5t, the error is small, and it that the calculation result can be applied in the mine field.

**Table 4. Capacity forecast of 13 fracturing wells in Ta 19 block**

| order number | well number | sandstone thickness (m) | measure thickness (m) | Permeability (mD) | fluid increase volume (m³) | amount of sand increase (m³) | daily oil capacity(t) before fracturing | stable period after fracturing | regression formula value | error value (t) |
|--------------|-------------|-------------------------|-----------------------|-------------------|---------------------------|--------------------------|-----------------------------------|---------------------------|---------------------|-----------------|
| 1            | T19-267-t202| 62.4                    | 60                    | 9.3               | 4826                      | 194                      | 4.1                               | 17.0                      | 12.4                | 4.6             |
| 2            | T19-260-t204| 35.4                    | 34.9                  | 19.7              | 4413                      | 179                      | 1.6                               | 15.4                      | 15.3                | 0.2             |
| 3            | T19-264-t205| 20.4                    | 20.4                  | 9.1               | 2748                      | 130                      | 2.5                               | 8.5                       | 7.2                 | 1.4             |
| 4            | T19-261-t203| 25.2                    | 24.2                  | 15.0              | 4536                      | 220                      | 3.6                               | 9.0                       | 9.4                 | 0.4             |
| 5            | T19-344-t221| 15.1                    | 15.1                  | 11.0              | 2549                      | 130                      | 4.2                               | 6.8                       | 6.7                 | 0.1             |
| 6            | T19-352-t206| 9.6                     | 8.6                   | 35                | 1919                      | 90                       | 2.2                               | 5.9                       | 8.9                 | 3.0             |
| 7            | T19-337-t216| 20.0                    | 20.0                  | 9.7               | 2310                      | 110                      | 1.3                               | 4.3                       | 6.2                 | 1.9             |
| 8            | T19-270-t204| 34.3                    | 33                    | 4.8               | 2750                      | 130                      | 2.9                               | 3.3                       | 5.9                 | 2.6             |
| 9            | T19-235-t215| 40                      | 38.3                  | 11.0              | 2097                      | 130                      | 2.8                               | 5.1                       | 9.7                 | 4.6             |
| 10           | T19-259-t207| 30.9                    | 30.4                  | 5.3               | 2085                      | 130                      | 0.5                               | 4.2                       | 5.9                 | 1.7             |
| 11           | T19-346-t214| 14.7                    | 14.7                  | 20.0              | 1843                      | 80                       | 4.6                               | 6.4                       | 7.7                 | 1.3             |
| 12           | T19-263-t195| 31.3                    | 31.2                  | 5.5               | 2753                      | 130                      | 2.5                               | 4.2                       | 6.2                 | 2.0             |
| 13           | T19-261-t197| 26.4                    | 25.9                  | 13.3              | 1644                      | 90                       | 4.1                               | 11.6                      | 8.8                 | 2.8             |
| average      |             |                         |                       |                   |                           |                          |                                   |                           |                     |                 |

**Fig. 7** the fitting relationship curve between the capacity forecast by multiple linear regression and the actual capacity

4. **Conclusion**

(1) The difference coefficient of in-situ stress in Hailar Oilfield is small, which is suitable for large-scale fracturing.

(2) The overall development effect of large-scale fracturing in Hailar Oilfield is good, the main factors that affect the fracturing effect are the thickness ratio of a single layer greater than 2m in the fracturing section, the single well controlled reserves in the fracturing section, and the pressure maintenance condition of the formation before fracturing, and scale of fracturing measures.
(3) Established forecast model of oil increase of large-scale repeated fracturing wells via pseudo-steady flow formula, its calculation accuracy is high, but the practical application is limited by the less data of fracturing fracture detection.

(4) The multiple linear regression formula of large-scale fracturing capacity adopts fracturing parameters for regression fitting, there are few restricted factors, parameters are easy to obtain, calculation error is small, and it can be applied in mines.

Symbol note:

