Modern Environmental Science and Engineering (ISSN 2333-2581)
September 2022, Volume 8, No. 9, pp. 453-458
Doi: 10.15341/mese(2333-2581)/09.08.2022/001
Academic Star Publishing Company, 2022
www.academicstar.us

Experimental Study on Characteristics of Massive Fracturing Flow Back Fluid

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Abstract: In Daqing oilfield, the produced water from fracturing cannot consistently meet the standard, especially the suspended solids. In order to improve the current produced water treatment, the basic properties of produced water from fracturing are monitored and analyzed, the separation properties of fracturing fluid, fracturing produced water and ordinary produced water were investigated and compared. Experimental results show that the separation of the fracturing produced water is more difficult than that of ordinary produced water, separation measures should be strengthened to improve the separation efficiency. Filtration technology has obvious effect on the removal of suspended solids. Centrifugal separation technology has a good effect on the treatment of fractured water, but which need to consider the size, construction investment, operation and maintenance costs and other factors. Air flotation technology has obvious effect on the removal of oil and suspended solids, the removal rate of oil content and suspended solids in more than 73.4 percent and 63.6 percent separately, industrial application can be considered.

Key words: the fracturing fluid, the produced water, the basic characteristics, the separation characteristics

1. Introduction

Massive fracturing is becoming an important technical measure to exploit tight reserves in peripheral oilfields of Daqing [1]. At present, there are two typical measures to massive fracturing stimulation in oilfields: network fracturing and cutting volume fracturing. In network fracturing, the fracturing fluid is typically composed of sliding water fracturing fluid and gelling fracturing fluid, whereas in volume fracturing, the major components are gelling fracturing fluid and acid [2]. After massive fracturing, only a portion of the fracturing fluid may flow back (fracturing flowback fluid), and it enters the production system when the oil well is placed into production [3]. This part of fracturing flowback fluid comprises various additives such as thickening agent, the slop oil returned from the formation and the terminal products of the reaction between the fracturing fluid and the formation [4]. The produced water containing fracturing flowback fluid is called fracturing produced water. The properties of the fracturing produced water change substantially as majority of the additives enter the water phase, and it has a severe impact on the normal operation of the wastewater treatment process. For example, the demand for water treatment agents has increased greatly [5], but the treatment effect of water treatment agents has dramatically decreased, and the wastewater treatment system (particularly suspended solids) is unable to fulfill the operational standard. In this paper, in a fracturing operation block of the oil production

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plant in the periphery oilfield of Daqing, the water qualities and laboratory comparative experiments are carried out to give a foundation for determining the industrialized process and operational parameters of this type of produced water up to the standard.

2. Properties of Fracturing Flowing Back Water

The gel plug was broken after 15 days of massive fracturing operation. From the beginning of pumping, the basic properties of produced water, such as oil content, suspended solid content, median particle size and viscosity, compared with those of non-fracturing wells in the same block are shown in Table 1.

Table 1 shows that the average oil content of the produced water of the fractured well is lower than that of the produced water of the non-fractured well due to the less oil in the initial stage of pumping. The suspended solid contents of the produced water of the fractured well are all higher than those of non-fractured produced water, with the average content of the non-fractured produced water being 113 mg/L and that of fractured produced water being 253 mg/L. The average viscosity of produced water from fractured wells increases significantly. The average viscosity of non-fractured produced water is 0.76 mPa·s, while that of fractured produced water is 1.50 mPa·s. Therefore, the treatment difficulty of produced water from fractured wells is higher than that of non-fractured wells.

Table 1 Basic properties of produced water in fractured wells and non-fractured wells.

NO.	Oil Content (mg/L)		Suspended Solid Content (mg/L)		Median Particle Size (μm)		Viscosity (mPa·s)	
	Fractured Wells	Non-fractured Wells	Fractured Wells	Non-fractured Wells	Fractured Wells	Non-fractured Wells	Fractured Wells	Non-fractured Wells
1	15.3	304	180	102	**	12.4	2.24	0.731
2	16.0	412	224	98.8	**	8.60	2.71	0.792
3	18.3	335	384	116	**	10.5	3.80	0.718
4	14.2	368	257	108	4.00	9.80	2.08	0.764
5	21.4	418	370	152	**	4.25	1.79	0.782
6	149	252	447	98.7	**	6.08	0.930	0.771
7	580	539	350	114	15.9	10.4	0.713	0.765
8	232	429	248	96.4	10.0	10.5	0.727	0.742
9	303	306	190	128	8.60	8.92	0.735	0.776
Average	87.5	374	253	113	6.89	9.05	1.50	0.760

Note: ** indicate that the water sample cannot be detected.

3. Separation Characteristics of Fractured Produced Water

3.1 Sedimentation Separation Test of Fractured Produced Water

The sedimentation test was carried on produced water from a combined station with cutting volume fracturing flowback fluid. The natural sedimentation characteristics of conventional water flooding produced water, fracturing produced water and fracturing flowback fluid without fracturing fluid are shown in the Figs. 1 and 2.

