Evaluation of reservoir reconstruction of horizontal well in the eastern southern area of Sulige gas field

Gang Huang 1, Ligang Lv 1, Runhua Zhu 2,*, Maoguo Liu1, Jing Ye1 and Yuanchao Wen1

1Geology Research Institute of No.1 Gas Production Plant, Changqing Oilfield Company China
2College of energy, Chengdu University of science and technology, Chengdu, Sichuan China

*Corresponding author e-mail: zhurunhua@stu.cdut.edu.cn

Abstract. In recent years, hydraulic jetting technology and pumping bridge plug technology have been used in horizontal good development in southeastern sulige Gas Field to improve single good production[1]. In order to maintain the sustainable development of oil and gas fields and effectively guide the follow-up reconstruction work, it is necessary to evaluate the economic benefits of the two technology reconstruction horizontal Wells, analyze the influencing factors of economic benefits and define the main controlling factors that affect the economic benefits[2~3]. In the process of oil and gas field development, to optimize the evaluation of the effect of two stimulation measures, to guide the reservoir improvement proposals and capital investment, to avoid the measures of poor efficiency.

1. Preface
The pumping bridge plug retrofitting technology in the southeastern sulige gas field has a good gas well test effect and obvious advantages in late production management, but its single well completion and fracturing construction cost are high[4]. To optimize the production, development, and retrofitting suggestions of gas fields in the southeastern sulige gas field, an economic benefit evaluation is carried out. Therefore, the reconstruction of pumping bridge plug Wells and water injection Wells and production effect between the differences between the situation, and make use of the site construction key data from drilling completion (casing, cementing), try gas fracturing (segmentation tools, transformation, construction section number displacement, the fracturing fluid, and proppant, etc.), environmental protection, subsequent cleanup measures put into production, etc. Systematic analysis of the combined costs of the two Wells. At the same time, according to the field construction parameters, the good groups of different fracturing construction technology types were selected respectively, the horizontal section length, number of fracturing stages, liquid volume in a single section, and sand volume in a single section were calculated, and combined with the net present value and internal rate of return two benefit evaluation methods, the optimal economic program was analyzed, and the economic benefit evaluation indexes of the two processes were defined. In the process of oil and gas field development, the combination of production dynamic analysis and economic benefit evaluation can provide accurate reconstruction suggestions for subsequent improvement of oil and gas field
development effect and optimization of the production management system, which can reduce the economic loss of oil and gas field development in the past and improve the economic efficiency[5–8].

2. Formation of reservoir reconstruction cost of horizontal well in southeastern sulige gas field

Pumping bridge plug and comprehensive cost of hydraulic jet fracturing two processes mainly include drilling, cementing, logging, real-time data remote transmission technology service (drilling, logging engineering), logging engineering technology (midway and completion logging, cementing quality detecting logging), test gas fracturing project technical service cost (fracturing scale: Number of fracturing stages, the quantity of proppant, quantity of fracturing fluid, the quantity of liquid nitrogen; Gas test engineering, fracturing engineering).

The construction costs of the two renovation processes are shown in the table:

| classification       | The drilling depth (m) | Horizontal length (m) | Drilling footage (yuan) | Casing (yuan) | The cementing (yuan) | Test log (yuan) | Remote transmission (yuan) | Combined |
|----------------------|------------------------|-----------------------|-------------------------|---------------|----------------------|----------------|-----------------------------|----------|
| Pumping bridge plug  | 4681.8                 | 1409                  | 6958000                 | 1700300       | 666300               | 873000         | 31400                       | 10229000 |
| Hydraulic jet        | 4585.4                 | 1284                  | 6695000                 | 1313000       | 519300               | 867000         | 30700                       | 9425000  |
| Combined             | 96.4                   | 125.3                 | 263000                  | 387500        | 147000               | 6000           | 700                         | 804000   |

Table 2. Technical service cost of gas test fracturing engineering

| classification       | Section number | Construction of displacement | Construction of fluid volume (m³) | Amount of sand (m³) | Test gas (yuan) | Fracturing (yuan) | For (yuan) | Tool (yuan) | Ceramicsite and chemical materials (yuan) | Combined |
|----------------------|----------------|-----------------------------|----------------------------------|---------------------|----------------|------------------|------------|-------------|------------------------------------------|----------|
| Pumping bridge plug  | 8.7            | 6.0-10.0                    | 4780.4                           | 447.2               | 1510000        | 2160000          | 631000     | 796000      | 2979000                                  | 8076000  |
| Hydraulic jet        | 6.4            | 2.4-3.0                     | 3448.4                           | 258.3               | 1360000        | 1790000          | /          | 714000      | 1596000                                  | 5460000  |
| Combined             | 2.3            | 3.6-7.0                     | 1332                             | 188.9               | 1500000        | 3700000          | 631000     | 820000      | 1383000                                  | 2616000  |

