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# Du 66 heavy oil hot water chemical flooding chromium system profile control agent injection parameters optimization

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**Abstract:** Since Du 66 heavy oil block begin hot water chemical flooding development, the reservoir heterogeneity and the high viscosity of heavy oil reservoirs and other factors caused water flooding along the large pore path onrush, water injection invalid cycle, some oil wells water content rise, formation of high water cut, and these problems have affected the effect of hot water injection of experimental area. To solve above problems, Du 66 heavy oil hot water chemical flooding profile control research has been did, optimize the injection quantity, injection concentration, injection rate and other parameters of chromium system profile control agent through laboratory core displacement test, formation of the optimal profile injection parameters of chromium system profile control agent, and evaluate the experiment effect of final injection parameters through laboratory core displacement test. Oil displacement experiment after profile control indicates that after gel the optimized chromium system profile control agent formula under the optimized injection parameters plugging excellently, breakthrough pressure, break through pressure gradient, drag coefficient, plugging ratio, recovery promotion effect and the elevated temperature resistant and scour resistant abilities can meet the site construction requirements.

***Keywords:*** *Du 66 block, heavy oil, hot water chemical flooding, profile control, injection parameter*

**Chinese library classification:** TE345

Du 66 heavy oil hot water chemical flooding test area located on the Tangchi structure of Taikang uplift zone of west slope region, this area is a common anticline structure, propagate three faults, the use of oil-bear area is 1.54km$^2$, it's geologic reserves is 84.8×10$^4$t, edge water is developmental in this block, and the energy is sufficient (Oil-Water transition zone in the vicinity of northeast construction line-630m. Only one reservoir developed in this whole region-SI1, the average thickness of single well drilled sandstone is 4.0m, effective thickness is 3.1m. The average air permeability is 1415mD, the porosity is 31.4%, the stock tank oil's viscosity is 1400mPa·s at formation pressure and temperature conditions), it belongs to the high porosity, middle or high permeability heavy oil reservoirs.

To solve the water onrush and increased water content in the process of developing in Du 66 heavy oil block, improve the effect of hot water development in this area, profile control technology has been studied for the block[1][2], the best profile control agent system-chromium system profile control agent formulation: polymer 0.3%(the concentration is 5000mg/L), crosslinking agent A 1%, crosslinking agent B 0.35%, stabilizing agent 0.25%, gelation time is 25h at a temperature of 35.5℃, gelation intensity is 25898MPa·s, The system has excellent heat resistance, shear resistance, acid resistance and salt tolerance, it can satisfy the requirements of Du 66 heavy oil hot water chemical profile control.

To guide the field construction, we undertake an laboratory oil displacement experiment of optimized chromium system profile control agent formula, optimize the injection quantity, injection concentration, injection rate and other parameters of profile control agent, the increasing rate of crude oil recovery and plugging effect are the main evaluation index[3][4]. Finally, undertaking the oil displacement experiments

according to the optimization injection parameters; verifying the overall effect of the profile control agent formula and injection parameters through breakthrough pressure, plugging ratio, displacement efficiency, elevated temperature resistant and scour resistant abilities, recovery promotion effect and other indexes[5].

## I. INJECTION PARAMETERS OF CHROMIUM SYSTEM PROFILE CONTROL AGENT OPTIMIZATION

Laboratory oil displacement experiment mainly optimize the injection quantity, injection concentration, injection rate and other parameters of profile control agent, in order to ensure the accuracy of the experiment and the uniqueness of influencing factor, change the undetermined parameter and fix the other two parameters in the process of optimization. Determine the final injection parameters by the change rate of recovery efficiency of the oil displacement experiment.

### 1.1 injection quantity of profile control agent optimization

Conducting the oil displacement experiment of the optimized chromium system profile control agent, the injection concentration is 2.5%, injection rate is 0.4ml/min, the injection quantity is 0.2PV, 0.4PV, 0.6PV, 0.7PV, 0.8PVrespectively, investigate the influence of the injection quantity to displacement efficiency and plugging performance, the result is shown in fig. 1-1 and table 1-1.The recovery efficiency presents a tendency of lower after the first increase with injection quantity increases, the recovery efficiency can be heightened 45.87% when the injection quantity is 0.7PV, breakthrough pressure, plugging rate and other indexes all achieve the best value, it has excellent plugging performance, so to determine the best injection quantity is 0.7PV.

