

Research and Application of DAM Monomer Polymerization Plugging Agent for Hydraulic Fractures

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Abstract

This paper presents a DAM monomer polymerization plugging agent to solve the problem of channel flow along the hydraulic fractures in ultra-low permeability reservoir. This plugging agent consists of DAM acrylamide monomer and additives including initiator, polymerizing agent, regulator and stabilizer. Its properties are evaluated based on the characteristics of ultra-low permeability reservoir and hydraulic fractures. Experimental results show that this agent exists as a Newtonian aqueous solution before gelling, with a low viscosity (below 3.1 mPa·s). After the polymerization in the formation, the agent forms polymeric gel with a strength over 2200 kPa and a long-lasting thermal stability. Physical plugging simulation of this agent for core samples shows using core samples shows a success rate over 99.5% and the threshold pressure reaches above 2.6 MPa. Hydraulic fractures plugging field tests using this agent has been conducted in Block E28 of Shengli Oilfield. The field results show that the tubing pressure in the injection well increased by 9.8 MPa after the plugging and cumulative oil production increased by 547.2 tons in the corresponding production well. This plugging agent is easy to prepare and field operations are easy to be implemented. It can give satisfying results in plugging hydraulic fractures and provides good technical supports for the development of low permeability reservoir.

Keywords

Ultra-low Permeability; Hydraulic Fractures; DAM Monomer Polymerization Plugging Agent; Plugging; Field Application.

1. Introduction

Block E28 is located in the east of Shengli Oilfield. It is a very low permeability reservoir with an average air permeability of $1.2 \times 10^{-3} \mu\text{m}^2$. For the development and utilization of ultra-low permeability reservoirs, fracturing technology must be adopted. In view of the channeling problem in the production wells put into production by fracturing technology, the technology of plugging fracturing cracks is often adopted to control the formation water [1 – 3]. Due to the serious heterogeneity of such reservoirs, many fractures, complex fracture structure, low permeability and small porosity [4 – 6], many plugging agents cannot enter the low permeability pores [7 – 9], which restricts the implementation of plugging technology. The analysis shows that the plugging agent needed for plugging fracturing fractures should have low viscosity solution property [10-11], easy to flow into formation pores, and high strength and stability after reaction in the formation. Therefore, according to the characteristics of ultra-low permeability reservoirs and fracturing wells, we developed a monomer polymerization plugging agent suitable for plugging fracturing fractures with

DAM acrylamide monomer as the main material and other chemicals as the auxiliary material. The plugging agent has achieved obvious results in field application.

2. Experiment Part

2.1 Materials and Instruments

Main material : DAM acrylamide monomer, white powder, industrial grade ; initiator : potassium persulfate, white crystalline powder, industrial products ; polymerizer : high-valence cationic solution, self-made, 32 % ; heat stabilizer : soluble polymer powder, industrial products ; regulators : potassium ferricyanide, red crystal powder, industrial products.

2.2 Determination of Formula

Through the orthogonal design method, five factors and three levels of optimization screening test, the basic formula of plugging agent was determined : the main agent DAM monomer was 3 % – 8 % ; initiator 0.06 % ~ 0.6 % ; polymerization agent 0.05 % ~ 0.2 % ; heat stabilizer 0.01 % ~ 0.05 % ; regulator 0.01 % -0.03 % ; it is water.

3. Experimental Results and Discussion

3.1 Discussion on Plugging Mechanism

- (1) The plugging agent solution is a low viscosity aqueous solution, similar to the flow performance of water, showing Newtonian fluid properties and easy to enter the pores formed by fracturing cracks.
- (2) In the pores formed by fracturing fractures, DAM acrylamide and thermal stabilizer react with initiator, polymerization agent and other components to form the overall polymer gel.
- (3) The polymerized plugging agent gel is a whole gel with very high strength, and its strength is greater than 2200 KPa, which forms high strength plugging for formation fracturing cracks.