The drilling and completion costs and gas test fracturing costs of hydraulic jet staged fracturing and pumping bridge plug staged fracturing are calculated respectively. The pre-drilling costs of the two retrofit processes include website engineering, rig foundation, blowout pipeline, mud pool excavation, and pre-drilling road. Drilling costs are mainly calculated based on completion depth, well-depth structure, and unit price per meter of horizontal section length. Casing and cementing costs mainly include four costs of vertical section, horizontal section, horizontal section accessories, and casing. According to site construction conditions, pumping bridge plug Wells are calculated based on completion depth of 4681.8m and horizontal section length of 1409m. The total cost of drilling and completion is 10,229,000 yuan. The total cost of drilling and completion of hydraulic injection well is 9,425,000 yuan, calculated according to the complete depth of 4,855.4m and horizontal section length of 1,844m.

Try gas fracturing mainly include section number, segmentation tools, proppant, fracturing fluid, liquid nitrogen, fracturing engineering, and testing engineering cost in seven aspects, because the two kinds of difference of construction technology of segmentation tools cost, therefore, according to the site construction conditions, according to the fracturing pumping bridge plug well condition to calculate
the number of 8.7 paragraphs, Calculated according to the number of fracturing stages of the hydraulic jet well is 6.4 stages, the total cost of hydraulic sandblasting gas test fracturing is 5.46 million yuan, and the cost of bridge plug stage test fracturing is 8.076 million yuan. The input cost of subsequent production aid drainage measures (tubing and pressure operation, design and supervision costs) and environmental protection costs are 1.2 million yuan and 1.26 million yuan respectively.

In summary, under the same well-depth structure, drilling completion depth, horizontal section length, and the number of stages, the construction cost of pumping bridge plug staged fracturing is slightly higher than that of hydraulic jet staged fracturing, which is about 3.42 million yuan higher.

3. The general model of benefit evaluation
Benefit evaluation of different development schemes of horizontal Wells in the southeastern sulige gas field is mainly based on the following documents to determine the composition of the evaluation model and parameter selection. (1) "before drilling engineering technology service cost indicators (2) the technical service of drilling engineering cost indicators (3) the cementing engineering service cost indicators (5) the logging project technical service cost indicators (6) the real-time data remote transmission service cost indicators (7) the logging project technical service cost indicators (8) the test gas fracturing engineering and technical services Cost index

The net present value (NPV) and internal rate of return (IRR) are used in the benefit evaluation of this project.

3.1. NPV
NPV can be calculated according to the following formula:

$$NPV = \sum_{t=1}^{n} \left( C_I - C_O \right) \left( 1 + i_c \right)^{-t}$$

Type in the NPV = \sum_{t=1}^{n} \left( C_I - C_O \right) \left( 1 + i_c \right)^{-t}:

$C_I$—Annual cash inflow, yuan

$C_O$—Annual cash outflow, yuan

$N$—The evaluation of, year

$i_c$—Industry benchmark yield or discount rate

3.2. IRR
IRR can be calculated by the following formula:

$$\sum_{t=1}^{n} \left( C_I - C_O \right) \left( 1 + IRR \right)^{-t} = 0$$

IRR refers to the discount rate when NPV=0 during the evaluation period, which reflects the yield level that can be achieved by the investment project itself.

It should be pointed out that both NPV and IRR can be used as the criteria of whether the project is viable or not, as well as the benchmark rate of return of NPV> or IRR>. However, the larger the NPV is, the better the scheme will be when there is no restriction of investment capital. However, IRR cannot be used as a condition for scheme comparison, that is, a scheme with a larger IRR is not necessarily better.

