Analysis of large scale fracturing effect and influencing factors in low permeability oil reservoir

Liu Lin *
School of Petroleum Engineering, Daqing Petroleum Institute, Daqing, China

* Corresponding author e-mail: hliulin@petrochin.com.cn

Abstract. H Oilfield is a complex fault field. Due to poor physical properties, it is still difficult to effectively inject wells after fracturing. In addition, the repeated fracturing effect has deteriorated year by year. Most of the blocks are generally low in production, and the oil recovery speed is less than 0.31 %. Since 2014, large-scale fracturing field tests have been carried out in H Oilfield. By analyzing the influence of various factors on fracturing effect, the grey correlation method was used to analyze the influence of various factors on oil production after fracturing. The results showed that the main factors influencing the fracturing effect in the test area were formation coefficient, porosity, oil saturation, amount of sand carrying fluid, amount of fracturing fluid, and amount of sand added. The research results can be used for reference and guidance to improve the development level of low-permeability oil fields.

Key words: low permeability; large-scale fracturing; influence factor; Grey Correlation Analysis.

Low permeability reservoir is a relative concept. It is internationally accepted that the reservoir with permeability between 0.1 and 50 millidarcy is defined as low permeability reservoir [1]. The development of low permeability reservoirs has been a worldwide problem, and the low permeability reserves account for a large proportion of the newly proved oil reserves [2]. The domestic Daqing Field, Jilin Oilfield, Tuha Oilfield, Changqing Oilfield have carried out large-scale fracturing, achieved good results, are vigorously promoted [3-13].

The geological reserves of low permeability reservoirs in H oilfield exceed 50 million tons, accounting for 55.4% of the total geological reserves. H oilfield is a complex fault block oilfield. Due to poor physical properties, it is still difficult to inject water effectively after fracturing, and most of the blocks are low production as a whole, in order to explore economical and effective development ways, large scale fracturing field experiments have been carried out in H oilfield, and the results of well fracturing are different, therefore, it is necessary to analyze and summarize the influencing factors of fracturing effect. In this paper, the influencing factors of fracturing effect are analyzed and evaluated through the analysis and statistics of the relevant data of large-scale fracturing, it provides selection in large scale fracturing in low permeability oilfield. Effective parameters for well selection and layer.
1. Current situation analysis of large-scale fracturing technology

1.1. Mechanism of increasing production
High viscosity GEL is used to form a main fracture in the direction of maximum principal stress, and proppant is placed in the main fracture to ensure the conductivity of fracture, to provide a seepage passage for crude oil, to make a fracture by using slip water, and to inject large displacement into the reservoir, increasing the net pressure in the fracture leads to the fracture initiation in multiple directions, forming a complex multi-fracture system and resulting in high fracture swept volume.

1.2. Application Status in China
At present, large-scale fracturing technology has been widely used in China, such as well N5-82 in Jidong oilfield, well Z165-inclined 2 in Shengli Oil Field and G892 in Qinghai Oilfield, well J40-6 in Hongliuquan oilfield, L172 well area of Dzungar basin.

The development of large-scale fracturing technology has experienced four stages. The first stage is aimed at increasing the success rate of fracturing operation; the second stage is aimed at improving the horizontal transformation degree; the third stage is aimed at improving the vertical transformation degree; and the fourth stage is aimed at achieving the "volume transformation". From 2011 to 2014, 88 wells were tested in the field of fracture pattern fracturing in Changyuan County, Daqing, with an average of 15.4 t per day and 5.4 t per day.

2. Effect of large-scale fracturing technology

2.1. Feasibility analysis
There are three aspects to evaluate the feasibility of large-scale fracturing technology: (1) the Brittleness of Rock, the study shows that more than 30% brittleness can form multiple branch joints, the Brittleness index of the study area is more than 30%. (2) the horizontal two-direction Stress Difference, the reservoir horizontal maximum stress and the Horizontal Minimum Stress Ratio can decide whether the fracturing can form the branch fracture, when the ratio is 1.0 ~ 1.3, the complex fracture network system can be formed, when the ratio is 1.3 ~ 1.5, when the ratio is > 1.5, the complex fracture system can not form the fracture net 14-17. The ratio of the horizontal maximum stress to the horizontal minimum stress is less than 1.3, which indicates that complex fractures can be formed. (3) The degree of development of natural fractures, the natural fractures are not developed in the study area (table 1).

