Experimental study on proppant embedment depth and fracture conductivity in coal seam

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Abstract. The fracturing of coal seam in one of the blocks in Xinjiang is significantly different from that of conventional formation. After fracture closure, there is the proppant embedment, especially in the soft formation with high closure pressure. The mechanical parameters of the coal core leave out of consideration in conventional proppant embedment tests, so the effect of proppant embedment on the fracture conductivity is uncertain, which brings a challenge to the optimization of proppant concentration and proppant selection. In order to quantitatively evaluate the proppant embedment in coal seam, the core drilled on the coal is tested to measure the mechanical parameters of the coal core, and the proppant embedment morphology of the natural coal core is tested. The mechanical parameter test of natural coal core provides relatively accurate data under simulated coal seam conditions, and provides reference basis for the design of coal seam fracturing.

1. Introduction

As the permeability of natural coal seam is very low, the fracture is often caused by the elastic deformation of coal seam and the strong hydraulic scouring, resulting in reduction of the conductivity of artificial fracture. How to quantitatively evaluate the proppant embedment depth and fracture conductivity under coal seam conditions has become a challenge in the fracturing of coal seams in a certain block of Xinjiang oilfield. According to the standard SY/T6302-2009 issued by the national energy administration, in the tests of proppant embedment depth and fracture conductivity, the plastic deformation and hydraulic scouring of coal seam are ignored. In recent years, the method of crushing coal core and then pressing it into standard API plant is widely used in China, but this method changes the natural properties of coal seam rocks, so the experimental results is still inaccuracy.

In this research, coal cores drilled from natural coals are used in the mechanical parameter experiments and proppant embedment morphological tests. By analyzing the influence factors of proppant embedment depth and fracture conductivity, the experimental basis was provided for...
optimizing fracturing of coal seam in a certain block of Xinjiang oilfield and improving fracture conductivity.

2. Experimental process
Coal seam fracturing is significantly different from conventional formation fracturing, which not only involves the elastic deformation of conventional formation fracturing, but also has a strong hydraulic scouring effect. Therefore, mechanical parameters of coal core rock are tested. The coal is first cored. After core drilling is completed, 27 cores are measured, including length, diameter, mass and density. The stress parameters of A1, A2, B6 and B8 of the 27 cores are determined, and the results are shown in Table 1.

| Numbering | Confining pressure (Mpa) | Poisson's ratio | Elastic modulus (Mpa) | Differential stress (Mpa) |
|-----------|--------------------------|----------------|-----------------------|--------------------------|
| A1        | 6.0                      | 0.457          | 4518.6                | 38.2                     |
| A2        | 6.0                      | 0.422          | 4291.4                | 37.0                     |
| B6        | 6.0                      | 0.371          | 4857.1                | 40.5                     |
| B8        | 6.0                      | 0.293          | 3788.2                | 37.6                     |

From Table 1, the range of poisson's ratio is from 0.293 to 0.457, with an average value of 0.386. The elastic modulus is ranged from 3788.2 to 4857.4, with an average value of 4363.9.

3. Analysis of Influencing Factors on Embedding Depth of Proppant

3.1 Influence of Different Types of Proppant
Figure 1 shows the comparison results of average values of different types of embedding depths at different closed pressure points in all the embedding depth test results of quartz sand and ceramsite embedding experiments. It can be seen from the figure that the quartz sand is more deeply embedded than the ceramsite, indicating that the sphericity of the quartz sand is far less than that of the ceramsite, so the influence of the embedding is greater than that of the ceramsite.

3.2 Influence of proppant diameter
Figure 2 shows the comparison results of average embedding depth of different particle sizes at each closed pressure point in all the embedding depth test results of quartz sand and ceramsite embedding experiments. As can be seen from the results, the embedding depth of proppant with large particle size was higher than that of proppant with small particle size. The reason is that the contact point between
the small-particle size proppant and the coal and rock is more, the stress area is larger, and the closure stress on a single proppant is smaller, so the embedding is relatively less.

Figure 2. The comparison of average proppant embedment depth with different proppant diameter

3.3 Influence of proppant placement concentration

Figure 3 shows the comparison results of average embedment depth with different sand concentration at each closed pressure point in all the embedding depth test results of quartz sand and ceramsite embedding experiments. It can be seen from the results that the proppant embedment depth when proppant placement concentration is of 5kg/m² is greater than that when its proppant placement concentration is of 10kg/m². This is because the total number of proppant placement layers is less under the lower proppant placement concentration. Once the embedment occurs, the proportion of the embedded layer in the total number of sand-laying layers is relatively large, and its influence is greater than that of the high proppant placement concentration.
Figure 3. The comparison of average proppant embedment depth with different proppant placement concentration

4. Effect of proppant embedment on fracture conductivity

According to the results of the proppant embedment experiment, the conductivity of different types of proppants under different conditions is analyzed. Figure 4 shows the results of Lanzhou quartz sand and Ningxia quartz sand in fracture conductivity test, which indicates that the higher the proppant placement concentration, the greater the proppant pack compression ability and the stronger the ability to resist breakage. Figure 5 shows the comparison of average values of fracture conductivity at different closed pressure points and different proppant concentration in the conductivity test results of ceramsite embedment experiment, which indicates that the higher the sand concentration, the stronger the compressive resistance of the proppant pack and the higher the fracture conductivity.

Figure 4. The comparison of average values of quartz sand conductivity under different proppant placement concentrations
Figure 5. The comparison of average values of ceramsite conductivity under different proppant placement concentrations

5. Conclusion
From the conductivity test and proppant embedment depth test, the performance of ceramsite in various aspects are significantly superior to that of quartz sand. High concentration of sanding helps support fracture conductivity and decrease the proppant embedment effect. High proppant concentration and large particle size can also help to maintain high fracture conductivity. Through experimental analysis, proppant embedment depth is tested at 5 closed pressures (10.35Mpa, 117.25Mpa, 24.15Mpa, 31.05Mpa, 37.95Mpa), and a total of 50 sets and 250 tests are conducted. The experimental results show that the quartz sand is deeper embedded than the ceramsite and the performance of the ceramsite is better than that of the quartz sand. The 20/40 of proppant is embedded deeper than the 30/50 of proppant. The amount of fine sand is increased to ensure that the proppant is more easily carried to the depth of the fracture. The embedment when proppant placement concentration is of 5kg/m² is deeper than that of 10kg/m².

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