Performance Evaluation of Straight Well Multi-Thin Layer Fracturing Fluids

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Abstract. Taking the straight wells of Su10, Su11 and Su53 blocks in Surig block as the research object, we analyze the performance of fracturing fluid and combine the reservoir physical properties, rock mechanics and fracturing construction factors to clarify the degree of influence of the fracturing scheme on the production capacity of a single well, and seek the optimization countermeasures accordingly to improve the development effect of the target blocks. Large-scale hydraulic fracturing in this well area faces three major problems, such as the poor damping effect of fracturing fluid and the great damage to the reservoir; the lack of water resources and the difficulty of oilfield wastewater treatment; and the distribution of residual oil in the interstices, which requires the improvement of the recovery rate. In view of these problems, hydraulic fracturing is the main means to transform low-permeability oil and gas reservoirs. Fracturing fluid is an indispensable and important material for hydraulic fracturing, therefore, it is especially important to carry out the research on the rheology, gel-breaking characteristics, filtration loss, damage characteristics of reservoir rock samples, and stratigraphic compatibility of fracturing fluids, so as to obtain the evaluation of the performance of fracturing fluids. After the indoor analysis and research tests, the characteristics of fracturing fluids used in the field were grasped, and the performance of fracturing fluids was demonstrated to provide reference for the scientific and reasonable development of oilfields.

Keywords: tight gas; water-based fracturing fluid; performance evaluation; high-temperature hexagonal.

1. Introduction

With the increasing demand for oil and gas in the world's economic development, conventional oil and gas resources are becoming increasingly depleted, and unconventional oil and gas reservoirs such as low-permeability, tight, and shale are getting more and more attention[1]. Over the past decades, hydraulic fracturing technology has developed into one of the commonly used production enhancement methods for the development of unconventional oil and gas reservoirs [2-3]. In the hydraulic fracturing process, highly viscous fluids are injected into wells at a large discharge rate to form fractures in the formation by generating high pressures higher than the fracture pressure of the formation, and then proppant fills the proppant fractures to keep the fracture with a high conductivity after the fracturing fluids break the gel and return to the well. Therefore, the fracturing fluid needs to have the characteristics of high viscosity, good viscoelasticity, temperature and shear resistance, easy to break the glue, low residue and so on[4]. Therefore, it is necessary to carry out the research on the performance of fracturing fluids. In this paper, we will carry out the research on the rheology of fracturing fluids, gel-breaking characteristics, filtration loss, damage characteristics of reservoir rock samples, and stratigraphic compatibility, and come up with the evaluation of the performance of fracturing fluids, so that we can make a theoretical guide for the extraction of petroleum.

2. Experimental preparation

2.1. Laboratory equipment and materials

Experimental equipment and materials are: high-temperature rheometer, turbidimeter, high-temperature and high-pressure filtration loss instrument, XZ4A centrifuge, rotating viscometer, densitometer, oven. Crosslinking agent, guar gum (HPG Dongying), crosslinking agent (organic boron), pH adjuster (sodium oxide), 1% ammonium persulfate solution, sodium chloride, tap water, 100 mesh ceramic granules, 3mm steel beads.

2.2. Referenced standard

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3. Indoor experiment evaluation content

Designed to conduct 85 sets of fracturing fluid performance evaluation experiments. A total of 85 sets of experiments were designed and performed for a total of 500 hours on the following five major aspects of the straight well fracturing fluid samples used.

Table 1 Fracturing fluid experimental design

Name of experiment	No. of groups
Single particle sedimentation	5
Abrasive suspension capacity	5
Emulsion stabilization	2/14h
rheology	1/2h
viscoelastic	2
filter out	3/45min
form a complete set	54
stromal damage	2/23.8h
stickiness	3
PH	3
densities	3
Breaking time	2/3.5h

3.1. Fracturing fluid rheology analysis

Apparent viscosity tests, static shear tests, and dynamic viscoelasticity tests of fracturing fluid samples were performed on a high temperature rheometer.A high-temperature rheometer with a coaxial cylinder sensor system was used to test the rheological properties of the fracturing fluid. In the viscosity test, the shear rates were set at 25 s-1, 50 s-1, 75 s-1 and 100 s-1, and the appropriate test duration was chosen. The zero-shear viscosity of the solution was extrapolated from the Newton's first plateau value at low shear rate. In the viscoelasticity test, the samples were first scanned at a fixed shear frequency of 1.0 Hz to determine the linear viscoelastic region, and the appropriate shear stress was selected according to the test results. The test temperatures were all 110°C.

