Research on Application of Composite Fracturing Fluid for Large Dip Coal Seam

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Abstract: Hydraulic fracturing is an important measure and main method for increasing production of coal reservoir. As one of the key materials of hydraulic fracturing, fracturing fluid directly determines the production of wells and greatly affects economic benefits. According to the requirement of fracturing fluid for large inclined coal seam, the low viscosity active water fracturing fluid was used in the early stage of fracturing, and the high viscosity clean fracturing fluid was used in fracturing and sand adding, thus forming a complex fracturing fluid system. After field construction application, the entering fluid and the operating pressure of the complex fracturing fluid system are lower than those of the active water fracturing fluid well, that shows that the compound fracturing fluid has many advantages, such as high fracture efficiency, strong sand carrying performance, small friction coefficient and high success rate. The desorption pressure, average gas production, bottom hole flow pressure and the highest gas yield of wells operated with compound fracturing fluid are all higher than those of wells operated with active water fracturing fluid, which shows good potential for high yield.

1. Introduction

Fracturing fluid technology is the core technology of coal seam fracturing. The function of fracturing fluid is to form a certain scale fracture in coal seam and to carry proppant into fracture to support it[1~3]. The fracturing fluids commonly used in coal seams include active water fracturing fluid[4], clean fracturing fluid[5,6], and gel fracturing fluid[7~9]. Active water fracturing fluid is the most commonly used fracturing fluid in coal seam fracturing. Its main component is clear water and potassium chloride. It has the characteristics of low damage to reservoir and low cost. However, because of its large filtration loss, poor sand carrying performance and high friction resistance, it is necessary to adopt the method of large displacement injection to increase the liquid flow rate and carry out sand carrying. The main component of clean fracturing fluid is viscoelastic surfactant and crosslinking agent. It has the characteristics of high fracture efficiency, good sand carrying performance and low friction, but the damage rate of clean fracturing fluid to coal seam is higher than that of active water fracturing fluid, and the cost is also higher.
than that of active water fracturing fluid. The gel fracturing fluid is the most commonly used fracturing fluid in conventional oil and gas wells, its main component is modified silica gel and crosslinking agent. Gel fracturing fluid has strong seaming efficiency and sand carrying capacity. The proppant is basically suspended in the gel fracturing fluid, it can carry the high concentration proppant to the far end of fracture at low displacement. However, guanidine gel fracturing fluid is not suitable for coal seam fracturing because the damage of guanidine gel fracturing fluid to coal seam is more than 70%. For this reason, this paper establish a complex fracturing fluid system for large inclined coal seams. After field application, the effect of gas production after pressing is very obvious.

2. The requirement of fracturing fluid for large dip coal seam
The coal seam in X area of Xinjiang belongs to low rank coal. long flame coal ~ gas coal, which has the characteristics of high porosity and permeability, the development of coal seam cleat and great dip angle, etc.. Therefore, its have higher requirements on the fracturing project. The purpose of hydraulic fracturing is to solve the problem of seepage channels. Therefore, the fracturing fluid should have a certain ability to make fracture and carry sand so that it can form long support fractures with certain conductivity. Because the hardness of coal is small, the propellants filled in the supporting cracks under higher closed stress will be inserted into the coal seam, which will result in a sharp decrease in the conductivity of the fractures. Therefore, the proppant laid in the fracture should have a higher concentration. Due to the upper space of the fracture is effectively supported in the large inclined seam, the performance of the fracturing fluid carrying sand will be higher in the coal seam. Therefore, fracturing fluid needs to have the following capabilities: opening and communicating micro-fractures in coal seam, dispersing pulverized coal to prevent accumulation and blockage, better filtration reduction, fracturing ability and sand carrying capacity, etc. Although the high viscosity fracturing fluid can achieve the purpose of filtrate resistance, high seam efficiency and high sand carrying capacity, but the coal seam is porous and loose, the low rank coal has higher porosity and permeability, and the fracture cleat of coal seam is also relatively developed. Therefore, under the pressure of fracturing, the coal seam will be compacted and the permeability of the matrix decreases sharply, and the loss of permeability can not be completely recovered after the confining pressure is released. The only use of high viscosity fracturing fluid can't solve this problem. The fracturing fluid should be low viscosity at the beginning of operation, so that it can enter into micro-fracture. Subsequently, its viscosity should be increased to ensure the joints are made and proppant can support the fracture, and its viscosity should be reduced after the end of construction to facilitate backflow. In the overall construction process, the tendency of viscosity change is low viscosity-change viscosity-high viscosity-low viscosity.

