Influence of proppant embedment on fracture conductivity

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Abstract. Using the national invention patent equipment, the proppant embedment experiment was carried out on the formation coal seam. The effects of proppant embedment on the conductivity of cracks under different proppant types, different proppant particle sizes, different sanding concentrations and different closing pressures were investigated. The experimental results show that with the increase of the closing pressure, the conductivity of quartz sand and ceramsite decreases rapidly; the conductivity of ceramsite is generally higher than that of quartz sand; the higher the concentration of sand, the proppant filling The stronger the layer's compressive capacity and crushing resistance, the higher the fracture conductivity. XY ceramsite has the best conductivity.

1. Introduction
In the development of coalbed methane, it is necessary to hydraulically fracture the coalbed methane to form a supporting crack for the conductivity[1]. The better the fracture conductivity, the better the development of coal seams. Under the closing pressure, the proppant will exhibit different degrees of embedding. If the proppant is embedded in the crack wall, the effective slit width will be reduced, the flow guiding ability will be reduced, and the coal rock will be destroyed under the action of pressure to generate debris, and the debris will block the gap passage, resulting in permeability and guidance[2]. The flow capacity is reduced. In addition, proppant type, particle size, sanding concentration, and closing pressure all have an effect on the conductivity[3].

2. Proppant embedment experimental study

2.1. Experimental device and principle
In this experiment, the national invention patent equipment was used to carry out the coal rock experiment in FL quartz sand, TX ceramsite, WL ceramsite and XY ceramsite. A total of 24 experimental tests were carried out in the experiment, using 4 types (FL quartz sand, TX ceramsite, WL ceramsite and XY ceramsite), and 2 kinds of particle size (20/40 mesh), 30/50 mesh), three kinds of sanding sand concentration (5kg/m², 10kg/m² and 15kg/m²) of quartz sand under one type of coal core, six kinds of closed pressure conditions for conductivity test and six kinds of closure Test of proppant embedment depth under pressure conditions.

2.2. Experimental process
The specific operation procedure of the proppant embedment experiment is as follows: ① Put the lower
coal rock plate into the diversion chamber; ② properly tighten the bottom fixing screw, and when the proppant is not needed, sink the proppant to the lower part; ③ lay it according to the experimental sanding concentration Propping agent; ④ put the upper coal rock plate into the diversion chamber; ⑤ tighten all the fixing screws, place the installed diversion chamber between the two parallel plates of the hydraulic frame; ⑥ close the vent valve; ⑦ install the displacement meter; ⑧ plus the corresponding closing pressure; ⑨ when the displacement meter no longer changes, stop the pressure; ⑩ conduct the conductivity test and proppant depth measurement. The proppant embedding experiment process is shown in Figure 1:

![Figure 1 proppant embedded in the experimental process](image)

2.3. Experimental results and analysis
Because the degree of embedded coal rock is related to the robustness of coal rock, the smaller the firmness coefficient, the worse the stability of coal rock, the smaller the ability to resist external damage, the easier the proppant is embedded in coal rock, and the proppant is embedded in coal rock. The greater the depth.

![Figure 2: Pre-embedded coal core and proppant embedded in the core](image)

After the embedding test, the embedded core was carefully removed from the embedding chamber, and a close-length observation was performed using an ultra-long focal length continuous zoom video microscope and a scanning electron microscope to measure the diameter of the embedded pores. Observations confirm the large embedding in the core.

3. Conductivity test

3.1. Experimental device and principle of conductivity
The proppant embedded in the experimental instrument works in accordance with Darcy's law[4]:

\[
k = \frac{10^{-2} \times Q \mu L}{A \Delta p}
\]

Where: \( k \) — support crack permeability, \( 10^{-3} \mu m^2 \); \( Q \) — crack flow, \( cm^3/s \); \( \mu \) — fluid viscosity, \( mPa \cdot s \); \( L \) — test section length, \( cm \); \( A \) — support crack area, \( cm^2 \); \( \Delta p \) — pressure difference at both ends of the test section, \( kPa \).
The conductivity tester uses the API standard diversion chamber and operates in strict accordance with the API procedure. The proppant permeability and conductivity calculation formula can be further expressed as the permeability and conductivity of the proppant crack [5].

\[ k = 5.411 \times 10^{-4} \mu Q / (\Delta p W_f) \]  

Proppant crack conductivity [6]:

\[ kW_f = 5.411 \times 10^{-4} \mu Q / (\Delta p) \]

the formula: \( W_f \) to fill the crack width, cm

3.2. Experimental procedure
Using the API standard diversion chamber, proppant-embedded coal rock experiments were carried out on FL quartz sand, TX ceramsite, WL ceramsite and XY ceramsite. The proppant particle size was 20/40 mesh and 30/50 mesh, respectively, and the proppant sanding concentration was 5, 10, and 15 kg/m², respectively. Sixteen closed coal pressure tests were performed on 21 coal plates.