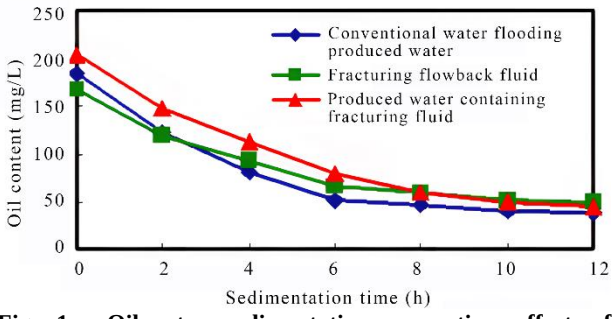

Fig. 1 Oil-water sedimentation separation effect of different produced water.

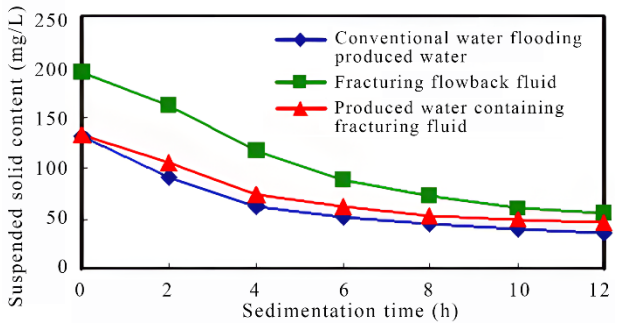

Fig. 2 Separating effects of suspended solids from different produced water.

After 6h sedimentation, the oil content of conventional water flooding produced water, fracturing produced water and fracturing flowback fluid without fracturing fluid reached 52.0 mg/L, 67.0 mg/L and 79.0 mg/L, respectively while the suspended solids content were 51.0 mg/L, 88.0 mg/L and 62.0 mg/L. After 6 h sedimentation, the oil content of the fracturing produced water is 51.9% higher than that of the conventional water flooding produced water, and the suspended solid is 21.6% higher. It demonstrates that the sedimentation separation of fracturing produced water is more difficult than that of conventional water flooding produced water, and the separation measures must be strengthened to improve the separation effect.

3.2 Flotation Separation Test of Fractured Produced Water

Test medium: the volume fracturing flowback fluid of cutting type (fracture network type) was mixed with the produced water, and stirred at a speed of 500 r/min for 5 min. The fracturing flowback fluid accounted for 50% and 100% of the total water. Cavitation air flotation test was conducted on the produced water containing fracturing fluid in the laboratory. The test results are shown in Figs. 4 and Fig. 5.

It can be seen from Fig. 4 that the oil and suspended solids removal rates of the produced water containing 50% cutting volume fracturing are 75.5% and 70.1% respectively after 12 min air flotation, and the oil content and suspended solids removal rates of the produced water containing 50% fracture network volume fracturing are 74.9% and 67.0%, respectively. The removal rates of oil content and suspended solid in 100% cutting volume fracturing fluid were 73.4% and 63.9%, respectively. The oil content and suspended solid removal rates in the produced water of 100% fracture network volume fracturing are 74.8% and 63.6%, respectively. The results indicate that air flotation has a significant removal effect on oil and suspended solids in fracturing water.

Fig. 3 Air floatation test picture of produced water containing fracturing fluid.

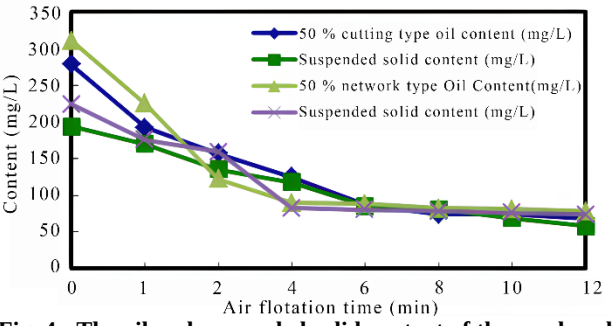

Fig. 4 The oil and suspended solid content of the produced water containing 50 % fracturing fluid.

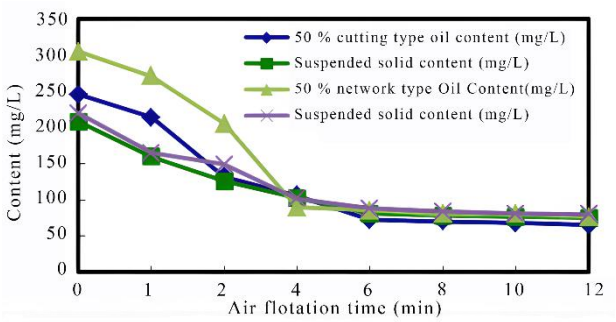

Fig. 5 The oil and suspended solid content of the produced water containing 100 % fracturing fluid.

