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Research on a New Nitrogen Foam Fracturing Fluid System and its Application in Tight Gas

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ABSTRACT

Sichuan XX block belongs to the "low porosity, low permeability, low pressure" gas reservoir, and the effect of conventional fracturing is ignored, and the nitrogen foam fracturing process is recommended after analysis. After the optimization and evaluation of laboratory experiments, a nitrogen foam fracturing fluid system suitable for Sichuan block was formed, and the results showed that the system had the characteristics of low damage, low filtration loss and strong sand carrying capacity compared with the traditional fracturing fluid. The pilot test of the nitrogen foam fracturing fluid system was carried out in this block, and compared with the conventional guanidine gum fracturing fluid construction wells in the same block, it has obvious advantages in terms of construction pressure, liquid efficiency, sand suspension capacity, and flowback rate. The gas time is significantly shortened, and the daily gas production is significantly increased, indicating that the new nitrogen foam fracturing fluid system has achieved good fracturing results.

KEYWORDS

Foam, Fracturing Fluid, Nitrogen, Low Damage.

1. INTRODUCTION

At present, the XX block in Sichuan is a typical gas reservoir with "low porosity, low permeability and low pressure", and the formation pressure coefficient is only 0.75. In the early stage, when the traditional guanidine fracturing fluid was used for stimulation operations, the flowback time was more than 15 days, and the average flowback rate was only 25.6%, and a large amount of working fluid was retained in the formation, causing further damage to the reservoir and the production was not high. In view of these phenomena, how to improve the flowback capacity of the reservoir well fluid has become the key to improve the fracturing effect. The field situation shows that the conventional fracturing technology can no longer be adapted to this block, and a new process needs to be introduced to improve the flowback rate and rate of fracturing fluid, so as to reduce the damage of fracturing fluid to the reservoir and improve the stimulation effect of fracturing transformation.

Foam fracturing fluid has the characteristics of low filtration loss, strong flowback ability, and good compatibility with formation fluid, and can be applied to the transformation of low-pressure, low-permeability and low-gas-producing wells[1-5]. Foam fracturing refers to the unstable dispersed foam system formed by gas, water and surfactant as fracturing fluid for fracturing construction process, due to the gas contained, the fracturing fluid system has the characteristics of small damage to the formation, less filtration loss, strong sand carrying capacity, fast flowback speed, high flowback rate, especially suitable for the stimulation and transformation of low-pressure and low-permeability formations[5-11]. At present, foam fracturing has become one of the important research directions of fracturing technology in low-pressure and low-permeability gas reservoirs.

According to the geological conditions of the block, a new nitrogen foam fracturing fluid system suitable for the reservoir was developed through a large number of experiments, and the foaming ability, foam stability, rheological properties, sand carrying properties, filtration properties and damage to the formation of the fracturing fluid system were evaluated in the laboratory, and it was successfully applied in the field, providing scientific experience for the development of the block.

2. EXPERIMENTAL PART

2.1. Materials and Equipment

Experimental materials: RD-1 foaming agent, RD-2 foaming agent, KR-10 foaming agent, KR-20 foaming agent, slippery water (0.2% thickener + 0.2% clay stabilizer + 0.25% waterproof lock agent + 0.005% ammonium persulfate), high-purity nitrogen.

Experimental equipment: electric stirrer, surface tension meter, rotary rheometer, static filtration instrument, constant temperature water bath, constant temperature drying oven, electronic balance, glass beaker, glass measuring cylinder, stopwatch.

2.2. Screening of foaming agents

The screening of foaming agent was carried out by WaringBlender experimental method, the same amount of slippery water was added to the same amount of different foaming agents, stirred for 3 min under the condition of electric stirrer speed of 4000 r/min, and the glass measuring cylinder was poured quickly after stirring, the foam volume was read and the foam quality was calculated under normal temperature and pressure, and the half-life of foam was recorded to characterize the half-life of foam precipitation, and the high-efficiency foaming agent was selected based on the foam quality and half-life of liquid separation[1-5].

