Heat-resistant agent used for control sand of steam huff and puff heavy oil well

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Abstract. Heat-resistant agent containing hydroxymethyl group was synthesized from coal tar, which has similar structure with phenolic resin and could improve the heat resistance of phenolic resin sand control agent. The results showed that the heat resistance of the sand control agent was improved by adding 10% to 30% heat-resistant agent, after 280 °C high temperature treatment for 7d, the compressive strength of consolidated core was increased to more than 5 MPa. The compressive strength of consolidation core was not decreased after immersion in formation water, crude oil, acid or alkaline medium, which showed good resistance to medium immersion. The sand control agent had small core damage and the core permeability damage ratio of sand control agent consolidation was only 18.7%.

1. Introduction
With the increase of oil demand, people are growing to strengthen the development of heavy oil reservoir. Steam stimulation is a kind of effective method to improve heavy oil reservoir in the heat. In the process of steam stimulation, oil reservoir bears reservoir rock and repeated incentive, resulting in easy sand of the oil well [1-2]. With the increase of stimulation rounds, increasing the degree of the sand, it brings a lot of harm to the production. In order to alleviate the contradiction between development and easy sand of oil well, oil field increases the experiment and application of sand control technology.

Current chemical sand control agent can be divided into inorganic kind and organic class [3-6]. (phenolic resin[7-8], epoxy resin, urea-formaldehyde resin, furan resin and so on). Although sand control technology obtains a certain result in oil field, there is a series of problem, for example, the inorganic sand control agent costs low and heat resistance performance is good, but the consolidation of strength is low. The consolidation strength of organic sand control agent is high, but the heat resistance performance is poor. The temperature of strata is high in the process of steam stimulation, and high strength steam has large scouring force to strata, so oil filed needs big cementing strength and high temperature resistant sand control agent [9-11]. In order to improve the performance of the phenolic resin heat-resistant [12], combining the coal tar with phenolic resin, but coal tar is different from phenolic resin in the structure, so compatibility performance is not ideal. Naphthalene, anthracene and rich in polynuclear aromatic hydrocarbons asphalt as raw material to synthesis of condensed polynuclear aromatic resin has excellent heat resistance [13-14], heat resistance up to 400°C above.

The author uses the coal tar which riches in phenolic compounds as raw materials [15], to synthetize heat-resistant agent which is similar to the structure of phenolic resin. This kind of heat
resistance agent and phenolic resin has good compatibility performance. Combine heat resistance agent and phenolic resin to get high temperature resistant control-sand agent. Not only it improves the heat resistance performance of phenolic resin, but also it can reduce the cost of control-sand agent.

2. Experimental

2.1. The synthesis of heat-resistant agent
The first step, put right amount of coal tar into three mouth bottle which installs blender. Then join the trioxymethylene whose quantity score is 5% to 10%, using N$_2$ to protect it, heating up to 110-120°C, adding 5% to 8% (of coal tar quality) of sulphuric acid, to react 6 to 8 hours. The second step, cooling to 80 to 90°C, to join KH550 whose quality score is 1% to 3%, continuing to 3-5 hours, to join right amount of ethanol when the reaction ends.

2.2. The evaluation of the compressive strength
(1) The equipment of the core: Take appropriate amount of find sand, to add to a certain amount heat resistance control-sand agent (phenolic resin + heat-resistant agent), quality score for 10% of curing agent and 1% of coupling agent, stirring well, and then put it in the glass tube (the lower end of pared with copper wire). Compact it well, then put it into airtight containers (equipped with right amount water). Keep the temperature of 40°C to 80°C for a certain time, waiting until after consolidation, then break the glass tube, using cutting machine to cut concretion body into the core of 25 mm long, then test the strength.

(2) The temperature resistance of the core: Put the core made into high pressure reactor (filled with proper amount of water) and keep the temperature of 280°C for 7 days, then take it out to test the strength.

(3) Take the core made to different medium, immersing 30d under 45°C, then take it out to test the compressive strength.

(4) Compressive strength test: According to the enterprise standard oil SY/T 5276-2000 "chemical sand control artificial flexural strength, compressive strength and the test of the gas permeability", using the electronic pressure test machine to test the compressive strength of the core.

2.3. The retention test of core permeability
The use of petroleum enterprise standard SY/6672"sand resin performance evaluation method “tests the retention of core permeability, using kerosene and 2% solution as medium, to test the permeability of the oil and water. The permeability retention ratio is the average value of oil phase and water phase permeability retention ratio. The permeability retention ratio = (the core permeability after consolidation / the core permeability before consolidation) × 100%.

3. The synthesis of heat-resistant agent
Coal tar riches in classification of compound, phenol, cresol, two cresol and alpha-naphthol, so including its derivatives, obtaining the heat-resistant agent with trioxane under the action of strong acid.

Chemical reaction mechanism and the use of the mechanism of phenol to phenolic resin are similar [16]. The trioxane happens the open loop reaction under the action of heat and strong acid, forming carbocation (’CH$_2$-O-CH$_2$-O-CH$_2$-OH or ’CH$_2$-OH), carbocation (’CH$_2$-O-CH$_2$-O-CH$_2$-OH) occur electrophilic substitution reactions with the aromatic ring of phenolic compounds (Ar-OH), then generate products (HO-Ar-CH$_2$-O-CH$_2$-O-CH$_2$-OH). The product forms new carbocation (HO-Ar-CH$_2$-O-CH$_2$-O-CH$_2$-) in the action of acid, reacting with another aromatic ring (Ar-OH), then it forms (HO-Ar-CH$_2$-O-CH$_2$-O-CH$_2$-Ar-OH). Its structure is easy to break because of C-O-C, forming relatively stable carbocation (HO-Ar-CH$_2$-), then it continues reacting with other aromatic electrophilic substitution (Ar-OH) to form products (HO-Ar-CH$_2$-Ar-OH). It repeats the electrophilic
substitution reaction, to make product have the structure of hydroxymethyl (HO-Ar-CH₂-OH). The structure of hydroxymethyl is as followed formula (1):