4. Analysis of benefit evaluation results

4.1. Evaluation of the economic benefit of horizontal section length
According to the fitting chart of horizontal section length with proppant dosage and liquid dosage (see Figures 1 and 2), it can be seen that; The longer the lateral section, the greater the proppant and fluid usage, and the higher the cost. As can be seen from the mathematical model results, the longer the horizontal section length is, the higher the gas production is and the higher the profit is.
To select the optimal length of the horizontal section from the perspective of economic benefit, we constructed five alternative schemes according to the numerical model results, with horizontal section lengths of 1000m, 1100m, 1200m, 1300m, and 1400m respectively. Set the horizontal segment length as $D$ (m), and the relevant parameters of each scheme are set in the following table.

| Parameter | Parameter selection |
|-----------|---------------------|
| $L_1$ (m) | 1000 | 1100 | 1200 | 1300 | 1400 |
| $D$ (Period) | 7 | 7 | 7 | 7 | 7 |
| $G_1$ ($m^3$) | 49.065×$D$-6.3308 (Determine according to the fitting chart) |
| $K_1$ (yuan/m$^3$) | 138 | 138 | 138 | 138 | 138 |
| $G_2$ ($m^3$) | 599.57×$D$-769.28 (Determine according to the fitting chart) |
| $K_2$ (yuan/m$^3$) | 225 | 225 | 225 | 225 | 225 |
| $K_3$ (yuan/Period) | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| The rest of the parameters | same | same | same | same | same |

By putting the parameters of different schemes into Equations (1) to (2), the economic benefit indexes of schemes with different horizontal section lengths can be obtained, as shown in Tables 4 to 5. It can be seen from the table that with the increase of horizontal segment length, NPV presents an increase-decrease trend. It can be seen from the benefit evaluation that when the horizontal section length of the pumping bridge plug well is 1400m, the economic benefit of the scheme is the best. When the horizontal section length of the hydraulic injection well is 1200m, the economic benefit of the scheme is the best.
### Table 4. Economic benefit index of different horizontal section length schemes (Pumping bridge plug well)

| Case serial number | Horizontal length (m) | NPV (yuan) | IRR  |
|--------------------|-----------------------|------------|------|
| Case 1             | 800                   | 4567494    | 0.1356 |
| Case 2             | 1000                  | 4837175    | 0.1365 |
| Case 3             | 1200                  | 4911181    | 0.1372 |
| Case 4             | 1400                  | 4931000    | 0.1378 |
| Case 5             | 1600                  | 4840025    | 0.1368 |

### Table 5. Economic benefit index of different horizontal section length schemes (Hydrojet well)

| Case serial number | Horizontal length (m) | NPV (yuan) | IRR  |
|--------------------|-----------------------|------------|------|
| Case 1             | 800                   | 2852080    | 0.0928 |
| Case 2             | 1000                  | 3374268    | 0.1039 |
| Case 3             | 1200                  | 3558991    | 0.1108 |
| Case 4             | 1400                  | 3334954    | 0.1036 |
| Case 5             | 1600                  | 3010493    | 0.0983 |

According to the NPV calculation results of different schemes, the relation diagram of horizontal segment length and corresponding NPV is drawn, as shown in Figure 3 and Figure 4. It can be seen from the figure that the NPV of the pumped bridge plug well is the highest when the horizontal section length is 1400m. The NPV of the hydraulic injection well is the largest when the horizontal section length is 1200m.

![Figure 3. Diagram of NPV variation with a horizontal length (Pumping bridge plug well)](image)

![Figure 4. Diagram of NPV variation with a horizontal length (Hydrojet well)](image)

### 4.2. Economic benefit evaluation of fracture stage number

According to the fitting chart of the number of fracturing stages with the amount of proppant and liquid (see Figures 5 and 6), it can be seen that the number of fracturing stages is the same as the amount of proppant and liquid. The more stages you have, the more proppant and fluid you need, and the higher
the cost. As can be seen from the numerical model results, the more fracturing stages, the higher the gas production and the higher the profit.

\[ y = 49.065x - 6.3308 \]

\[ y = 599.57x - 769.28 \]

**Figure 5.** Fitting chart of fracture stages and proppant dosage

**Figure 6.** Fitting chart of fracture stages and fluid consumption

To select the optimal number of fracturing stages from the perspective of economic benefits, we constructed five alternative schemes based on the numerical model results, with the number of fracturing stages being 6 stages, 7 stages, 8 stages, 9 stages, and 10 stages respectively. Set the number of segments as \( D \) (segment), and set relevant parameters of each scheme as shown in the table below.