2.3. Performance evaluation method of fracturing fluid system

2.3.1. Foaming capacity and foam stability

According to the formula in 1.2, different treatment agents were added to the high-temperature and high-pressure foam evaluation instrument in turn, the initial solution was 100 mL, the experimental temperature was set to 60 °C, then nitrogen was filled to a certain pressure, after high-speed stirring for 3 min, the foam volume V was measured, and then the half-life T of the foam was measured using a stopwatch timer, so as to evaluate the foaming ability and foam stability of the fracturing fluid system under different pressure conditions[3-4].

2.3.2. Rheological properties

According to the formula in 1.2, the nitrogen foam fracturing fluid system with a foam mass fraction of 75% was formulated, and the viscosity value of the new nitrogen foam fracturing fluid system was determined by DV-II. Pro digital display rotational viscometer at different shear times at an experimental temperature of 60 °C and a shear rate of 170 s^{-1}.

2.3.3. Sand carrying performance

The formula of the fracturing fluid system is the same as that described in 1.2, quartz sand with a particle size of 30~50 mesh is selected as the proppant to evaluate the sedimentation rate of the single particle proppant in the new nitrogen foam fracturing fluid system, and compared with the clear water, conventional guanidine gum fracturing fluid and slippery water fracturing fluid system to evaluate its sand carrying performance, and the experimental temperature is selected as 60 °C.

2.3.4. Filtration performance

The formula of the fracturing fluid system is the same as that described in 1.2, and the static filtration coefficient of the nitrogen foam fracturing fluid system was determined by using a high-temperature and high-pressure filtration instrument, and compared with the conventional guanidine fracturing fluid and slippery water fluid system, the experimental temperature was selected as 40, 50, 60 °C, and the experimental pressure was 5Mpa[3-6].

2.3.5. Damage to the reservoir

The formula of the fracturing fluid system is the same as that described in 1.2, and the damage of the nitrogen foam fracturing fluid system to the permeability of the core matrix of the target block was evaluated with reference to the standard of NB/T 10034-2016 "Performance Evaluation Method of Water-based Fracturing Fluid", and compared with the conventional guanidine gum fracturing fluid and slippery fracturing fluid system at an experimental temperature of 60 °C[1-5].

3. EXPERIMENTAL RESULTS

3.1. Screening results of foaming agents

The foam quality and half-life of different blowing agents after foaming at the same concentration are shown in Figure 1. As can be seen from Figure 1, the foam quality of RD-2 blowing agent reached 74.70% and the half-life was 23.2 min after stirring in slippery water with a concentration of 1% and a volume of 250 m, and the performance was the best.

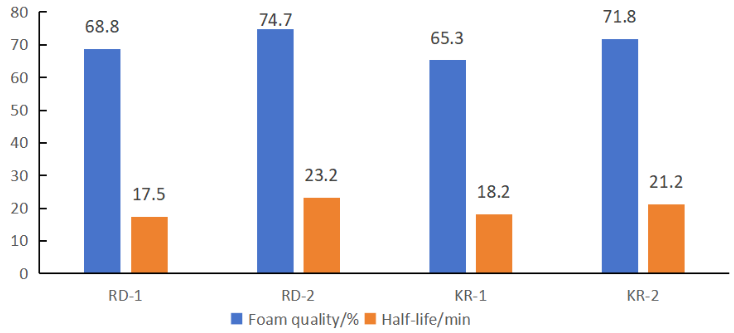

Figure 1: Foam quality and half-life of different blowing agents after foaming in slippery water

3.2. Foaming capacity and foam stability

The foaming volume and half-life of the fracturing fluid system under different pressure conditions were evaluated according to the experimental method in 1.3.1, as shown in Figure 2. Under formation conditions, the system has good foaming ability and foam stability, which can ensure the smooth progress of fracturing construction.