Table 2 Experimental setup conditions for fracturing fluid rheology analysis

Type of system	numerical value
shear temperature	110°C
shearing time	50s
Shear rate	25 s^{-1}、50 s^{-1}、75 s^{-1} 、 100 s^{-1}
consistency factor K	1.08 $Pa.s^n$
Fluidity index n	0.15

Lower fluidity index of the sample indicates higher shear dilution, poorer temperature and shear resistance, and faster viscosity drop.

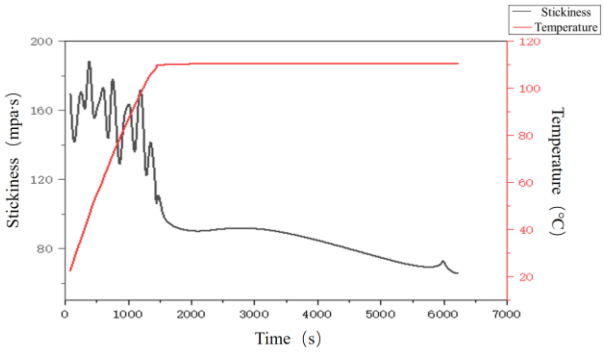

Figure 1 Time-viscosity relationship curve

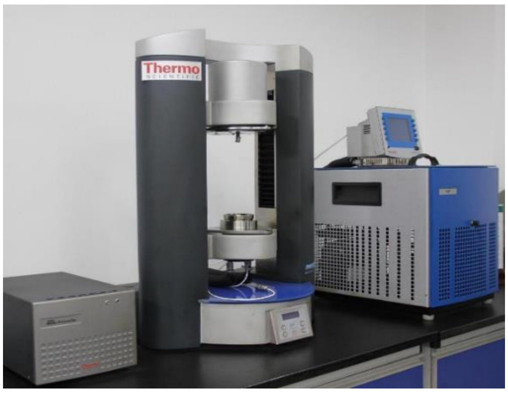

Figure 2 High temperature rheometer

3.2. Characterization of fracturing fluid gel breakage

Gum-breaking propertyGum-breaking property is an important index to evaluate the characteristics of fracturing system.Bad gum-breaking property will make the proppant produce certain subsidence, which will increase the gum-breaking residue and contaminate the reservoir[5]. A certain amount of kerosene was added to the fracturing fluid and stirred to homogenize, and then the apparent viscosities of the samples were continuously measured using a rheometer at a constant temperature of 80°C. The time taken for the apparent viscosity of the samples to decrease to below 5.0 mPa's was the breaking time, and the apparent viscosity at this time was the viscosity of the broken fluid.

Table 3 Experimental condition settings for fracturing fluid breakage characterization

Type of system	numerical value
Gum-breaking temperature	95°C
Concentration of glue breaker	0.01% ammonium persulfate
Ratio of broken rubber liquid ground water	1:2, 1:1, 2:1
Breaking time	37min
Viscosity of glue breaking liquid	3.5

The fracturing fluid used is compatible with Su10, Su11 and Su53 simulated formation water. There is no obvious precipitation.