Theoretical formula method

\[ Q_{uf} \] – Daily fluid capacity of conventional fracturing layer at the initial stage, t/d;
\[ Q_{uf} \] – Daily fluid capacity of un-fracturing layer at the initial stage, t/d;
\[ Q_{uf} \] – Initial fluid capacity of conventional oil wells at the initial stage, t/d;
\[ Q_{uf} \] – The remaining conventional fracturing fluid capacity after large-scale fracturing, t/d;
\[ Q_{uf} \] – The remaining fluid capacity of un-fracturing layer after large-scale fracturing, t/d;
\[ Q_{mf} \] – Fluid capacity of the large-scale fracturing part, t/d;
\[ Q_{mf} \] – Total fluid capacity after large-scale fracturing, t/d;
\[ Q_{mf} \] – Oil capacity after large-scale fracturing at the initial stage, t/d;
\[ c \] – Increase in production multiple of large-scale fracturing;
\[ \omega \] – water content, %;
\[ N_{mf} \] – Total oil capacity after large-scale fracturing, t/d;
\[ K_1 \] – Air permeability of conventional fracturing section, mD;
\[ K_2 \] – Air permeability of un-fracturing section, mD;
\[ K_3 \] – Air permeability of large-scale fracturing section, mD;
\[ H_1 \] – Effective thickness of conventional fracturing section, m;
\[ H_2 \] – Effective thickness of un-fracturing section, m;
\[ H_3 \] – Effective thickness of newly-added large-scale fracturing section, m;
\[ H_d \] – Effective thickness of the second large-scale fracturing section in the original conventional fracturing section, m;
\[ H_d' \] – Effective thickness of the second large-scale fracturing section in the original un-fracturing section, m;
\[ X_1 \] – Converted well diameter of conventional fracturing section, m;
\[ X_2 \] – Converted well diameter of large-scale fracturing section, m;
\[ \Delta P \] – Production pressure difference, MPa;
\[ \mu \] – Viscosity of formation crude oil, mPa.s;
\[ r_e \] – Oil drainage radius, m;
\[ r_e' \] – Large-scale fracturing converted oil drainage radius, m;
\[ r_d \] – The diameter of the oil production well, mPa.s;
\[ D_i \] – Initial decrease rate, decimal

Multiple linear regression formula method

\[ Q_{mf} \] – Large-scale fracturing oil capacity, t/d;
\[ k \] – Air permeability of fracturing layer mD;
\[ h \] – Effective fracturing thickness, m;
\[ h_s \] – Fracturing sandstone thickness, m;
\[ s_o \] – Oil saturation, decimal;
\[ v_f \] – Fracturing fluid volume, m3;
\[ v_s \] – Amount of sand increase, m3.
5. References

[1] Zhang Li, Han Wenqiao. Application and Analysis of Network Fracturing Technique in Fuyu Reservoir [J]. Sino-Global Energy, 2015, 20(1): 57-60.

[2] Deng Xianwen. Research and Application of Network Fracturing Technology in Hailar Oilfield [J]. Petroleum Geology and Engineering, 2013, 27(6): 112-114.

[3] Cheng Shixing. Research and Application of Large-scale Long Fracturing Technology in Low Permeability Reservoirs [J]. Inner Mongolia Petrochemical Industry, 2011, (20): 116-117.

[4] Xie Chaoyang, Shang Litao, Tang Pengfei, et al. Research and Test of Large-Scale Inside-Seam Steering Fracturing Technique [J]. Petroleum Geology & Oilfield Development in Daqing, 2016, 35(2): 66-69.

[5] Han Lichun. Development Efficiency Analysis of Large-scale Fracturing Testing in Tight Reservoirs [J]. Special Oil & Gas Reservoirs, 2017, 24(4): 112-116.

[6] Fan Wengang, Liu Qinghua, Hailar Oilfield Tight Oil Development Test [J]. Sino-Global Energy, 2016, 21(5): 54-57.

[7] Wang Hongwei. Application of Integrated Large-Scale Fracturing and Water Flooding Development Technology in Extra Low Permeability Oil Reservoirs [J]. Oil Drilling & Production Technology, 2018, 40(1): 102-106.

[8] Jiang Hongfu, Wang Yunzeng, Liu Qiuhong, et al. Application Of The Large-Scale Fracturing Technique In Extra-Low Permeability Reservoir Development [J]. Petroleum Geology & Oilfield Development in Daqing, 2016, 35(2): 70-74.

[9] Zhao Jingzhe, Li Shuheng, Qu Xuefeng, etc. Fracturing Technique Of Super-Low Permeability Reservoir Development [J]. Petroleum Exploration and Development, 2005, 26(5): 93-95.

[10] Li Yongming, Zhao Jinzhou, Yue Yingchun, et al. Research And Application Of Systematic Fracturing Technology Of Oil Reservoir In Block G43 [J], Fault-Block Oil and Gas Field, 2010, 17(5): 611-613.

[11] Weng Dingwei, Lei Qun, Xu Yun, et al. Network Fracturing Techniques And Its Application In The Field [J]. Acta Petrolei Sinica, 2011, 32(2): 280-284.

[12] Li Feng. Pre-fracturing Forecast and Post-fracturing Evaluation Technology [J]. Computer Applications of Petroleum, 2012, 76(4): 35-38.