According to the specific conditions of the coal seam in the X area of Xinjiang, this paper establish the compound fracturing fluid system, that is, the low viscosity active water fracturing fluid was used in the early stage of fracturing, and the high viscosity clean fracturing fluid was used in the fracturing process and sand adding.

3. Construction technology of composite fracturing fluid

3.1 Composite fracturing fluid construction method
According to the requirement of fracturing fluid in large inclined coal seam, several steps should be done:
First, the fracturing fluid injected in the early stage of construction should be able to filter into the pores and natural fractures of coal seam, fully open and communicate the micro-fractures in coal seam, and alleviate the pressure sensitive damage of reservoir. Therefore, the new fracturing fluid with low viscosity can be used in this stage.
Second, the injected fracturing fluid should be able to carry small particle size proppant into the open microfracture, support it and reduce filtration, while grinding the bending cracks to ensure smooth follow-up sand fracturing. Therefore, a new type of active water fracturing fluid with low viscosity
should be used in the fracturing fluid at this stage.

Third, the purpose of injection fracturing fluid should be to form a large scale fracture, and should also be considered to ensure that the fracturing fluid at the far end of the fracture is fully gel-break. Therefore, the fracturing fluid in this stage is composed of low viscosity new active water fracturing fluid and high viscosity clean fracturing fluid. Namely, inject a new type of active water fracturing fluid mixed with gel breaking agent firstly, then inject the high viscosity clean fracturing fluid, and form a large scale fracture while ensuring a certain amount of gel breaking fluid in the front section of the fracture.

Fourth, the injected fracturing fluid should have better sand carrying performance and stronger filtration performance to ensure the smooth fracturing sand and form a longer supporting fracture, so the fracturing fluid at this stage should be clean fracturing fluid with high viscosity.

Fifth, the injected fracturing fluid should push the sand carrying fluid in the wellbore into the formation and ensure the full breaking of the gel in the cleaning fluid. Therefore, the fracturing fluid at this stage should adopt a new type of active water fracturing fluid mixed with gel breaking agent. The change of fracturing fluid viscosity in the whole fracturing process accords with the trend of low viscosity, variable viscosity, high viscosity and low viscosity.

3.2 Composite fracturing fluid pump injection procedure

The composite fracturing fluid makes full use of the characteristics of the new active water and the clean fracturing fluid to achieve the purpose of relieving the pressure-sensitive effect, fully creating fracture, ensuring the length of the supporting fracture, and fully breaking the fracturing fluid. Pump injection program shows in Table 1.

| No. | Fracture stage | Fracturing fluid type | Fracturing fluid volume m³ | Construction displacement m³/min | action |
|-----|----------------|-----------------------|----------------------------|----------------------------------|--------|
| 1   | Prepositioning fluid | Active water | 80-120 | 1-8 | Grade 5-7 gradually increase displacement, relieve pressure sensitive |
| 2   | Prepositioning fluid | Active water | 120-160 | 8-10 | Sand slug filtering, grinding the cracks |
| 3   | Prepositioning fluid | Gel breaking liquid - Action water | 80-120 | 9-10 | Ensure that the front of the crack cleaning fluid is fully broken, further forming fissure, prevents premature breaking of the sand-carrying fluid |
| 4   | Prepositioning fluid | Isolating fluid - Cleaning liquid | 100-150 | 10-8.5 | |
| 5   | Sand-carrying fluid | Sand-carrying fluid - Cleaning liquid | 400-450 | 7.5-8.5 | 50-60m³ of sand added |
| 6   | Replace fluid | Replacement fluid - Gel breaking liquid | 1.2 times well capacity | 7.5-8.5 | The sand-carrying fluid is pushed into the formation to ensure that the near-well cleaning fluid breaks the gel |
| 7   | Replace fluid | Replacement fluid - Action water | 2 times well capacity | 1.5-2.0 | Breaking the gel into the stratum |