Table 1. Rock mechanical parameters in the study area

| Horizon | Horizontal maximum principal stress (MPa) | Horizontal Minimum Principal Stress (MPa) | Ratio of horizontal maximum principal stress to horizontal minimum principal stress | Brittleness Index(%) |
|---------|------------------------------------------|-------------------------------------------|---------------------------------------------------------------------------------|---------------------|
| X       | 36.9                                     | 33.3                                      | 1.11                                                                            | 47.3                |
| N       | 48.6                                     | 42.1                                      | 1.16                                                                            | 48.9                |

2.2. Comparison of large-scale fracturing and conventional fracturing
Compared with normal fracturing, the amount of fracturing fluid is 3.65 times of normal fracturing, and the amount of normal fracturing well is 502m³, 1834m³ for large-scale fracturing; The strength of adding sand is 4.8 times of normal fracturing, 2.0m³/m of normal fracturing well, 9.6m³/m of large scale fracturing, and 2.67 times of normal fracturing oil production in initial stage (table 2).
Table 2. Comparison table of Operation Parameters and effect of large-scale fracturing well

| Lot Size | Fracture layer (number) | Total volume of liquid (m³) | Sand strength (m³/m) | Construction Displacement (m³/min) | Initial oil production (t/d) |
|----------|-------------------------|----------------------------|---------------------|-----------------------------------|-----------------------------|
| Large scale | 1.0                     | 1833.6                     | 9.6                 | 6.3                               | 5.6                         |
| Normal   | 3.2                     | 502.0                      | 2.0                 | 3.2                               | 2.1                         |

Downhole micro-seismic fracture monitoring shows that large-scale fracturing effectively increases the transformation volume and achieves effective reservoir production. For example, in well B28-02, the scale of fracture network formed after fracturing is 399m (length) × 87m (width) × 155m (height), and the swept volume of geologic body is 332 × 10⁴ m³, which is 3-5 times of that in well B14-01 (table 3).

Table 3. Downhole microseismic monitoring data sheet

| Pound sign | Coverage | Notes                      |
|------------|----------|----------------------------|
| L (m) | W (m) | H (m) | V (10⁴ m³) |                          |
| B14-01     | 163     | 87   | 27    | 66     | Conventional fracturing well |
| B28-01     | 271     | 101  | 96    | 231    | Large scale fracturing well  |
| B28-02     | 399     | 87   | 155   | 332    | Large scale fracturing well  |

3. Analysis of influencing factors

3.1. Geological Survey of the study area
The study area is located in S oilfield and B oilfield in the central part of the H District Basin. The main fracturing zones are X reservoir of S oilfield and N reservoir of B oilfield. The interval of porosity distribution is 2.1-39.8%, the interval of porosity is 10-15% and 15-25%, the average value is 15.4%, and the permeability is and the permeability is 0.1-1×10⁻³ μm² and 1-10×10⁻³ μm², the average value is 1.1×10⁻³ μm², which is a low porosity and ultra-low permeability reservoir, mainly with ultra-low permeability. The porosity of N is 1.1~23.8%, average 10.4%, the maximum permeability is 0.01~276×10⁻³ μm², the average value is 3.23×10⁻³ μm², the permeability is mainly distributed in the range of less than 0.5×10⁻³ μm², and belongs to the medium-low porosity and low permeability reservoir.

3.2. Grey relational analysis
Grey relational analysis is based on the theory of grey system. Its aim is to find out the main relationship among the factors in the system. The degree of correlation describes the relative change of the factors in the system development, and the degree of correlation rank represents the order of the factors' influence.

3.3. Determination and analysis of influencing factors
There are many factors affecting the fracturing effect, which can be considered from the geological factors and construction parameters. Formation factors include porosity, Formation Coefficient, single well controlling geological reserves, cumulative injection-production ratio of well group, oil saturation and so on. Because of many factors, it is necessary to choose parameters which have significant influence on fracturing effect and are easy to obtain and quantify.