**Table 6.** Parameter determination of different fracturing stage schemes

| parameter          | Case 1   | Case 2   | Case 3   | Case 4   | Case 5   |
|--------------------|----------|----------|----------|----------|----------|
| \( L \) (m)        | 1500     | 1500     | 1500     | 1500     | 1500     |
| \( D \) (Period)   | 6        | 7        | 8        | 9        | 10       |
| \( G_1 \) (m\(^3\)) | 49.065\(D\) - 6.3308 (Determine according to the fitting chart) |
| \( K_1 \) (yuan/m\(^3\)) | 138      | 138      | 138      | 138      | 138      |
| \( G_2 \) (m\(^3\)) | 599.57\(D\) - 769.28 (Determine according to the fitting chart) |
| \( K_2 \) (yuan/m\(^3\)) | 225      | 225      | 225      | 225      | 225      |
| \( K_3 \) (yuan/Period) | 7.5      | 7.5      | 7.5      | 7.5      | 7.5      |
| The rest of the parameters | same    | same    | same    | same    | same    |

By putting the parameters of different schemes into Equations (1) to (2), the economic benefit indexes of different fracturing stage schemes can be obtained, as shown in Table 7 to Table 8. It can be seen from the table that with the increase of the number of fracturing stages, NPV presents an increase-decrease trend. It can be seen from the benefit evaluation that the economic benefit of the scheme is the best when the number of fracturing stages is 8 for the pumping plug well, and the economic benefit of the scheme is the best when the number of fracturing stages is 7 for the hydraulic injection well.
Table 7. Economic benefit index of different fracturing stage schemes (Pumping bridge plug well)

| Case  | Fracturing section number | NPV (yuan) | IRR  |
|-------|--------------------------|------------|------|
| Case 1| 6                        | 4843827    | 0.1319 |
| Case 2| 7                        | 4911181    | 0.1372 |
| Case 3| 8                        | 5120938    | 0.1458 |
| Case 4| 9                        | 5066446    | 0.1422 |
| Case 5| 10                       | 4922219    | 0.1447 |

Table 8. Economic benefit index of different fracturing stage schemes (Hydrojet well)

| Case  | Fracturing section number | NPV (yuan) | IRR  |
|-------|--------------------------|------------|------|
| Case 1| 6                        | 3055933    | 0.0949 |
| Case 2| 7                        | 3558991    | 0.1108 |
| Case 3| 8                        | 3389862    | 0.1006 |
| Case 4| 9                        | 3223997    | 0.1002 |
| Case 5| 10                       | 3031582    | 0.0978 |

According to the NPV calculation results of different schemes, the relationship diagram of horizontal segment length and corresponding NPV is drawn, as shown in Figure 7 and Figure 8. It can be seen from the figure that the NPV of the pumped plug well is the highest when the number of fracturing stages is 8. The NPV of a hydraulic injection well is the largest when the number of fracturing stages is 7.

4.3. Economic benefit evaluation of single-stage liquid volume

The amount of fracturing fluid directly affects the fracture conductivity, fracture length, and other construction parameters, and the higher the amount of proppant and fluid, the higher the cost. As can be seen from the numerical model results, the more fracturing stages, the stronger the conductivity, the more fracturing fluid used, the higher gas production, and the higher the profit.

To select the optimal single-stage liquid volume from the perspective of economic benefit, we constructed five alternative schemes according to the numerical model results, with the single-stage...
liquid volume being 600m$^3$, 700m$^3$, 800m$^3$, 900m$^3$, and 1000m$^3$ respectively. Set the number of segments as D (segment), and set relevant parameters of each scheme as shown in the table below.

**Table 9. Parameter determination of different single-stage liquid volume schemes**

| parameter                          | Parameter selection |
|------------------------------------|---------------------|
| $L_1$ (m$^3$)                      | 600 | 700 | 800 | 900 | 1000 |
| Theory of fractures (m)            | 130 | 150 | 160 | 170 | 180 |
| D (Period)                         | 7   | 7   | 7   | 7   | 7   |
| $K_1$ (yuan/m$^3$)                 | 138 | 138 | 138 | 138 | 138 |
| $K_2$ (yuan/m$^3$)                 | 225 | 225 | 225 | 225 | 225 |
| $K_3$ (yuan/Period)                | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| The rest of the parameters         | same | same | same | same | same |

By putting the parameters of different schemes into Equations (1) to (2), the economic benefit indexes of different single-stage liquid volume schemes can be obtained, as shown in Tables 10 to 11. It can be seen from the table that with the increase of liquid amount, NPV presents an increase-decrease trend. It can be seen from the benefit evaluation that the economic benefit of the scheme is the best when the single section fluid volume of the pumping bridge plug well is 700m$^3$, and the economic benefit of the scheme is the best when the single section fluid volume of the hydraulic injection well is 900m$^3$.

