Study on the evaluation method and influencing factors of fracture conductivity of hydraulic fracturing support in shale reservoir

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Abstract: The conductivity of supporting fractures is an important parameter to evaluate the hydraulic fracturing effect of shale reservoirs, and its size is affected by many factors.In this paper, the proppant is optimized and evaluated on the basis of real rock slab simulation and actual construction proppant test. The laboratory experimental study on the influence of proppant type, sand concentration, proppant embedding and fracturing fluid residue on propping fracture conductivity is carried out,the results show that the average conductivity of 40 / 70 mesh proppant is about 7.15d · cm at 5kg / m^2 sand concentration under the condition of reservoir closure pressure of about 50MPa, which can basically meet the requirements of main fracture conductivity of Kong 2 shale reservoir in Dagang Oilfield；the damage of guar gum fracturing fluid and proppant embedment are two important factors that cause the great decline of conductivity of rock slab, and the damage of guar gum fracturing fluid has a great influence on the conductivity, reaching about 50%; the stronger the mud is (the higher the clay content is), the greater the embedment degree of proppant is, and the greater the loss of conductivity is;for the same lithology, the proppant particle size has little damage to the conductivity, and the sand concentration has a greater impact on the conductivity. The larger the sand concentration is, the smaller the loss of the conductivity is.

1 Introduction

Compared with conventional oil and gas reservoirs, tight shale gas reservoirs usually have the characteristics of low porosity, low permeability and low natural productivity. Therefore, it is necessary to use hydraulic fracturing to increase production in order to obtain industrial gas flow[1-3].Through hydraulic fracturing, the reservoir matrix is "broken" to form network fractures and increase the volume of reservoir reconstruction. The conductivity of supporting fracture is an important parameter to evaluate the effect of hydraulic fracturing in shale reservoir, and its size is affected by many factors[4-7].In order to maintain a good conductivity of fractures after the shale reservoir pressure, this paper evaluates the proppant by using the real rock plate simulation and the actual construction proppant to test the conductivity of the supporting fracture,laboratory experiments were carried out to study the effects of proppant type, sand concentration, proppant embedding and fracturing fluid residue on the conductivity of propped fractures.

2 Self supporting fracture conductivity test

In order to understand the conductivity of self-supporting fractures in Kong 2 shale oil reservoir without proppant, the core of well GD14 was used to prepare rock plate, and the fracture formed during fracturing was simulated by manual fracturing. The shear dislocation was 2.54mm to form self-supporting fractures. The conductivity test was conducted with reference to the short-term conductivity test standard SY/T 6302-2019 of fracturing proppant filling layer[8].

The self supporting fracture conductivity test is conducted by the fracturing acidizing conductivity test system developed by the laboratory. The principle of self supporting fracture conductivity test is Darcy law, as shown in Figure 1.After the self-supporting conductivity test, the test results of rock sample conductivity are shown in Figure 2.

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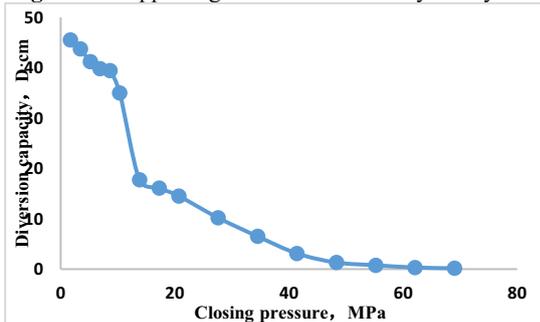**Fig. 1** Self supporting fracture conductivity test system

Fig. 2 Variation of self-supporting conductivity with closing stress

The conductivity of the self-supporting fracture decreases with the increase of closing stress, and the change process can be divided into three stages. In the first stage (the closure stress is less than 6.9MPa), when the closure stress is low, the conductivity of self-supporting fracture decreases with the increase of the closure stress, but the decrease is slow.In the second stage (the closure stress is between 6.9MPa and 13.8MPa), the conductivity of self-supporting fracture decreases rapidly when the closure stress increases. In the third stage (the closure stress is greater than 13.8MPa), the conductivity of self-supporting fracture decreases gradually with the increase of closure stress. When the closure pressure is 55.2MPa, the conductivity of self-supporting fracture is still 0.77d.cm, which meets the requirements of optimized conductivity of self-supporting micro fracture.But the self-supporting fracture can not meet the demand of conductivity of main fracture, so proppant should be added to meet the demand of reservoir stimulation.

