Study on Performance Evaluation of Self Suspension Proppant

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Abstract

In recent years, Unconventional oil and gas resources have gradually become an important part of oil and gas development. The development of the above resources must be applied to hydraulic fracturing technology. As a key material in fracturing technology, the proppant is an important factor influencing the success of fracturing. Experimental study on the basic parameters of proppant (roundness and sphericity, acid solubility, volume density, apparent density) and static settlement rule is based on extensive research. Compared to the proppant performance evaluation criterion, the parameters of quartz sand are basically in accordance with fracturing construction indicators, which can be applied for fracturing operation with low proppant requirement. The parameters of ceramsite are excellent which can be used in most fracturing operation. And self-suspension proppant also has good parameters, gelling and gelling breaking, can greatly simplify the oilfield fracturing site construction difficulty, so it can be a new kind of fracturing material as oilfield operation.

Keywords

Hydraulic fracturing, Low density proppant, Performance evaluation.

1. Introduction

As a key material in fracturing technology, the proppant is a vital factor influencing the success of fracturing.

The important role of proppant is to support fracturing fracture, so as to expand the oil and gas channel and enhanced oil recovery.

Conventional proppant due to high density, together with the fracturing fluid through the pump in the process of transporting, prone to sedimentation, the proppant is hard to reach the depths of the cracks or some branch fracture networks, cannot achieve the desired production, but if change the fracturing fluid viscosity or improve on fracturing fluid discharge, probably damage reservoir. Need low-density proppant at this moment, at the same fracturing fluid, proppant can migration further, enter the branch cracks that high-density proppant cannot reach, and achieve the goal of production.

Unconventional reservoirs, especially shale and tight oil and gas development, the current fracturing technology put forward higher requirements on the performance of the fracturing material, in order to meet the construction conditions, to be the comprehensive evaluation has lower density and strong compressive strength of the self-suspension proppant, compared with the current main application of proppant after provides a new choice to oilfield construction material as oilfield operation.

2. Experimental Test

According to the Enterprise standard of CNPC: *Performance index and evaluation test method of fracturing proppant*（Q/SY 125-2007）[1,2], testing the roundness and sphericity, acid solubility, apparent density, bulk density, self-suspension performance and other performance parameter of quartz sand(20/40 mesh) , ceramic granular, and self-suspension proppant.

2.1 Roundness and Sphericity

Roundness refers the relative sharpness or curvature of the edges of the proppant particles.

Sphericity refers the degree that proppant particles are close to the sphere[3].

Sphericity Standards: the sphericity and roundness of natural quartz sand is supposed to be greater than 0.60, and that of artificial ceramsite is greater than 0.80.

21~30 granules of proppant are taken out in different proppant samples at random and pictured under the stereomicroscope. According to the plate (Figure 1) , determine the roundness and sphericity of each proppant particle and calculate the average roundness and sphericity.

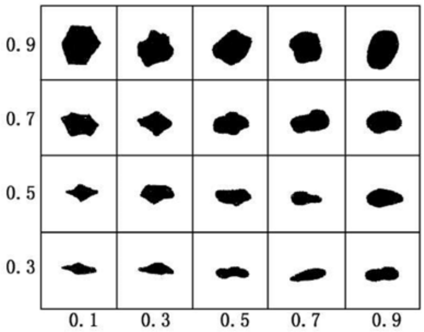

Fig.1 Plate of roundness and sphericity

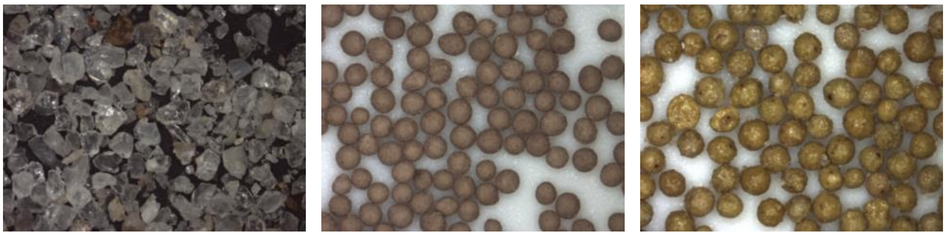

Fig.2 Microscope figures of the three types of prop pants (from left to right: quartz sand, Ceram site, self-suspension prop pant)

Table1 Roundness and sphericity of three types of prop pants

	quartz sand	ceramsite	self-suspension proppant
roundness	0.436	0.9	0.882
sphericity	0.74	0.9	0.9

The Table 1 shows the roundness and sphericity of three types of proppants .