According to the grey correlation analysis method, combined with the actual situation, 34 large-scale fracturing data are selected and the following assumptions are made: the initial daily increment of single well and the daily increment of March are selected as the parent sequence after fracturing of single well reservoir, SUB-SEQUENCE: POROSITY, Formation Coefficient, amount of fracturing fluid, geological reserves, oil saturation, sand ratio, amount of adding sand, etc. After homogenizing with mean value method, the correlation degree of each parameter is calculated as follows:
Table 4. Table of results of correlation analysis

| Classification       | Relatedness       | Initial daily increase (t) | Three-month average daily fuel increase (t) | Mean value |
|----------------------|-------------------|-----------------------------|--------------------------------------------|------------|
| Geologic Reserve (10^4 t) |                  | 0.730                       | 0.736                                       | 0.733      |
| Fracturing fluid consumption (m^3) |      | 0.811                       | 0.775                                       | 0.793      |
| Sand addition (m^3) |                  | 0.773                       | 0.736                                       | 0.755      |
| Sand carrying capacity (m^3) |              | 0.838                       | 0.822                                       | 0.830      |
| Sand ratio (%)       |                  | 0.609                       | 0.684                                       | 0.646      |
| Oil Saturation (%)   |                  | 0.866                       | 0.826                                       | 0.846      |
| Porosity (%)         |                  | 0.885                       | 0.885                                       | 0.885      |
| Formation Coefficient (10^{-2}μm^2.m) |  | 0.875                       | 0.903                                       | 0.889      |
| Effective thickness (m) |                | 0.540                       | 0.630                                       | 0.585      |

According to the analysis results, the main influencing factors and weight of fracturing effect in low permeability oilfield of H District Basin are listed in the following table.

Table 5. Influential factors and weight of large-scale fracturing effect

| Influencing factor | Formation Coefficient | Porosity | Oil Saturation | Sand carrying capacity | Fracturing fluid consumption | Sand addition |
|--------------------|------------------------|----------|----------------|------------------------|-----------------------------|---------------|
| Unit               | 10^{-2}μm^2.m           | %        | %              | m^3                    | m^3                         | m^3           |
| Code Name          | I                      | II       | III            | IV                     | V                           | VI            |
| Weight             | 0.889                  | 0.885    | 0.846          | 0.830                  | 0.793                       | 0.755         |

The correlation degree of factors affecting post-fracturing oil production in low permeability oilfields in the H District Basin can be ranked as follows: 0.889>0.885>0.846>0.830>0.793>0.755; he order of the parameters affecting the post-fracturing production of large-scale fracturing wells in the low permeability oilfields of the H District Basin is: Formation Coefficient, porosity, oil saturation, sand-carrying fluid, fracturing fluid and sand addition.

3.4. Field application

In 2018, according to the result of grey correlation analysis, the optimum Formation Coefficient is greater than $5 \times 10^{-2} \mu m^2.m$. The porosity is more than 13.5%, the oil saturation is more than 50.4%, the amount of adding sand is increased by 25.0%, the amount of carrying sand is increased by 23.0%, the total amount of fracturing fluid is increased by 5.0%, and the average daily increase of oil per well is increased from 3.8 t to 4.5 t at the initial stage after fracturing, after 3 months production, the average daily oil increase of single well increased from 3.6 t to 4.2 t. Field test results show that the large-scale fracturing effect of low permeability reservoir can be improved by properly increasing sand loading, sand carrying fluid and total fracturing fluid.

Another sec

4. Conclusion

(1) The stress difference between X and N reservoir of H District Oilfield is small, the Brittleness Coefficient is more than 30%, and there is no artificial fracture.

(2) In the initial stage of large-scale fracturing, the daily oil production is 2.67 times of normal fracturing, and the swept volume of geologic body is 3-5 times of normal fracturing. This technology can shorten the displacement distance, alleviate the reservoir pressure, reduce the surrounding water injection pressure, thus improving fracturing stimulation effect.

(3) The main influencing factors of large-scale fracturing effect are analyzed by grey correlation analysis method, the factors that influence the daily increase of oil after fracturing are: Formation
Coefficient, porosity, oil saturation, amount of sand-carrying fluid, amount of fracturing fluid and amount of adding sand.

(4) The key factors affecting the large-scale fracturing effect in low permeability oilfield are the material base of the reservoir itself, I. E. Formation Coefficient, porosity and oil saturation, and the next are the fracturing operation parameters. The large scale fracturing effect of low permeability reservoir can be improved by properly increasing the amount of sand addition, sand carrying fluid and total fracturing fluid.

References

[1] Pindao Li. Development of low permeability Sandstone Oilfield M. BEIJING: Petroleum Industry Press, 1997.

[2] Xu liang. Research and practice of differential development technology in low permeability reservoirs -- a case study of boxing depression in jiyang depression [J]. Oil and gas geology and recovery, 2014, 21(04): 107-110+118.

[3] Renmei Wang. Application of volume fracturing technology in Petroleum Development J. Science and technology innovation and application, 2015, (18): 123.