Figure 3 Gum Breaking Fluid and Compatibility Situation

Figure 4 Turbidimeter

3.3. Fracturing fluid loss analysis

The filtration loss coefficients are used to evaluate the filtration loss properties of the four fracturing systems. Under fixed temperature and pressure conditions, the performance can be evaluated by using a high-temperature and high-pressure filtration loss meter in the experiments, and the filtration loss coefficients can be calculated according to the formula.

$$C = 0.005 \times \frac{m}{A} \quad (1)$$

In the public:

C Loss on filtration coefficient controlled by filter cake $m / (min)^{1/2}$

m Slope of the filtration loss curve $ml / (min)^{1/2}$

A Lost area (of a filter) cm^2

Table 4 Fracturing fluid filtration loss experimental condition settings

Type of system	numerical value
Loss of filtration temperature	85 ℃
Differential pressure	3 MPa
Filtration time	1, 4, 9, 16, 25, 36min

Fracturing fluid filtration loss over time is large.

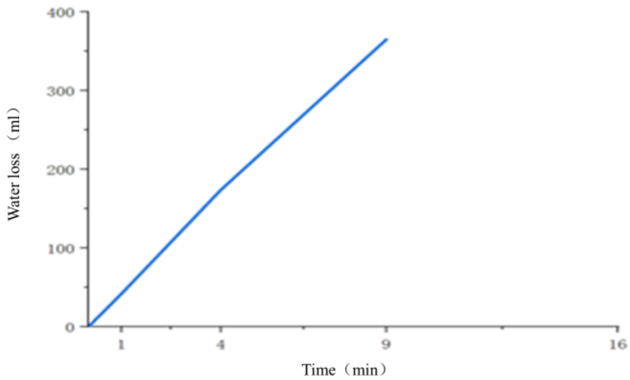

Figure 5 Time-Loss Relationships

Figure 6 Experimental High Temperature High Pressure Filtration Loss Meter

3.4. Characterization of fracturing fluid damage to reservoir rock samples

The fracturing fluid had different damage rates for different layer groups, and the damage for the Stone Box group was twice as high compared to the damage for the Shanxi group, reaching 43.9%. This is due to the fact that the bound water saturation was higher after the damage in the experiments in the Stone Box Formation, which may have produced a water lock.

Figure 7 Comparison before and after core experiment

Table 5 Matrix Damage

stratum group (geology)	Porosity (%)	Permeability (mD)	Bound underwater gas-phase permeability (mD)	Bound water saturation after damage (%)	Permeability after damage (mD)	Damage rate (%)
Shanxi Group	0.0797	0.0455	0.0402	0.43	0.0311	22.64%
Stone Box Group	0.0635	0.011	0.0041	0.709	0.0023	43.90%

4. Summary

If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process. Based on the experiments for evaluating the performance of fracturing fluids, the following conclusions were drawn:

1. The viscosity and fluidity of fracturing fluids are important factors affecting their permeability and fracture extension effect in oil and gas reservoirs. Fracturing fluids with high viscosity can improve the ability of fluid retention in the fracture, thus effectively increasing the length and width of the fracture and increasing the hydrocarbon production.

2. The lower fluidity index of the samples indicates a higher shear dilution rate, poorer temperature and shear resistance, and a rapid decrease in viscosity, which may lead to the inability to effectively maintain fluid stability in the fracture, thus affecting the long-term effectiveness of the fracture and hydrocarbon production.

3. The fracturing fluids used are mated with Su10, Su11 and Su53 simulated formation water without obvious precipitation generation, which ensures the chemical stability and performance stability of the fracturing fluids during prolonged use, and avoids unnecessary chemical reactions and physical phase separation, thus improving the success rate and stability of fracturing operations.

4. Fracturing fluid has a large filtration loss over time, which leads to the loss of active ingredients in the fluid when passing through the pores of the rock and reduces the effective infiltration and effect of the fluid in the fracture, which may affect the effect and success rate of fracturing operations.

By comprehensively evaluating the various performance indicators of fracturing fluids, the formulation of fracturing fluids suitable for different formation conditions can be more accurately selected and designed, thereby improving the success rate and productivity of fracturing operations.

In general, by carefully studying and evaluating the performance of fracturing fluids, we can more effectively guide the oil and gas exploration and development work, and enhance the oil and gas production and economic benefits. In the future, we will further study and optimize the formulation and performance of fracturing fluids in depth, so as to make greater contributions to the development of the oil and gas industry.

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