Compared with the roundness and sphericity of quartz sand is 0.74, ceramic granule and self-suspending proppant is 0.9. The experiment results show that the self-suspension proppant has better roundness and sphericity.

2.2 Acid Solubility

The acid solubility of proppant refers that the ratio of the mass of a certain mass of proppant dissolved by acid to the total proppant mass under provided experimental condition[4].

Table 2 Referencing table of the acid solubility

Grain size specification /μm	Maximum allowable value of acid solubility %
3350~1700, 2360~1180, 1700~1000, 1180~850	≦5
1700~850, 1180~600, 850~425, 600~300, 425~250, 425~212, 212~106	≦7

(1) acid preparation

1.Add 250mL distilled water to the 500ml polytetrafluoroplastics measuring cylinder; then add 145.5ml(173g) hydrochloric acid whose concentration is 36% to 38% ; and then add the 35.45ml(40g) hydrofluoric acid(concentration :40%).

2. The above solution is diluted to 500 mL with distilled water and stir well(the solution density is 1.066 g/cm3 at the temperature of 20 ℃)getting the hydrochloric-hydrofluoric acid solution with 12:3 (mass ratio).

（2） Experimental Methods

1.Prepare the samples of proppant and dry the proper amount of proppant sample under the temperature of 105 ℃ for 1 hour. Then put it in the dryer to cool for 0.5 hour and weigh;

2. Take samples of the processed proppant 5 ±0.1 g;

3. Add 100 mL (106.6g) hydrofluoric acid solution to 250ml polytetrafluoroplastics beaker, and pour the weighed samples into the beaker;

4. Heat the beaker of acid solution and proppant samples for 0.5 h underwater bath temperature of 65 ℃;

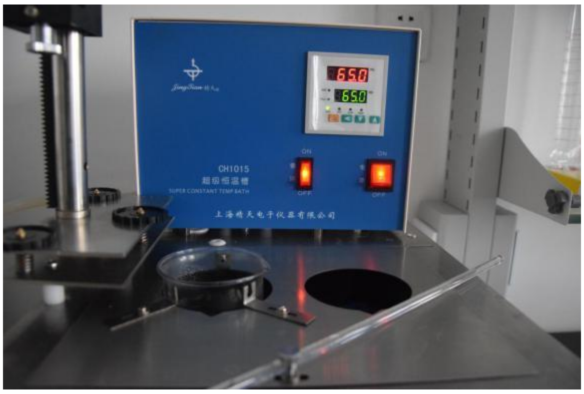

Fig.3 reaction of acid and proppant thermostatic water bath

5. Prepare filtration equipment: dry the qualitative filter paper for 1 h under the temperature of 105 ℃, weighing and recording its quality.

6. Pour the proppant samples and acid liquor into acid funnel. Make sure that all the proppant particles will pour into the acid funnel and then vacuum filtration;

7. During the extraction filtration process, the proppant samples are washed 5 ~6 times respectively with distilled water, and 20ml of distilled water was used every time, until the flushing liquid shows neutral.

8. Dry the filter paper and proppant samples for 1 h under the temperature of 105 ℃, and then cool for 0.5 h into the dryer;

9. Weigh the cooling filter paper and proppant sample immediately and record.

$$S = \frac{W_s + W_{fp} - W_{fs}}{W_s} \times 100\% \tag{1}$$

S ——acid solubility of proppant, %

W_s ——proppant sample mass, g

W_{fp} —— filter paper mass, g

W_{fs} —— total mass of filter paper and sample dissolved, g

The acid solubility of proppant can be calculated by formula (1) and the calculations are summarized in the table 3.

Table 3 Acid solubility of three types of proppant

	quartz sand	ceramsite	self-suspension proppant
Proppant mass before reaction W_s /g	5.0630	5.0041	5.0398
Filter paper mass W_{fp} /g	1.0134	1.0193	1.0179
total mass after drying W_{fs} /g	5.7771	5.7715	5.8259
Acid solubility of proppant S	5.91%	5.03%	4.60%

The experiment results show that the acid solubility of quartz sand is the highest at 5.91% while that of self-suspension proppant is lower at 4.60%. According to the standard, the solubility of acid is not less than 7%, so the self-suspension proppant shows good performance of acid-resistance.

2.3 Apparent density

Apparent density refers to the mass of proppant measured by its mass per unit of particle volume[5].