[4] Yongfeng Li. Application of volume fracturing technology in Petroleum Development [J]. Chemical Management, 2014, (30): 74.

[5] Chenglin Ye, Wang Guoyong. Application of volume fracturing technology in horizontal well development of Sulige gas field -- taking block Su 53 as an example J. Petroleum and natural gas chemicals, 2013, 42(04): 382-386.

[6] Fan Wengang, Liu Qinghua. Test of tight oil development in H District oilfields J. China and foreign energy, 2016, 21(05): 54-57.

[7] Xie Chaoyang, Shang Litaot, Tang Pengfei, etc. Research and test of large-scale in-fracture Steering Fracturing Technology J. Petroleum Geology and development in Daqing, 2016, 35(02): 66-69.

[8] Jiang Hongfu, Wang Yunzeng, Liu Qiuhong, etc. Application of large-scale fracturing technology in ultra-low permeability reservoir development J. Petroleum Geology and development in Daqing, 2016, 35(02): 70-74.

[9] Jin Liyang. Research and application of horizontal fracture large-scale fracturing technology—take the northern transition zone of the North Sabei Development Zone as an example [A]. collected papers on oil extraction engineering, volume 1 [C], 2016: 6.

[10] Wu Boqin. Research and discussion on volume fracturing technology in low permeability reservoir [J]. Standard and quality of China Petroleum and chemical industry, 2013, 34(04): 72.

[11] Cheng Shixing. Study and application of large-scale long fracture fracturing technology in low permeability reservoir [J]. Inner Mongolia petrochemical industry, 2011, 37(20): 116-117.

[12] Li Jianshan, Lu Hongjun, Du Xianfei, etc. Study and field test on repeated reconstruction technology of mixed water volume fracturing in ultra-low permeability reservoir [J]. Petroleum and Natural Gas Chemicals, 2014, 43(05): 515-520.

[13] Sui Yang, Liu Jianwei, Guo Xudong, etc. Application of volume fracturing technology in Hongtai low oil saturation tight sandstone reservoir [J]. Oil Drilling and production process, 2017, 39(03): 349-355.

[14] Wang Jun. Application of large-scale fracturing technology in the development of low permeability thin interbed oilfield [J]. Inner Mongolia petrochemical industry, 2008, (10): 334-335.

[15] Liu Yafei. Study on evaluation method of volume fracturing effect in low permeability reservoir [J]. Chemical Management, 2016, (14): 195.

[16] Jia Ting, he Qiang, Sun Ming. Analysis on the effect of volume fracturing in tight oil area [J]. Journal of Xi'an University of Arts and Sciences, 2017, 20(02): 113-116.

[17] Tu Zhimin. Analysis on application effect of coal bed gas fracturing technology in PSC block of
Hancheng [JL]. Coal Engineering, 2017, 49(02): 62-64.

[18] Ma Pinghua, Huo Mengying, He Jun, etc. Analysis of influencing factors and optimization of fracturing technology for coalbed gas wells — Taking the Hancheng mining area in the southeast edge of Ordos Basin as an example [J]. Gas Geoscience, 2017, 28(02): 296-304.

[19] Ray chuanling. Analysis on fracturing effect of low permeability fractured reservoir in Massy oilfield [J], 2017, (06): 89-90.

[20] Hou Wei, Wang Jun. Study and test of volume fracturing technology in ultra-low permeability reservoir [J]. Liaoing Chemical Industry, 2014, 43(06): 776-777.

[21] Liang Chenggang, Tang fuping, Xie Jianyong, etc. Analysis of oil pressure characteristics and fracturing effect of horizontal well after fracturing in tight reservoir—Taking three horizontal wells in Changji oilfield as an example [J]. Petroleum Geology of Xinjiang, 2014, 35(01): 63-66.

[22] Li Jianshan, Lu Hongjun, Du Xianfei, etc. Study and field test on repeated reconstruction technology of mixed water volume fracturing in ultra-low permeability reservoir [J]. Petroleum and Natural Gas Chemicals, 2014, 43(05): 515-520.

[23] Han lingchun. Analysis on development effect of large-scale fracturing test in tight reservoir [J]. Special Oil and gas reservoir, 2017, (04): 1-7.

[24] Wang Rui. Analysis of influencing factors on volume fracturing effect of horizontal well in tight reservoir [J]. Special Oil and gas reservoir, 2015, 22(2): 126-128.