Table 1-1The influence of injection quantity of profile control agent to oil displacement rate

| Core number | Injection quantity (PV) | Breakthrough pressure (MPa) | breakthrough pressure gradient(MPa/m) | Remnant drag coefficient | plugging ratio (%) | plugging ratio after 80℃scouring(%) |
|---|---|---|---|---|---|---|
| 14C | 0.2 | 0.52 | 5.17 | 51.94 | 98.07 | 97.89 |
| 16C | 0.4 | 0.61 | 6.05 | 77.49 | 98.71 | 98.12 |
| 2C | 0.5 | 0.68 | 6.82 | 112.86 | 99.11 | 98.97 |
| 12C | 0.6 | 0.76 | 7.56 | 87.04 | 98.85 | 98.56 |
| 13C | 0.7 | 0.8 | 7.96 | 398.33 | 99.75 | 98.79 |
| 3C | 0.8 | 0.75 | 7.51 | 60.88 | 98.36 | 97.31 |

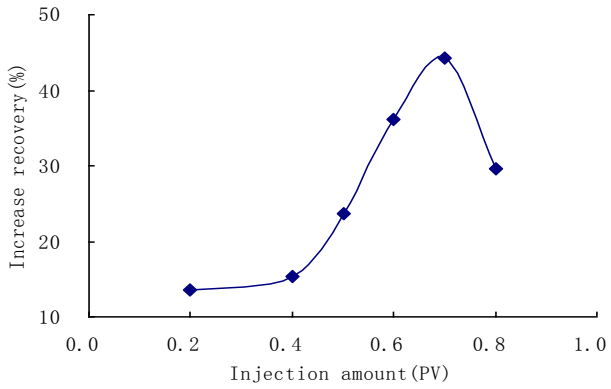


Fig. 1-1 the influence of injection quantity of profile control agent to the crude oil recovery efficiency

**1.2 injection concentration of profile control agent optimization**

Conducting the oil displacement experiment of the optimized chromium system profile control agent, the injection quantity is 0.7PV, injection rate is 0.4ml/min, the injection concentration is 0.5%, 1%, 2%, 3%, 4%, 5%,respectively, investigate the influence of the injection concentration to displacement efficiency, the result is shown in fig. 1-2 and table 1-2.The recovery efficiency presents a tendency of lower after the first increase with injection concentration increases, the recovery efficiency can be heightened 46.98% when the injection concentration is 2%, and breakthrough pressure, plugging rate and other indexes all achieve the best value, so to determine the best injection concentration of profile control agent is 2%.

Table 1-2The influence of injection concentration of profile control agent to oil displacement rate

| Core number | Injection quantity (PV) | Breakthrough pressure (MPa) | breakthrough pressure gradient (MPa/m) | Remnant drag coefficient | plugging ratio (%) | plugging ratio after 80℃ scouring (%) |
|---|---|---|---|---|---|---|
| 4C | 0.5 | 0.69 | 6.9 | 48.64 | 97.94 | 96.65 |
| 5C | 1 | 0.75 | 7.49 | 84.13 | 98.81 | 98.54 |
| 7C | 2 | 0.81 | 8.06 | 112.86 | 99.11 | 98.67 |
| 9C | 3 | 0.72 | 7.14 | 103.31 | 99.03 | 98.12 |
| 10C | 4 | 0.73 | 7.23 | 99.2 | 98.99 | 97.77 |
| 11C | 5 | 0.72 | 7.17 | 64.85 | 98.46 | 97.94 |

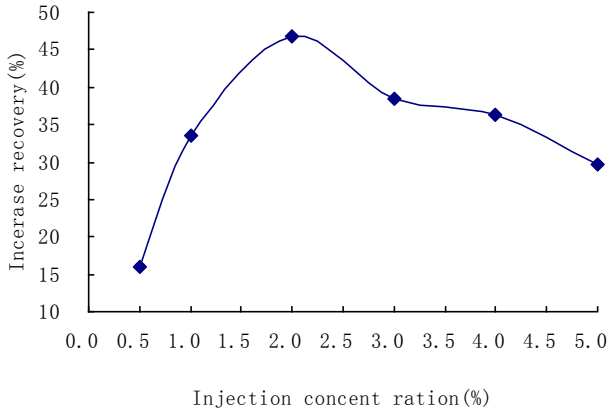


Fig. 1-2The influence of injection concentration of profile control agent to the crude oil recovery efficiency

**1.3 injection rate of profile control agent optimization**

Conducting the oil displacement experiment of the optimized chromium system profile control agent, the injection quantity is 0.7PV, injection concentration is 2%, the injection rate is 0.1ml/min, 0.15ml/min, 0.2ml/min, 0.3ml/min, 0.4ml/min, 0.5ml/minrespectively, and the result is shown in fig. 1-3 and table 1-3. The recovery efficiency presents a tendency of lower after the first increase with injection rate increases, the recovery efficiency can be heightened44.59% when the injection rate is 0.3 ml/min, and breakthrough pressure, plugging rate and other indexes all achieve the best value.

Table 1-3 The influence of injection rate of profile control agent to oil displacement rate

| Core number | Injection quantity (PV) | Breakthrough pressure (MPa) | breakthrough pressure gradient (Mpa/m) | Remnant drag coefficient | plugging ratio (%) | plugging ratio after 80℃ scouring (%) |
|---|---|---|---|---|---|---|
| 17C | 0.1 | 0.75 | 7.43 | 35.22 | 97.16 | 96.99 |
| 21C | 0.15 | 0.74 | 7.36 | 43.29 | 97.69 | 97..59 |
| 18C | 0.2 | 0.69 | 6.83 | 153.7 | 99.35 | 99.06 |
| 13C | 0.3 | 0.8 | 7.96 | 398.33 | 99.75 | 99.12 |
| 6C | 0.4 | 0.71 | 7.08 | 218.35 | 99.54 | 99.25 |
| 8C | 0.5 | 0.73 | 7.25 | 81.38 | 98.77 | 98.34 |