(1) Experimental Methods

1. weigh the density bottle mass g_1 ;

2. weigh the bottle full of water g_2 ;

3. pour out the water and dry the bottle;

4.Add a proper amount of proppant into the bottle and weigh it g_3 ;

5.fill the bottle with water and eliminate the air, fill it again and weigh g_4 ;

6. calculate the apparent density:

a) the mass of water in the bottle: $G_w = g_2 - g_1$

b) the mass of proppant in the bottle: $G_s = g_3 - g_1$

c) the volume of water in the bottle: $V_w = G_w / P_w$

d) the volume of water in the bottle with proppant : $V_{w1} = g_4 - g_3 / P_w$

e) the volume of proppant in the water: $V_s = V_W - V_{w1}$

f) the apparent density of proppant:

$$S= S=G_s/V_S \tag{2}$$

the mass of bottle (g_1) is 23.364g;

the mass of bottle full of water (g_2) is 72.5239g;

Table 4 Relative apparent density data of three types of proppant

	quartz sand	ceramsite	self-suspension proppant
mass of bottle with proppant g_3 /g	55.9884	58.2016	50.9446
mass of proppant added into the bottle G_s /g	32.6244	34.8376	27.5806
mass of proppant added into the bottle g_4 /g	93.0433	96.0513	89.5996
volume of water added into the bottle V_w /ml	49.344	49.344	49.344
volume of bottle with water and proppant V_{w1} /ml	37.0549	37.8497	38.6550
volume of proppant added into the bottle V_s /ml	12.2891	11.4943	10.6890
The apparent density/g·cm^{-3}	2.5915	3.0309	2.5803

The three types of proppant are tested by the above methods and the data are summarized in the table 4. The experiment results show that the apparent density of ceramsite is the highest at 5.91% while that of self-suspension proppant is lower than quartz sand at 4.60%.

2.4 Bulk density

Bulk density refers to the mass of proppant measured by its mass per unit of packing volume.

（1）Experimental methods

1 weigh the density bottle(50mL)；

2. Add the sample to the bottle reaching the scale of 50mLand weigh the bottle with proppant, repeat the process three times and average the results;

3. calculate the bulk density of proppant:

$$\text{Bulk Density}=W_{gp}-W_{g}/50 \qquad (3)$$

W_{gp} = the mass of bottle and proppant, g

W_{g} = the mass of the density bottle, g

Table 5 Relative bulk density data of three types of proppant

	quartz sand	ceramsite	self-suspension proppant
The total mass of bottle and proppant reaching the scale of 50mL of the bottle W_{gp}/g	87.4409	105.4486	94.3780
	87.4412	105.4485	94.3781
	87.4407	105.4462	94.3782
Average result/g	87.4409	105.4478	94.3781
Bulk density/g·cm^{-3}	1.7488	2.1100	1.8876

The three types of proppant are tested by the above methods and the data are summarized in the above table 5 .The experiment results show that the bulk density of ceramsite is the highest at 2.11g/cm3 while that of quartz sand is the lowest at 1.7488 g/cm3. Meanwhile, the bulk density of self-suspension proppant is 1.8876 g/cm3.

2.5 Static sedimentation experiment

Design the static sedimentation experiment of different proppant in fracturing fluid to measure the performance of proppant more comprehensive. Two different guar gum fracturing fluid whose viscosity are 50 mPa·s and 100 mPa·s respectively are used in the experiment to make the results more objective.

Under the 170s-1 sheer rate condition, the apparent viscosity of different guar gum fracturing fluid which are made up with guar gum powder (3%) and clear water (30℃) and different quantity of crosslinking agent (0.4% and 0.5% respectively) are 50 mPa·s and 100 mPa·s respectively. Quartz sand of 20/40 mesh and ceramsite of 20/40 mesh and self-suspension prppant of 20/40 mesh are used in the experiment.

（1）Experimental methods

1. Add 500mL guar gum fracturing fluid whose viscosity is 50 mPa·s to three cylinder respectively;

2. Measure 50mL of three types of proppant respectively, and the sand concentration of fracturing fluid is 10%;

3. Add proppant to three cylinders respectively and mix well making sure uniform distribution of proppant in the fracturing fluid. Take pictures to record the settlement of proppant every once in a while and record the final sedimentation time;

4. Chang the viscosity of fracturing fluid to 100 mPa·s and repeat the above steps and record.

（2）Experimental processes

Figure 4 shows that in the gaur gum fracturing fluid whose viscosity is 50mPa•s, ceramsite is the earliest to settle among the three types of proppant once stopping mixing and sink at the bottom in 92s. Quartz sand also begin to settling once stopping mixing but the rate is slower sinking 138s of settlement time. It takes the longest time for self-suspension proppant to sink at the bottom and it sinks half of the height in 300s. The whole settlement time of self-suspension proppant takes 1380s.