3 Test of short term conductivity of proppant

Before testing the conductivity of proppant in the cracks of rock slab, it is necessary to know that proppant itself is not damaged by gel breaking fluid and the conductivity of proppant is not considered when it is embedded. Therefore, the short-term conductivity performance of proppant used in the process of rock slab testing is tested according to the short-term conductivity Test Standard

SY/T 6302-2019.The experimental scheme is shown in Table 1.

Tab. 1 Experimental scheme of conductivity test

Serial number	Test medium	Proppant particle size, mesh	Sand concentration，kg/m^2
1	clean water	30/50	5
2	clean water	40/70	5

The test results show that the conductivity decreases with the increase of closure pressure, and the conductivity decreases exponentially with the increase of closure stress.As shown in Figure 3 and Figure 4.
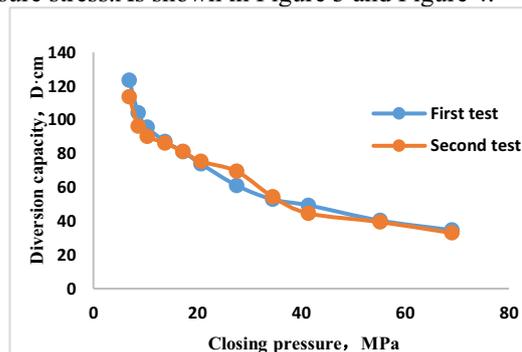

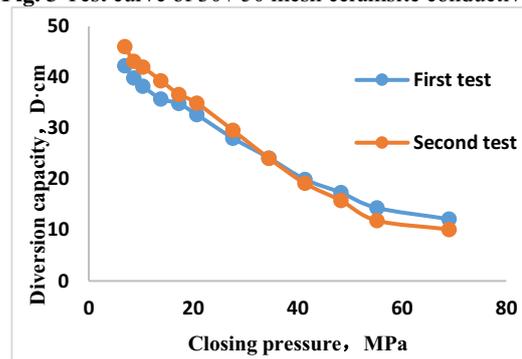**Fig. 3** Test curve of 30 / 50 mesh ceramsite conductivity

Fig. 4 Test curve of 40/70 mesh ceramsite conductivity

4 Test and Analysis on conductivity of rock slab with sand

This experiment simulates the conductivity of real formation fractures in Kong 2 formation of Dagang Oilfield, and tests the conductivity of supporting fractures by using field core, actual proppant, actual fracturing fluid and real formation pressure.

Shale oil reservoir fracturing adopts ceramsite with smaller particle size, and the designed maximum sand ratio and average sand ratio are low during fracturing operation. In order to understand the propping fracture conductivity under the condition of low sand ratio, the designed experimental scheme is shown in Table 2.

Tab. 2 Experimental scheme for conductivity of propped fracture

Serial number	Sand concentration，kg/m^2	Particle size, mesh	Type of fluid	Pretreatment type
35	5	30/50	0.45%gum guar+High anti swelling	
39	5	30/50	0.45%gum guar+Medium anti swelling	
36	3	30/50	0.45%gum guar+High anti swelling	
42	3	30/50	0.4%gum guar+Low anti swelling	Low flow displacement of breaker for 2 hours
40	5	40/70	0.4%gum guar+Medium anti swelling	
41	5	40/70	0.4%gum guar+Low anti swelling	
43	3	40/70	0.4%gum guar+Medium anti swelling	
38	3	40/70	0.45%gum guar+Medium anti swelling	

From 40 / 70 mesh and 30 / 50 mesh proppant conductivity test results , the proppant fracture conductivity is greatly affected by the roughness of the fracture surface in the low closure pressure stage, and the guar gum concentration and anti swelling performance have little influence. But under the high closure pressure, the proppant conductivity is mainly affected by the sand concentration. As shown in Figure 5 and Figure 6.

Fig. 5 Test results of fracture conductivity of 30/50 mesh ceramsite support

Fig. 6 Test results of fracture conductivity of 40/70 mesh ceramsite support

To sum up, the guar gum concentration and anti swelling performance in the fracturing fluid formula, as well as the particle size and sand concentration of proppant have a certain impact on its conductivity[9-11].According to the experimental results, when the reservoir closure pressure is about 50MPa, the average conductivity of 30/50 mesh proppant at 5kg/m^2 sand concentration is about 10.84D·cm, the average conductivity at 3kg/m^2 sand concentration is about 5.26D·cm; the average conductivity of 40/70 mesh proppant at 5kg/m^2 sand concentration is about 7.15D·cm, the average conductivity at 3kg/m2 sand concentration is 4.16D·cm about. Therefore, 40/70 mesh can basically meet the requirements of main fracture conductivity of Kong 2 tight oil reservoir at 5kg/m^2 sand concentration.