3.3 Centrifugation Test of Fracturing Produced Water

Test medium: The cutting (fracture mesh) volume fracturing flowback fluid and the produced water were mixed at a speed of 500 r/min for 5 min. The fracturing flowback fluid accounts for 50% and 100% of the total water. Test conditions: Centrifuge at 2500 r/min for 3 min. The results are shown in Table 2.

According to Table 2, the removal rates of oil content and suspended solids content in produced water containing 50% cutting volume fracturing flowback fluid by centrifugation were 77.6% and 86.4% respectively after centrifugation. The oil content and suspended solids content removal rates in produced water containing 50% fracture mesh volume fracturing flowback fluid were 86.1% and 87.5% respectively. The removal rates of oil content and suspended solids content of cutting volume fracturing flowback fluid were 62.7% and 83.2% respectively; The removal rates of oil content and suspended solids content of fracture mesh volume fracturing flowback fluid were 70.5% and 77.2% respectively. The results show that centrifugation has a good removal effect on produced water containing fracturing flowback fluid, fracture mesh volume fracturing flowback fluid has a better removal impact than cutting volume fracturing flowback fluid.

3.4 Filtration Test of Fracturing Produced Water

Test medium: The cutting (fracture mesh) volume fracturing flowback fluid and the produced water are mixed at the speed of 500 r/min for 5 min. The

Fig. 6 Centrifugation test of produced water containing fracturing fluid.

fracturing flowback fluid accounts for 50% and 100% of the total water. Test method: After 6 h of static sedimentation at 40℃, the water sample is obtained in the middle of the sedimentation column as the raw water, and the filtration test with neutral filter paper is conducted. The results are shown in Table 3.

The results of suspended solids contents of produced water comprising fracturing fluid treated by filtration are shown in Table 3. The suspended solids in the produced water of 50% cutting volume fracturing flowback fluid were removed by 70.1% after filtration and the suspended solids were removed by 74.8%. The suspended solids of 100% cutting volume fracturing flowback fluid were removed by 65.4%and the suspended solids were removed by 66.1%. The test results show that filtration has a significant effect on the removal of suspended solids in produced water

containing fracturing fluid.

Table 2 Centrifugation test results of produced water containing fracturing fluid.

NO.	Medium	Oil content mg/L		Oil removal rate %	Suspended solids content mg/L		Suspended solids removal rate %	Appearance description of water sample
		Before centrifugation	After centrifugation		Before centrifugation	After centrifugation		
1	Produced water containing 50% cutting volume fracturing flowback fluid	136	30.5	77.6	121	16.4	86.4	Yellow flocculent suspended solids
2	Produced water containing 50% fracture mesh volume fracturing flowback fluid	145	20.2	86.1	144	18.0	87.5	Yellowish gray granular suspended solids
3	Cutting volume fracturing flowback fluid	201	75.0	62.7	152	25.6	83.2	Yellowish gray granular suspended solids
4	Fracture mesh volume fracturing flowback fluid	258	76.1	70.5	149	34.0	77.2	Black granular suspended solids

Table 3 Test results of filtration of produced water containing fracturing fluid.

NO.	Medium	Suspended solids content mg/L		
		Raw water	First filtration	Second filtration
1	Produced water containing 50% cutting volume fracturing flowback fluid	182	148	53.0
2	Produced water containing 50% fracture mesh volume fracturing flowback fluid	210	131	53.0
3	Cutting volume fracturing flowback fluid	202	87.0	70.0
4	Fracture mesh volume fracturing flowback fluid	214	91.2	72.5

4. Conclusions and Suggestions

According to experimental study on basic characteristics and separation characteristics of produced water containing fracturing fluid in laboratory, the following conclusions are drawn：

1) The sedimentation separation test demonstrates that the treatment difficulty of different produced water treated by sedimentation separation ranges from difficult to easy in the following order: fracturing flowback fluid > produced water containing fracturing fluid > produced water from ordinary water drive.

2) The centrifugation test and filtration test show that treating produced water containing cutting volume fracturing flowback fluid is more challenging than treating produced water containing fracture mesh volume fracturing flowback fluid. Especially the increase of suspended solids and viscosity.

3) The treatment result of air flotation technology for produced water containing fracturing fluid is favorable, and it can be considered for industrial application; the effect of centrifugal treatment is also good, but other factors such as treatment scale, operation and maintenance cost must be taken into account for industrial application.

4) The results show that sedimentation, air flotation and filtration technologies can efficiently treat the produced water containing fracturing fluid. The majority of current sewage treatment stations adopt two-stage sedimentation and two-stage filtration processes. Therefore, the industrial treatment process can be implemented by adjusting the sedimentation section and filtration section of the sewage treatment station.

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