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\begin{align*}
& \text{Ar} - \text{CH}_2 - \text{Ar} - \text{CH}_2 - \text{Ar} - \text{CH}_2 - \text{Ar} \\
& \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH}
\end{align*}
\]

(1)

4. Experimental results

4.1. The influence of heat-resistant to the temperature performance of phenolic resin

In the process of steam stimulation oil well steam injection, the formation temperature is around 280°C and the injection cycle is generally 5 to 7 d. Adding to the heat-resistant agent whose structure is similar to can improve its heat resistant performance in the resin, extending the validity of the sand operations. Make sand control processing of sand well in the production process. Reservoir temperature is lower (low curing temperature), usually 40 to 50°C. We should pay attention to make sand control processing of sand well in the production process. Reservoir temperature is higher (high curing temperature), about 180°C. In order to adapt to the reservoir of control agent temperature requirements in different construction conditions. Examine the 40°C low temperature curing and 180°C heat curing conditions, the consolidation strength of the control-sand agent and core experiences high-temperature processing of 180°C for 7d. The results are shown in figure 1 and figure 2.

![40°C consolidation](image)

**Figure 1.** Influence of heat-resistance agent to the temperature performance of phenolic resin at 40°C consolidation
From figure 1 and figure 2, we can see the control-sand agent solidify in the 40℃. The consolidation strength decreases with the increase of the amount of heat-resistant agent. It solidifies in 180℃ high temperature, then the consolidation strength tends to increase with the increase of the amount of heat-resistant agent. The main reason is that kerosene for the synthesis of heat-resistant agent has a similar structure with phenolic resin, but the activity than that of phenolic resin is low. In the low temperature high-resistant agent can participate in the activity of quality score that is not high, so it can't participate in the curing of the cores after the consolidation, decreasing the strength of the core. In the case of 40℃ low temperature curing, heat-resistant whose quality scores is too much will lead to strength loss. In the high temperature of 180℃, its quality score of activity which participates in curing with phenolic resin is relatively high. In a certain extent, it reflects the heat resistance performance of the heat-resistant agent. With the increase of the heat-resistant agent content, the compressive strength increases.

From figure 1 and figure 2, the strength of the consolidation core of phenolic resin decreases greatly to 1.0MPa approximately after a 280℃ processing for 7 d. In the heat-resistance agent quality score of 10% to 30% of the case, the core which was obtained by the curing of 40℃ reacts after 280℃ for 7d. The strength decreases greatly, but it can keep above 5.0MPa.It can improve the heat resistance performance of phenolic resin greatly by joining in the heat-resistant agent and it also can reduce the cost of control-sand agent.

4.2. The stability of consolidation core medium resistance
The resistance to media immersion stability of the core of consolidation has a certain impact on the cycle of the control-sand agent. From table 1, we can see the compressive strength of the core which was soaked 30d in different media of 45℃.
Table 1. The influence of different media to the compressive strength of the core.

| Core curing temperature /°C | The strength before soaking /MPa | The strength of different media soaking /MPa |
|-----------------------------|---------------------------------|------------------------------------------|
|                             | Formation Water                | Crude oil                                | HCl solution (5%) | Lye solution pH=11.2 |
| 45                          | 9.5                             | 9.4                                      | 9.5               | 9.3                   | 9.2               |
| 160                         | 13.6                            | 13.5                                     | 13.4              | 13.2                  | 13.3              |

From table 1, crude oil, formation water and hydrochloric acid have no effect on the compressive strength of the core of consolidation. Alkaline medium of the core encountered in normal circumstances is the dissolution of the alkaline steam in the steam stimulation process. The PH of alkaline steam won't more than 11. The lye of PH=11.2 has no effect on the compressive strength of consolidation. It explains that the control-sand agent has good resistance to media immersion stability.

4.3. The permeability and retention of consolidation of core

In the condition of control-sand agent of 6%, curing agent mass fraction of 10%and coupling agent mass fraction of 1%, to get the core by curing of 180 °C, testing the compressive strength and the retention of permeability.

Table 2. The permeability retention rate of the consolidation core.

| The length of the core, /cm | The diameter of the core, /cm | The compressive strength, /MPa | Permeability retention ratio, /% | Permeability loss rate, /% |
|-----------------------------|-------------------------------|--------------------------------|---------------------------------|---------------------------|
| 5.3                         | 2.5                           | 9.5                            | 81.3                            | 18.7                      |

From table 2, we can see that the permeability retention rate and permeability loss rate are 81.3% and 18.7% respectively after consolidation. The sand control agent has less damage to the core permeability.

5. Conclusion

The heat-resistance agent which is using coal tar as raw material and similar to the structure of phenolic resin can happen condensation reaction with phenolic resin.

The strength of consolidation core of high temperature control-sand agent which consists of heat-resistant agent and phenolic resin is still larger than 5.0MPa after 280 °C of aging 7d in the condition of the quality score 10% to 30% of the heat-resistant agent. It explains that phenolic resin blends with heat-resistant properly, but also can reduce the cost of control-sand agent.

The core by consolidation of heat resistance control-sand agent was soaked by the formation water, crude, acidic medium and alkaline soak. The strength doesn't decrease. It explains that it has good resistance to media immersion performance.

After the consolidation of heat-resistant, sand control agent has less damage to core permeability.

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