**Table 10. Economic Performance Indicators for Different Single Stage Flow Schemes (Pumped Bridge-Plug Wells)**

| Case  | The serial number | A single period of fluid volume | NPV (yuan) | IRR |
|-------|-------------------|---------------------------------|------------|-----|
| Case 1| 1                  | 600                             | 4693445    | 0.1352 |
| Case 2| 2                  | 700                             | 5368081    | 0.1437 |
| Case 3| 3                  | 800                             | 5056232    | 0.1385 |
| Case 4| 4                  | 900                             | 4856029    | 0.1379 |
| Case 5| 5                  | 1000                            | 4733256    | 0.1355 |

**Table 11. Economic Performance Indicators for Different Single Stage Flow Schemes (Hydrojet well)**

| Case  | The serial number | A single period of fluid volume | NPV (yuan) | IRR |
|-------|-------------------|---------------------------------|------------|-----|
| Case 1| 1                  | 600                             | 3154532    | 0.0974 |
| Case 2| 2                  | 700                             | 3397893    | 0.1008 |
| Case 3| 3                  | 800                             | 3551664    | 0.1096 |
| Case 4| 4                  | 900                             | 3629475    | 0.1122 |
| Case 5| 5                  | 1000                            | 3571094    | 0.1101 |

According to the NPV calculation results of different schemes, the diagram of the relationship between the liquid volume of a single stage and the corresponding NPV is drawn, as shown in Figures
9~10. It can be seen from the figure that the NPV of the pumped bridge plug well is the highest when the single section fluid volume is 700m$^3$. The NPV of a hydraulic injection well is the largest when the single fluid volume is 900m$^3$.

**Figure 9.** Diagram of NPV as a function of fluid flow in a single-stage (Pumping bridge plug well)

**Figure 10.** Diagram of NPV as a function of fluid flow in a single-stage (Hydrojet well)

4.4. Economic benefit evaluation of single section sand quantity

The amount of proppant directly affects the fracture conductivity, cluster number, fracture length, and other construction parameters. The greater the amount of sand and fluid used, the higher the cost. According to the model results, the more stages, the better the conductivity, the more proppant used, the higher the gas production, and the higher the profit.

To select the optimal single section sand amount from the perspective of economic benefit, we constructed five alternative schemes according to the numerical model results, with the single section sand amount being 50m$^3$, 55m$^3$, 60m$^3$, 65m$^3$, and 70m$^3$ respectively. Set the number of segments as D (segment), and set relevant parameters of each scheme as shown in the table below.

| Parameter                     | Parameter selection |
|-------------------------------|---------------------|
| Case 1                        | Case 2              | Case 3          | Case 4          | Case 5          |
| Single period of sand content (m$^3$) | 50                  | 55              | 60              | 65              | 70              |
| Theoretical conductivity (mD·m) | 380                 | 410             | 430             | 450             | 460             |
| $D$ (Period)          | 7                   | 7               | 7               | 7               | 7               |
| $K_1$ (yuan/m$^3$)  | 138                 | 138             | 138             | 138             | 138             |
| $K_2$ (yuan/m$^3$)  | 225                 | 225             | 225             | 225             | 225             |
| $K_3$ (yuan/Period) | 75000               | 75000           | 75000           | 75000           | 75000           |
| The rest of the parameters | same                | same            | same            | same            | same            |
By putting the parameters of different schemes into Equations (2-1) to (2-2), the economic benefit indexes of different single-section sand capacity schemes can be obtained, as shown in Tables 13 to 14. It can be seen from the table that with the increase of sand content in a single section, NPV presents an increase-decrease trend. It can be seen from the benefit evaluation that the economic benefit of the scheme is the best when the single section sand amount of the pumping bridge plug well is 55m³, and the economic benefit of the scheme is the best when the single section sand amount of the hydraulic injection well is 65m³.