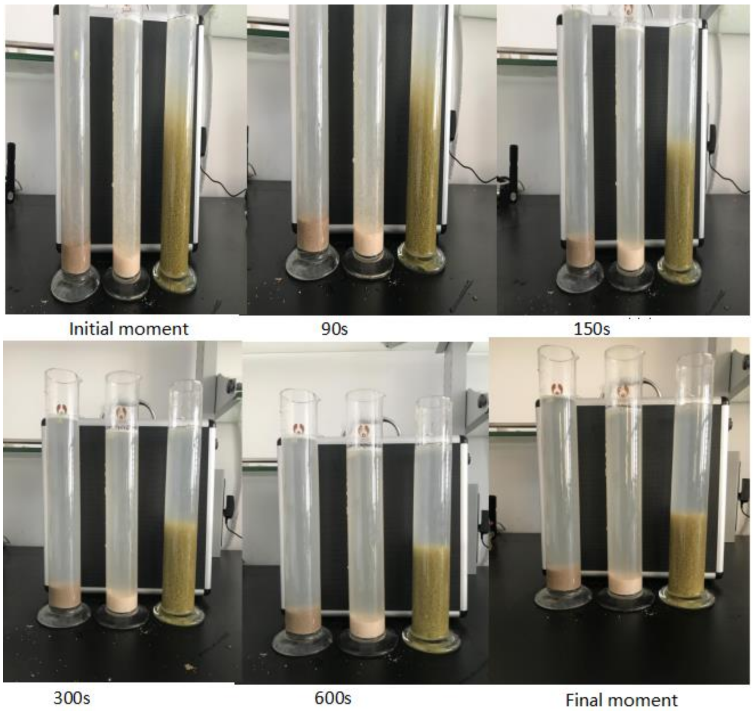

Fig.4 Pictures of static sedimentation experiment (fracturing fluid viscosity: 50mPa•s. from left to right: quartz sand, ceramsite, self-suspension proppant)

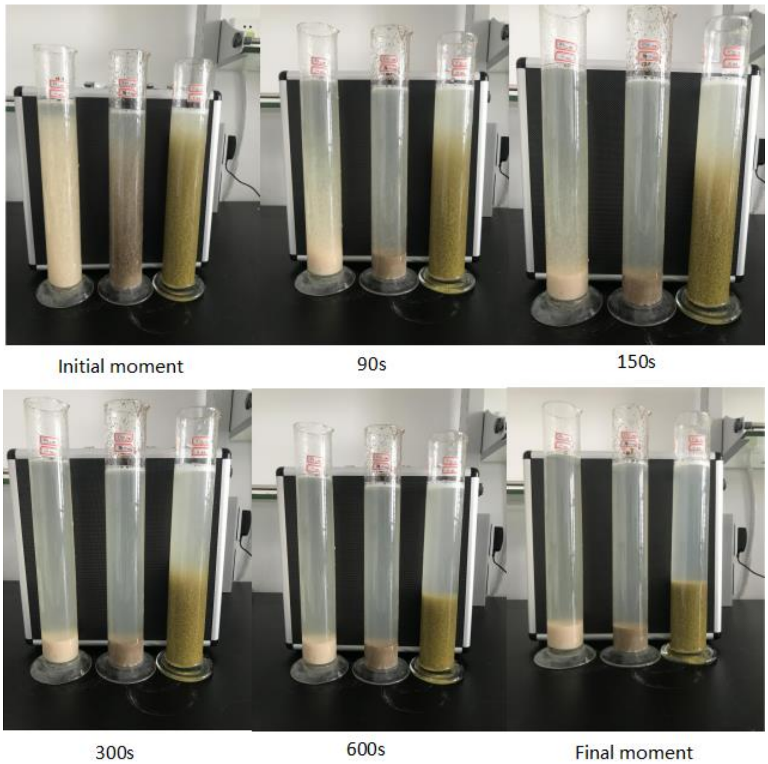

Fig.5 Pictures of static settlement experiment (fracturing fluid viscosity: 100mPa•s. from left to right: quartz sand, ceramsite, self-suspension proppant)

Figure 5 shows that in the gaur gum fracturing fluid whose viscosity is 100mPa•s, the settlement law is similar to the law presented in the precious fracturing fluid except that the settlement time is slower. Ceramsite experiences 160s of settlement time and it takes the 258s for quartz sand to sink at the bottom. Self-suspension proppant sink half of the height in 300s and one third in 600s. The whole settlement time of self- settlement time suspension proppant takes 2520s.