4. Application effect analysis

4.1 Application situation
In the X District of Xinjiang, 89 layers of field tests were carried out by using compound fracturing fluid system. Except for one well, the construction pressure was too high due to the abnormal ground stress, and the remaining wells were all over 33m³. The maximum fluid input volume is 1068m³ and the minimum is 695m³, with an average of 835m³. The highest level of sand addition is 60m³, the lowest is 33m³, the average is 50m³. The average sand ratio is 15.9%, the lowest is 6.2%, the average is 10.89%. The success rate of one-time construction (the actual amount of sand added is ≥ 80% of the designed amount of sand) is 96.62%.

4.2 Effect analysis

Table 2. Comparison of construction parameters between composite fracturing fluid and active hydraulic fracturing fluid

| No. | Fracturing fluid type          | Construction pressure MPa | Inlet fluid volume m³ | Inlet sand volume m³ | Average sand ratio % | Pressure gradient MPa/m | Construction success rate % |
|-----|--------------------------------|----------------------------|-----------------------|----------------------|-----------------------|--------------------------|-----------------------------|
| 1   | Composite fracturing fluid     | 24.06                      | 835                   | 50                   | 10.87                 | 0.0286                   | 96.6                        |
| 2   | Conventional active water      | 31.13                      | 969                   | 37                   | 6.36                  | 0.0425                   | 62.5                        |

By comparing the related parameters of the wells operate with compound fracturing fluid and the wells operate with active water fracturing fluid, the results are shown in Table 2 and Fig. 1. The results are obvious, the entering fluid and the operating pressure of the complex fracturing fluid system are lower than those of the active water fracturing fluid well. The amount of sand entering the well, the average sand ratio, the success rate of construction and the scale of fracture are higher than those of the active water fracturing fluid. The results show that the compound fracturing fluid has many advantages, such as high fracture efficiency, strong sand carrying performance, small friction coefficient and high success rate.
Figure 2. Comparison of production parameters between compound fracturing fluid and active water fracturing fluid for construction wells

Table 3. Comparison of production parameters between compound fracturing fluid and active water fracturing fluid for construction wells

| No. | Fracturing fluid type   | Proportion of gas production wells | Gas production cycle % | Desorption pressure MPa | Average water production m³/d | Average gas production m³/d | Flow pressure MPa |
|-----|------------------------|-----------------------------------|------------------------|-------------------------|-------------------------------|-----------------------------|------------------|
| 1   | Composite fracturing fluid | 74                                       | 140                   | 3.9                     | 33.2                          | 678                          | 2.65             |
| 2   | Conventional active water | 67                                       | 112                   | 3.43                    | 25.1                          | 583                          | 2.53             |

By comparing the production of complex fracturing fluid construction well and active water fracturing fluid well. The gas emergence period, desorption pressure, daily water production, bottom hole flow pressure, daily gas production and maximum high gas yield of each well are counted respectively, the results are shown in Table 3 and Fig. 2. According to the statistics, the desorption pressure, bottom hole flow pressure, average gas production and the most high gas yield of wells operated with compound fracturing fluid are higher than those of wells operated with active water fracturing fluid, it has good potential for high yield.

5 Conclusion

1. The composite fracturing fluid system with low viscosity and high viscosity was determined by studying on the adaptability of the fracturing fluid in large inclined coal seam.

2. The characteristics of new active water and clean fracturing fluid are used to relieve pressure sensitivity, make full seam, ensure the length of support seam and clean fracturing fluid.

3. The field operation technology of compound fracturing fluid is studied and 89 layers of field test are carried out. The test results show that the effect of fracturing fluid well is better than that of active water fracturing fluid well either in the case of fracturing operation or in gas production after compression.

Acknowledgments

This paper was supported the Xinjiang Uygur Autonomous Region Geological Exploration Fund Project,
China (No. N14-4-XJ01).

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