According to the optimization results of multi fracture conductivity in the early stage of Kong 2 shale oil reservoir[12], the 40/70 mesh proppant used in Kong 2 shale oil reservoir can meet the requirements of supporting fracture conductivity. Therefore, the amount of 40/70 mesh proppant should be optimized in fracturing design.
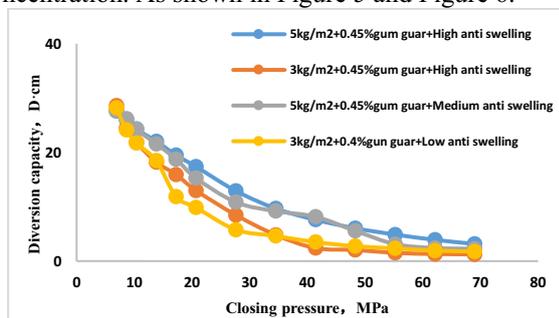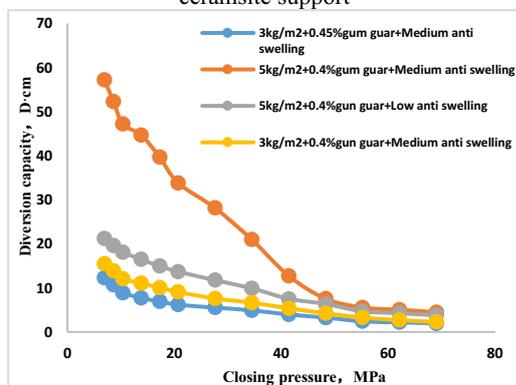
5 Analysis of influencing factors of diversion capacity

5.1 Effect of fracturing fluid residue on conductivity

After the proppant filling layer is damaged by the fracturing fluid, the proppant fracture conductivity will be greatly reduced. When the reservoir closure pressure is about 40MPa, the damage of fracturing fluid to the conductivity is about 50%, which indicates that the fracturing fluid residue has a great impact on the conductivity, as shown in Figure 7.
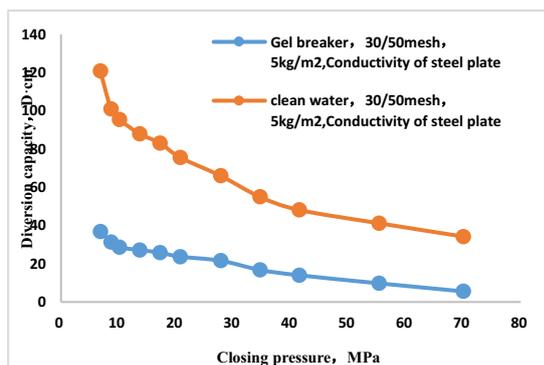
Fig. 7 Sand conductivity of 30/50 mesh ceramsite steel plate before and after fracturing fluid damage

5.2 Effect of proppant embedment on conductivity

In addition to the influence of fracturing fluid damage on proppant conductivity, the amount of proppant embedded in rock plate also has a certain influence on the conductivity. Therefore, the damage of proppant insertion is evaluated by completing the observation experiment of proppant embedding. The embedded depth of the test is analyzed by means of the ultra long focal length continuous zoom video microscope in the micro analysis room of the State Key Laboratory The results show that the depth and degree of the embedded rock plates are compared.As shown in Figure 8.

Fig. 8 Ziess STEMI SV 11 super long focal length continuous zoom video microscope

The embedding of proppant was observed and marked by ultra long focal length continuous zoom video microscope, as shown in Figure 9.
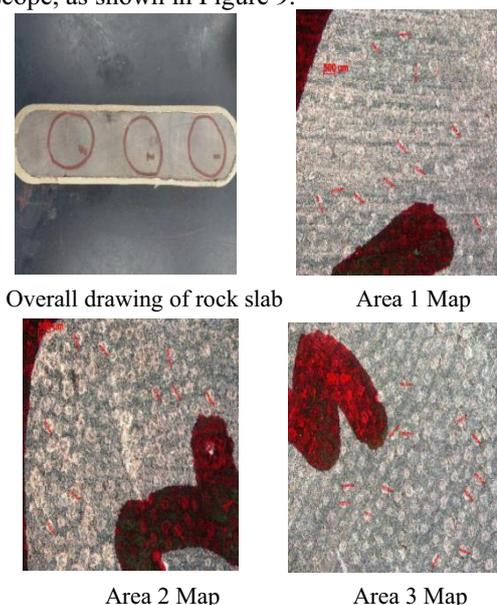

Overall drawing of rock slab   Area 1 Map

Area 2 Map   Area 3 Map

Fig.9 Observation and statistical chart of each area in the slab

According to the statistics and calculation of the points marked in the above figures, the embedded depth of each rock plate and the loss degree of conductivity are obtained, as shown in Table 3.