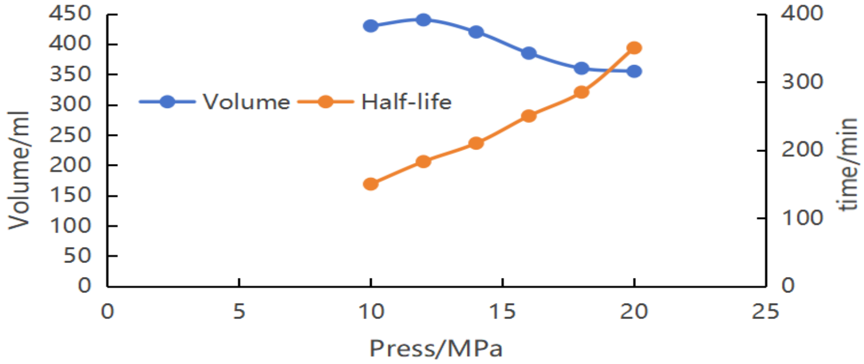

Fig.2 Foaming capacity and foam stability

3.3. Rheological properties

According to the experimental method in 1.3.2, the viscosity of the new nitrogen foam fracturing fluid system was evaluated as a function of shear time, as shown in Figure 3. After 120 min, the viscosity was also stable at 60mPa.s, indicating that the foam fracturing fluid system had high shear resistance and thermal stability.

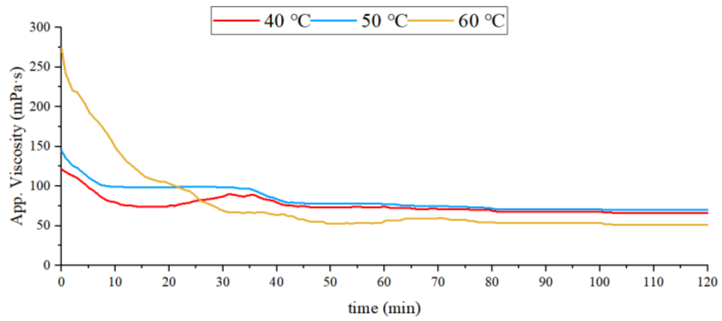

Figure 3 Viscosity curve

3.4. Sand carrying performance

According to the experimental method in 1.3.3, the sedimentation rate of quartz sand in the new nitrogen foam, conventional guanidine gum and slippery water fracturing fluid system is determined, and a large amount of liquid enters the formation, and the formation temperature will decrease, so the temperature is designed to be 40, 50 and 60 °C respectively, and the experimental results are shown in Table 1. It can be seen that the sedimentation velocity of nitrogen foam fracturing is the smallest, which is conducive to the distal transport of proppant and can effectively improve the laying of proppant in fractures.

Table 1 Sedimentation velocity of proppant in different fracturing fluids

Liquid type	Sedimentation velocity at different temperatures/(mm.s-1)		
	40℃	50℃	60℃
Nitrogen foam fracturing fluid	0.0034	0.0045	0.0041
Slippery water	0.013	0.024	0.056
Guanidine gum fracturing fluid	0.0073	0.012	0.018

3.5. Filtration performance

The static filtration coefficients of different fracturing fluid systems were determined according to the experimental method in 1.3.4, and the experimental results are shown in Table 2.

It may be seen that the filtration coefficient of nitrogen foam fracturing is significantly reduced, which greatly increases the efficiency of liquid use. The reduction of filtration increases the net pressure and reduces the risk of sand plugging

Table 2 Filtration performance of different liquids

Liquid type	Filtration coefficient at different temperatures /(×10-3m.min-1/2)		
	40℃	50℃	60℃
Nitrogen foam fracturing fluid	0.034	0.042	0.065
Slippery water	1.23	1.89	2.5
Guanidine gum fracturing fluid	0.078	0.91	1.08

3.6. Damage to the reservoir

The damage of different fracturing fluid systems to the permeability of the core matrix in the target block was evaluated according to the experimental method in 1.3.5, and the experimental results are shown in Table 3. Compared with other types of fracturing fluids, nitrogen foam fracturing fluids cause less damage to the reservoir