3.2 Rheological Properties of Plugging Agent Solution

The plugging agent solution was prepared under stirring, and the viscosity of the solution was measured at different times. The test data are shown in Table 1. It can be seen from Table 1 that the viscosity of the solution reached 3.1 mPa·s after 10 min of stirring in the preparation of the plugging agent, and the viscosity remained basically unchanged after continuous stirring, indicating that the plugging agent had rapid solubility and small viscosity value, which was close to that of water.

Table 1. Measuring table of solution time and viscosity

Time / min	Viscosity / mPa·s	Time / min	Viscosity / mPa·s
0	0	12	3.11
2	1.22	14	3.15
4	2.15	16	3.13
6	2.96	18	3.11
8	3.02	20	3.12
10	3.16	22	3.11

3.3 High Strength Performance of Plugging Agen

The developed monomer polymerization plugging agent is composed of DAM acrylamide monomer, other chemicals and water; before gelation, it was a low viscosity aqueous solution, and polymerized at temperature and other conditions to generate polymerized gel. According to the formula, each component of the plugging agent was weighed and prepared into aqueous solution. Then it was poured into three glass bottles and sealed. Then it was placed in a constant temperature box with a set temperature of 65 °C. Viscosity and strength were measured at different times. The experimental

results are listed in table 2. It can be seen from Table 2 that the plugging agent maintains the solution state before gelation, and exhibits obvious polymerization reaction when the reaction occurs, and high-strength polymer gel is formed after gelation.

Table 2. Data table of strength properties before and after gelation

Time, min	Viscosity, mPa·s	Intensity, KPa
0	0	0
60	3.11	0
120	3.13	0
180	20.18	0
240	140.16	0
300	1500.33	0
360	9500.22	0
420	E	2218.55
480	E	2218.55
540	E	2218.55
600	E	2218.56
660	E	2218.56

3.4 Temperature Resistance of Polymer Gel

Each component of the blocking agent was weighed according to the formula, and the blocking agent solution was prepared under stirring. The blocking agent solution was placed in several special stainless steel tubes and sealed, and then placed in a thermostat with different temperatures. The blocking agent solution was regularly taken out to observe the state of the blocking agent solution and measure the strength of the gel. The test data are shown in table 3. It can be seen from the data in Table 3 that the plugging agent solution has completely reacted to the polymer gel within 1 d at 80 °C – 120 °C. After 30 days of temperature resistance test, the polymer gel remains in the gel state, which fully indicates that the plugging agent has high temperature resistance.

Table 3. Temperature resistance table of polymer gel

Influences of temperature °C	Strength values measured at different times , / KPa					
	1d	5d	10d	15d	20d	30d
80	2218.56	2218.21	2218.01	2217.22	2215.63	2214.37
120	2218.56	2209.33	2208.55	2201.65	21124.21	2035.16

4. Applications in the Field

4.1 Reservoir Properties and Application of Plugging Fractures

The oil-bearing area of Block E28 is 2.1 km², and the geological reserves are 3.7 million tons. It belongs to ultra-low permeability structural lithologic reservoir. There are 24 production wells in this block, including 8 water injection wells. In view of the problem of injection water flowing along the fracturing cracks in the production wells, the plugging fracture test was carried out on two fracturing wells in 2017. The construction situation and effect statistics are shown in Table 4. It can be seen from Table 4 that the oil pressure of the injection well is increased by 9.8 MPa after plugging, and

the corresponding cumulative oil increase of the oil well is 547.2 tons, and the validity period is more than 170 days.