Tab. 3 Proppant embedment depth and conductivity loss

Plate number	Lithology	Proppant mesh	Sand concentration (kg/m²)	Average particle size of proppant (mm)	Embedment depth of proppant (mm)	Seam width of steel plate (mm)	Loss of diversion capacity (%)
35	Argillaceous dolomite	30/50	5	0.3625	0.0922	0.7775	0.24
36	mudstone	30/50	3	0.3625	0.1138	0.4551	0.50
38	mudstone	40/70	3	0.312	0.0615	0.2345	0.52
39	mudstone	30/50	5	0.3625	0.0875	0.7775	0.23
40	fine sandstone	40/70	5	0.312	0.0187	0.62595	0.06
41	fine sandstone	40/70	5	0.312	0.0177	0.62595	0.06
42	fine sandstone	30/50	3	0.3625	0.0339	0.4551	0.15
43	fine sandstone	40/70	3	0.312	0.0173	0.2345	0.15

The calculation results in Table 3 show that the stronger the argillaceous (the higher the clay content) is, the greater the embedding degree of proppant is, the greater the loss of conductivity is, as shown in Figure 10; for the same lithology, the proppant particle size has little damage to the conductivity, the sand concentration has a greater impact on the conductivity, and the greater the sand concentration is, the smaller the loss of conductivity is, as shown in Figure 11. Therefore, it is necessary to strengthen the anti swelling ability of rock and increase the sand concentration.
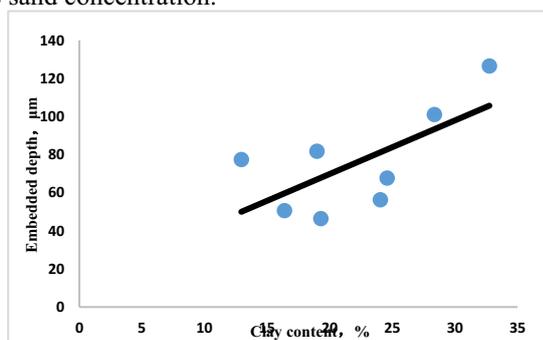

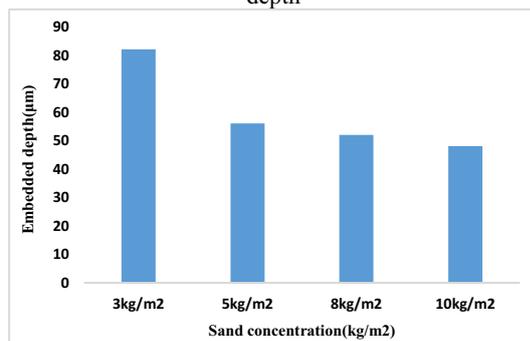**Fig. 10** Relationship between clay content and embedded depth

Fig. 11 Relationship between sand concentration and embedment depth

6 Conclusion and understanding

（1）According to the previous optimization results of the conductivity of the shale oil reservoir in kong 2, combined with this experiment, it shows that the average conductivity of 40/70 mesh proppant at 5kg/m^2 sand laying concentration is about 7.15d · cm under the condition of reservoir closure pressure of about 50MPa, which can basically meet the requirements of the main fracture conductivity of the shale oil reservoir in kong 2.

（2）Fracturing fluid damage and proppant embedment are two important factors that cause the conductivity of rock slab to decline greatly. Among them, fracturing fluid damage is greater, reaching about 50%, which is inevitable for vegetable gum fracturing fluid. If we want to further improve the proppant fracture conductivity, we can consider appropriately reducing the amount of guar gum.

（3）The degree of proppant embedding has a great influence on the conductivity. To reduce the damage of proppant embedding, the fractured layer should choose the section with low clay content as far as possible. In the reservoir with high clay content, the amount of anti expansion agent should be increased as much as possible, and the sand laying concentration of proppant should be increased as much as possible in the main fracture.

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