Table 3 Experimental results of damage to cores by different fracturing fluid systems

Liquid type	Core number	Initial permeability/md	Permeability after damage/md	Core damage rate/%
Nitrogen foam fracturing fluid	1	2.35	2.12	9.7
Slippery water	2	1.86	1.62	12.9
Guanidine gum fracturing fluid	3	2.56	2.14	16.4

4. EFFECT OF ON-SITE APPLICATION

The test well XX-2 adopts the process of nitrogen foam volume fracturing to increase the formation energy and increase the volume of transformation. The displacement is 18 m3/min, a total of 70 m3 of sand is added, the total liquid volume is 1700m3, the net liquid volume is 1400m3, and the liquid nitrogen is 300 m3. During the construction process, the construction pressure was smooth and stable, and the sanding process was smooth and there was no obvious pressure fluctuation, indicating that the foam fracturing fluid had good adaptability in the block.

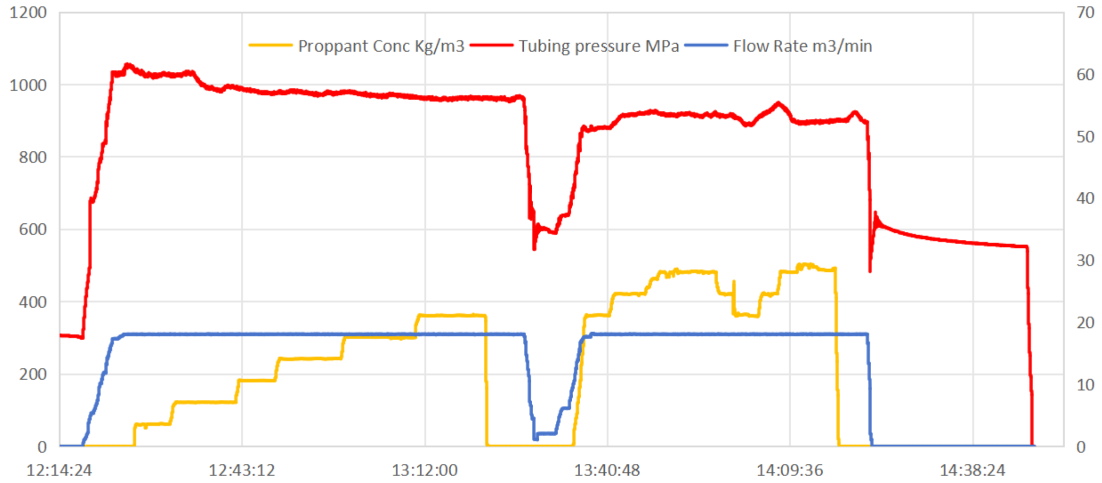

Fig.4. Construction curve

Table 4 compares the results of different fracturing fluid systems in this block. As can be seen from Table 4, compared with conventional fracturing fluid, foam fracturing fluid has the characteristics of fast flowback speed and high flowback rate, and the gas production has been greatly improved, which provides a good reference for the long-term sustainable development of this block.

Table 4 Effect comparison

Liquid type	Well name	See gas time/d	Flowback rate/%	Flowback cycle/d	Output/×104m3
Nitrogen foam fracturing fluid	XX-2	1	70.5%	6	2.3
Guanidine gum fracturing fluid	XX-1	4	25.5%	17	0.8

5. CONCLUSION

(1) Through laboratory experiments, the foaming agent in line with the western Sichuan block was optimized, and a set of foam fracturing fluid system with slippery water as the base fluid was formed.

(2) The performance test results of the system show that it has the characteristics of good stability, high viscosity, strong sand suspension performance, small filtration loss, low residue content and small reservoir damage.

(3) The field application results show that after the construction of the new nitrogen foam fracturing fluid system, the gas breakthrough time is short, the average daily gas production is greatly increased,

and the construction effect is significantly better than that of the wells using guanidine gum fracturing fluid system in the same block, and a good fracturing effect is obtained.

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