Table 6 Settlement time of prop pant in guar gum fracturing fluid

Type	Settlement time in fracturing fluid (501mPa•s)/s	Settlement time in fracturing fluid(100mPa•s)/s
Quartz sand	138	258
Ceramsite	92	160
Self-suspension proppant	1380	2520

The static settlement times are summarized in the above table (Table 6) and it shows that the settlement laws of three types of proppant are similar in different guar gum fracturing fluid. The settlement time of ceramsite is the shortest followed by quartz sand. Compared with the ceramsite and quartz sand, the settlement time of self-suspension proppant can even grow to more than ten minutes to dozens minutes.

2.6 Gelling property experiment of self-suspension proppant

Experiment on the evaluation of gelling property of self-suspension proppant is performed. Mix self-suspension proppant with 400mL formation water whose salinity is 500mg/L at room temperature while the proppant concentration is 30%, 40% and 50% respectively. Record the time when the liquid level bulges slightly as the time starting suspending, at the very condition of proppant concentration and salinity. Test the static self-suspension performance at room temperature and the results are in the following table.

Table 7 Self-suspension performance data at certain salinity (500mg/L)

Proppant concentration,%	Suspension time, s	Self-suspension performance (room temperature)
30	90	Sink slightly(5min) ,Sink 1/2(30min) Sink at bottom(2h)
40	80	Sink slightly(30min) ,Sink 1/6(2h)
50	70	No sinking

When the proppant concentration is 30%, the proppant sink slightly after 5 minutes and sink half of the height after 30 minutes and sink at bottom after 2 hours. When the proppant concentration is 40%, the proppant sink slightly after 30 minutes and sink one sixth after 2 hours. There is no sinking behavior when the proppant concentration is 50%

2.7 Gel-out property experiment of self-suspension proppant

Experiment on the gel-out property of self-suspension proppant is performed aimed at its gelling property. Prepare fracturing fluid whose proppant concentration is 20% with clear water and add in gel breaker ammonium persulfate of different proportions. Put them in 90℃ water to keep constant temperature and stir every 10 minutes until the bottom proppant dispersing. Test the viscosity of top clear liquid and take the time when the viscosity is under 5mPa·s as the gel breaking time. Observe the behavior of gel breaking.

Table 8 Gel breaking time at different amount of gel breaker and the viscosity of top clear liquid

Amount of gel breaker	Gel breaking time, min	Viscosity, mPa·s
0.05%	360	7.46
0.08%	80	4.37
0.10%	70	4.06
0.12%	60	4.90
0.15%	50	4.88

Stop stirring at room temperature, the proppant in the suspension of self-suspension proppant (proppant concentration: 20%) adding in different amount of gel breaker at the temperature of 90℃

sink quickly causing negative effects on suspension. Put the top clear liquid quietly to break gel. The lower fracturing fluid can be picked up. Stir every 10 minutes in the water bath until the bottom proppant dispersing. Test the viscosity of top clear liquid and take the time when the viscosity is under 5mPa·s as the gel breaking time. When the amount of gel breaker is 0.05%, there is no gel breaking at all after 360 minute（final viscosity:7.46 mPa·s）.

Amount of gel breaker 0.08%: taking 80 minutes to break gel (viscosity of gel breaking liquid: 4.37mPa·s)

Amount of gel breaker 0.10%: taking 70 minutes to break gel (viscosity of gel breaking liquid: 4.06mPa·s)

Amount of gel breaker 0.12%: taking 60 minutes to break gel (viscosity of gel breaking liquid: 4.90mPa·s)

Amount of gel breaker 0.15%: taking 50 minutes to break gel (viscosity of gel breaking liquid: 4.88mPa·s)

3. Conclusion

(1) The roundness and sphericity of quartz sand are 0.43 and 0.74 respectively and individual shape difference is obvious. The apparent density and bulk density are 2.5915g/cm3 and 1.7488g/cm3 respectively and the acid solubility is 5.91% , meeting the standards. The settlement rate of quartz sand is fast a little which can be used in the fracturing operations having lower requirement for proppant;

(2) The roundness and sphericity of ceramsite are both 0.9. The apparent density and bulk density are 3.0309g/cm3 and 2.1100g/cm3 respectively and the acid solubility is 5.03% meeting the standards. But its settlement rate is fast a little so it can be used in most fracturing operations;

(3) The roundness and sphericity of self-suspension proppant are both 0.9. The apparent density and bulk density are 2.5803g/cm3 and 1.8876g/cm3 respectively. The settlement rate of self-suspension proppant is slow and it has the self-suspension property. Meanwhile, it owns good performance of gelling property and gel-out property which can be used as a new alternative in in the fracturing operations.

Acknowledgements

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