Table 4. Statistics on Construction and Effect

Injection well	Before closure		After closure		Corresponding oil wells		
	Daily dose /m3/d	oil pressure /Mpa	Daily dose /m3/d	oil pressure /Mpa	well number	oil increment /t	period of validity /d
E12-15	14.2	17.5	18.1	25.7	E29-4	120.1	162
					E29-5	130.6	243
					E27-10	89.3	194
E8-18	11.3	16.2	20.1	27.7	E7-3	96.5	152
					E10-6	110.7	103
Total						547.2	170.8

4.2 Analysis of Construction Wells

Well E8-18 is a fractured injection well in this block. Water channeling along the fractured fracture occurs in the well area, and the water flooding efficiency is reduced. On October 19,2017, the single polymer plugging agent was used to block the fracturing fracture, and 52 parties of DAM monomer polymer plugging agent were injected. The construction results are shown in the production curve 2 of the well. It can be seen from figure 1 that the production curve before and after plugging fracturing has changed obviously. After plugging, the average oil pressure of injection well is increased by 8.2 MPa, and the production days of keeping oil pressure above 27 MPa are more than 220 days, corresponding to the cumulative oil increase of 340 tons. The plugging process is simple in construction, high in strength and long in validity, which meets the requirements of plugging fracturing fractures in ultra-low permeability reservoirs.

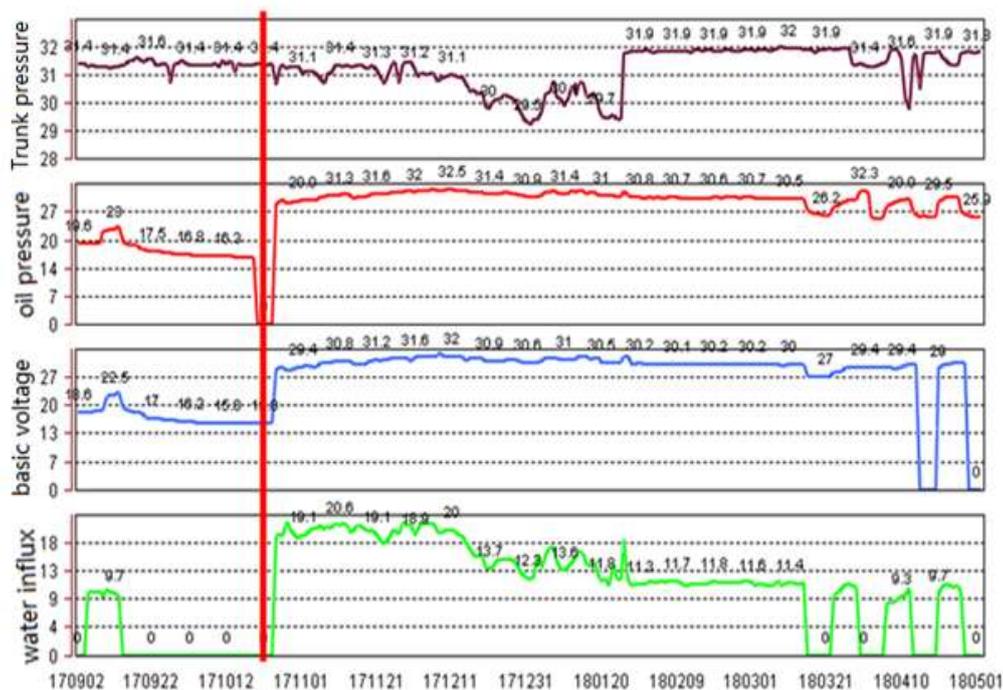


Fig. 1 Production curve before and after fracturing fracture plugging in Well E8-18

5. Conclusion

According to the properties of ultra-low permeability reservoirs and the characteristics of fracturing fracture channeling, a DAM monomer polymerization plugging agent with low viscosity water solution before gelling was successfully developed, and polymerized gel was generated under formation conditions. This plugging agent is simple in preparation and convenient in construction, and the plugging rate of core is greater than 99.7%. In the field test, the oil pressure can be effectively increased by 8.2 MPa after plugging the fracture. Through the research and field application of DAM monomer polymerization plugging agent, the technical means suitable for plugging fracturing cracks are established.

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