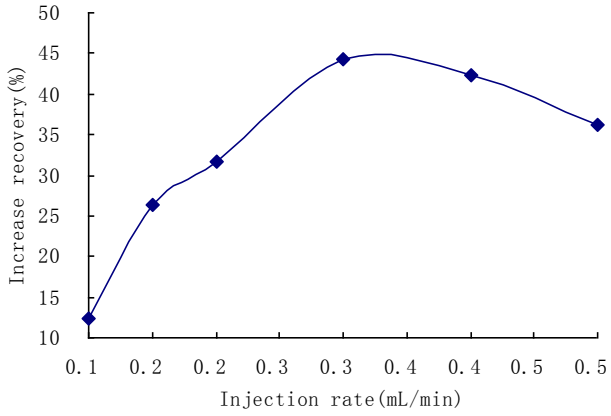


Fig. 1-3 The influence of injection rate of profile control agent to the crude oil recovery efficiency

## II. THE OIL DISPLACEMENT EXPERIMENT OF OPTIMAL PROFILE CONTROL PARAMETERS

Conducting the oil displacement experiment of chromium system profile control agent by using optimal injection parameters[6]. The optimal injection parameters: injection quantity is 0.7PV, injection concentration is 2%, injection rate is 0.3ml/min, the experimental result is shown in the table 2-1, and the pressure deviation in displacement process is shown in fig. 2-1.

Table 2-1 Plugging performance and the ability of oil displacement evaluation

| Core number | Breakthrough pressure (MPa) | breakthrough pressure gradient (MPa/m) | Plugging ratio (%) | Remnant drag coefficient | Oil displacement efficiency after profile control (%) | plugging ratio after 80℃ scouring (%) | Enhanced oil recovery (%) |
|---|---|---|---|---|---|---|---|
| 15C | 0.72 | 7.2 | 99.75 | 398.8 | 82.66 | 99.78 | 44.12 |

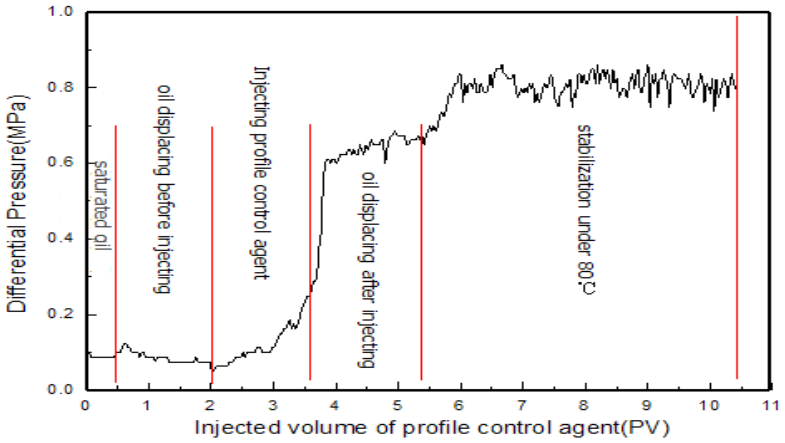


Fig 2-1 The tendency of pressure deviation in the process of the displacement

From the table 2-1, we can know that the result of plugging is excellent after gel, breakthrough pressure, breakthrough pressure gradient, drag coefficient, plugging ratio and other indexes all achieve the site requirements. The recovery efficiency can be heightened 44.12% under the optimal injection parameters, the plugging rate of the profile control agent can achieve 99.78% after water flush 10PV, fig. 2-1 illustrates that when conducting oil displacement experiment after profile control, the pressure difference shows an obviously increasing trend, this confirms that the plugging performance of the profile control agent is excellent, and it effectively reduces the permeability of cores; in 80℃scouring resistant stage, the pressure difference changes gently. All these suggest that the chromium system profile control agent has good profile control performance and strong abilities of elevated temperature and scour resistant under the optimal injection parameters, the optimal injection parameters of chromium system profile control agent can guide the hot water chemical flooding profile control field construction of Du 66 block.

## III. CONCLUSIONS

(1)Optimizing the chromium system profile control agent for Du 66 block through laboratory core flooding experiments (polymer of 5000mg/L is 0.3%, crosslinking agent A is 1%, crosslinking agent B is 0.35%, stabilizing agent is 0.25%) injection parameters: injection quantity is 0.7PV, injection concentration is 2%, injection rate is 0.3mL/min.

(2)Obtained from the oil displacement experiment that under the optimal injection parameters the chromium system profile control agent breakthrough pressure is 0.72MPa, breakthrough pressure gradient is 7.2MPa/m, core plugging rate is 99.75%, the plugging rate after 80℃ subsequent water flooding is 99.78%, the oil recovery increased by44.12%. The result illustrates that the breakthrough pressure, plugging performance, recovery rising effect, the abilities of elevated temperature and scour resistant and other indexes all relative high, the optimal injection parameters of chromium system profile control agent can guide the hot water chemical flooding profile control field construction of Du 66 block.

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