Table 13. Economic benefit index of different single section sand yield schemes (Pumping bridge plug well)

| Case   | A single period of sand content | NPV (yuan) | IRR  |
|--------|--------------------------------|------------|------|
| Case 1 | 50                             | 4793445    | 0.1382|
| Case 2 | 55                             | 5068081    | 0.1391|
| Case 3 | 60                             | 4836232    | 0.1371|
| Case 4 | 65                             | 4706029    | 0.1339|
| Case 5 | 70                             | 4670696    | 0.1327|

Table 14. Economic benefit index of different single section sand yield schemes (Hydrojet well)

| Case   | A single period of sand content | NPV (yuan) | IRR  |
|--------|--------------------------------|------------|------|
| Case 1 | 50                             | 3175642    | 0.0994|
| Case 2 | 55                             | 3366726    | 0.1007|
| Case 3 | 60                             | 3667224    | 0.1127|
| Case 4 | 65                             | 3717685    | 0.1133|
| Case 5 | 70                             | 3291603    | 0.1004|

According to the NPV calculation results of different schemes, the relation chart of single section sand quantity and corresponding NPV is drawn, as shown in Figures 11 to 12. It can be seen from the figure that the NPV of the pumped bridge plug well is the highest when the single section sand content is 55m³. The NPV of the hydraulic injection well is the highest when the single section sand content is 65m³.

Figure 11. NPV as a function of sand yield in a single section (Pumping bridge plug well)

Figure 12. NPV as a function of sand yield in a single section (Hydrojet well)
5. Conclusion

(1) When the NPV change diagram reaches the maximum value, the corresponding scheme has the best economic benefit.

(2) Analysis of comprehensive mathematical model results: the longer the length of the horizontal section, the higher the gas production, the higher the income; The more stages, the higher the gas production, the higher the benefit; The more stages you have, the more conductivity you have, the more fluid and proppant you use, and the more gas you produce, the better your return.

(3) According to the economic benefit index and the NPV calculation results of different schemes, it can be concluded that the scheme with the horizontal section length of 1400m for the pumping bridge plug well and 1200m for the hydraulic injection well has the best economic benefit. The optimal economic benefits are obtained when the number of fracturing stages is 8 for the pumping plug well and 7 for the hydraulic injection well. The economic benefit of the scheme is the best when the single section fluid volume of the pumping bridge plug well is 700m³ and the single section fluid volume of the hydraulic injection well is 900m³. The economic benefits of the scheme are the best when the single-section sand volume is 55m³ for the pumping plug well and 65m³ for the hydraulic injection well.

Acknowledgments
The authors are grateful to the referee for her or his careful reading of the manuscript and helpful suggestions on this work. This work was supported by low porosity and low permeability major project of Study on the adaptability of volume fracturing in Shaximiao tight sandstone reservoir (No. Study on the adaptability of volume fracturing in Shaximiao tight sandstone reservoir-XNS15JS2019-045).

References
[1] SHENG Jun. Comprehensive research on tight sandstone gas reservoir and development strategy of horizontal well [D]. Northwestern University, 2016.
[2] WANG Xiaolei. Dynamic analysis of fractured horizontal well in southeastern Jiangsu gas reservoir, Jingbian [D]. Southwest Petroleum University, 2015.
[3] XIE Jing. Well-type optimization and economic benefit evaluation of tight gas reservoir [D]. Northeast Petroleum University, 2014.
[4] Jiping Wang, Chengwei Zhang, Jianyang Li, Ya Li, Xiaofeng Li, Ping Liu, Jiachun Lu. Development of tight sandstone gas reservoirs in the Sulige Gas Field and suggestions for stable production [J]. Natural Gas Industry, 2014, 41(02):100-110.
[5] Yang Hao, Li Xinfia, Chen Xin, Chen Xiaoyi, Liu Peng, Feng Qing, Geng Shaoyang. Research on optimization method of horizontal well-staged fracturing in low permeability gas reservoir [J/OL]. Special Oil and Gas Reservoirs: 1-7.
[6] ZHANG Guo-sheng, TANG Mei-Rong, CHEN Wen-bin, XU Chuang-Chao, YANG Dian-sen, ZHOU Zai-le. Optimization design of fracture spacing [J]. Science Technology and Engineering, 2012(04):1367-1374.
[7] Zhong Min. Dense oil exploitation technology economic evaluation research [D]. China university of mining & technology (Beijing), 2018.
[8] YU Yuanlin. Benefit evaluation of unconventional gas field development in Sichuan Basin [D]. Southwest Petroleum University, 2015.