3.3. Experimental results and analysis
The curves of the conductivity of the FL quartz sand and the XY ceramsite with the closing pressure are shown in Fig. 3 and Fig. 4. The curves of the different proppants with the closing pressure are shown in Fig. 5. The analysis results are as follows:

![Fig.3 Curve of conductivity of FL quartz sand with closed pressure](image-url)
(1) Close the pressure. As the closing pressure increases, the conductivity of quartz sand and ceramsite decreases rapidly. When the closing pressure is increased to 40 MPa, the conductivity of the quartz sand decreases, but the conductivity is weak. As the closing pressure increases, the conductivity of the ceramsite decreases much less than that of quartz sand, and the conductivity is always maintained. When the sand concentration is 15kg/m$^2$, the conductivity is maintained at $60\times10^{-14} \text{ m}^3$ or higher, which can provide higher conductivity; when the sand concentration is 10kg/m$^2$, the conductivity is maintained at $50\times10^{-14} \text{ m}^3$; the sand concentration is 5kg/m$^2$. At the time, the conductivity is only about $40\times10^{-14} \text{ m}^3$. The sanding concentration is 15kg/m$^2$, 10kg/m$^2$ and 5kg/m$^2$, and the conductivity is maintained above $50\times10^{-14} \text{ m}^3$, which can provide high conductivity. The conductivity of ceramsite is better than that of quartz sand. Figure 3 shows that the compressive strength of quartz sand is low, only suitable for medium and shallow reservoirs, and high sand concentration is required. Figure 4 shows that the ceramsite has strong compressive strength and is suitable for deep reservoirs, which is sufficient for seepage support. Requirements for fracture conductivity;

(2) Sanding concentration. Under different closing pressures, the conductivity of sanding concentration of 15kg/m$^2$ is significantly higher than that of sanding concentration of 10kg/m$^2$ and 5kg/m$^2$. This indicates that the greater the concentration of sand, the stronger the pressure resistance and crushing resistance of the proppant pack, and the higher the conductivity. Therefore, in order to obtain a higher conductivity, the sanding concentration of the proppant can be appropriately increased within the range permitted by the construction conditions.

(3) Proppant particle size. When the sanding concentration is 5kg/m$^2$ and the closing pressure is less than 20Mpa, the conductivity of 20/40 mesh quartz sand and ceramsite is about 1/2 times higher than that of 30/50 mesh quartz sand and ceramsite. It shows that under low closing pressure, large-size quartz sand and ceramsite can provide higher conductivity; when the closing pressure is greater than 20Mpa, the conductivity of the two is similar, 20/40 mesh quartz sand and ceramsite The conductivity is slightly higher than that of 30/50 mesh quartz sand and ceramsite. When the sand concentration is 15kg/m$^2$ and 10kg/m$^2$, the conductivity of 20/40 mesh quartz sand and ceramsite is always higher than that of 30/50 mesh quartz sand and ceramsite, indicating higher sanding. At the concentration, the pressure proppant increases, which is beneficial to reduce the fracture rate of the large particle size proppant, reduce the decrease of the conductivity, and help to maintain the conductivity of the proppant packing layer, even if the closing pressure increases. At a high level.
Figure 5 Trends in the conductivity of different types of proppants with closure pressure

4. Conclusion
(1) The quartz sand with low sand concentration has low conductivity at high closing pressure (>24.15MPa). Therefore, for a reservoir with a high closing pressure, a certain sand ratio must be ensured, so that the laying concentration is higher, so that a higher conductivity is obtained; if only quartz sand can be used and a certain sand ratio cannot be guaranteed, then the grain is selected. And quartz sand with smaller diameter has higher conductivity.

(2) Under high closing pressure, while ensuring large-size quartz sand and a certain high sand ratio for fracturing construction, hydraulic fractures can maintain high conductivity.

(3) In the case that the particle size of the proppant is difficult to increase, the highest sand ratio of the construction should be increased as much as possible, and the sanding concentration should be increased to reduce the damage of the proppant embedding to the conductivity (especially the permeability of the near well).

(4) The performance of ceramsite is obviously better than that of quartz sand. Under the condition of cost, ceramsite is properly mixed to increase the conductivity of fracturing crack and reduce the embedding depth.

(5) Increasing the amount of fine sand in 40/70 mesh can ensure that the proppant could enter the fracture depth more easily.

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