

Chemical water shutoff profile research status and development trends

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Abstract. Excess water production is now a common problem encountered in almost every water flooding mature oilfield. The exploitation of oil field is faced with great challenge because of the decrease of oil field production. For the development of high water cut rare the status quo chemical water shutoff profile control technology is an important solution to solve this problem. Oilfield chemical water shutoff has important application prospects. This paper analyzes the water shutoff profile control and water shutoff profile control agent currently oilfield applications, moreover the use and development of blocking agent profile technology is to improve reservoir recovery and propose solutions. With the constant increase in water cut, profile technology should be simple, efficient, practical and profile control agent of development should be economic, environmental, and long period

1. Introduction

The status quo of oil fields in China, an injection profile along with the increasing of water injection, is increasingly uneven, so the well water yield increases/decreases. For example, In Daqing oil field, the average water cut oil wells are more than 95%. The good physical conditions of remaining reserves depend on deep mining so as to reduce reservoir. High temperature conditions of reservoir heterogeneity have become the focus of the development of oilfield forcing the water shutoff technology continue developing, in order to improve the recovery rate to a good development effect. According to the construction of different objects, water shutoff technology can be divided into water injection profile control and water shutoff. But these two kinds of operation modes are used on a large number of chemical agents, so these can also be used by chemical means for water plugging, and currently the most be used by control.

2. Water shutoff technology status

Water shutoff technology is composed of the near well profile control technology and the deep profile control technology. Near wellbore profile control technology mainly solves the reservoir heterogeneity between the contradictions, as strong or stronger gel plugging agent; In the late stage of oilfield development, water injection wells in the reservoir margin under the condition of less use of deep profile control technology; The plugging agent for particles or gel. The near wellbore area weakened with the oilfield development, and the increasingly deep profile control [1], including deep weak gel profile control system, has more application.

Water shutoff profile control technology application research in China generally has the following four stages of development, as described in table 1.



Table 1. The development of water shutoff profile control technology application in China.

| Years | Stage of oil field | Technical type | Plugging agent |
|-----------|----------------------------|---|---|
| 50s -70s | Early stage | Mechanical water plugging profile control technology | Cement, resin, heavy oil, calcium chloride, etc. |
| 70s-80s | Early stage | Physical barrier blocking | Strong gel plugging agent based polymer and crosslinking agent |
| 90s | high water cut stage | Polymer water shutoff and deep water plugging and profile control | Applied in different system of nearly 100 kinds of plugging agent |
| After2000 | Extra high water cut stage | Deep water shutoff and the deep fluid diversion | Deep water flooding technology supporting water shutoff agent |

Flooding problems in high water cut period are increasingly complex, so requirement of water shutoff technology is becoming higher, driven by its rapid development. In recent years, water shutoff technique and plugging agent research in China has made many advances in the international leading position, R & D, containing weak gel dispersion gel, swellable particle profile control technology, the high water cut oilfield water flooding development effect is improved, and improved the recovery ratio [2, 3].

3. Field application of chemical plugging agent type

Non selective and selective water shutoff agents are currently two kinds of commonly used chemical plugging agents.

3.1. Non selective water shutoff agent

Non selective water shutoff technology is used to seal single or high aquifer. The plugging agent has no selectivity to oil and water, so it can be blocked. Before the profile, make sure the water layer section, plugging agent injection water layer, use the appropriate method to separate oil and water layer, injected water plugging agent formation blockage can be achieved. Main plugging agents are cement, calcium silicate gel, resin, gel, etc [4].

3.1.1. Weak gel plugging agent. The weak gel is a kind of polymer which is close to the polymer flooding, formed by adding a small amount of delayed crosslinking agent [5]. Usually use the concentration of 800 ~ 3000 mg/L of high molecular weight polyacrylamide to advocate agent for crosslinking. There are many different kinds of crosslinking agents, like resin, dialdehyde, polyvalent metal ion, etc. Moreover acetic acid chromium, aluminium citrate and glyoxal are commonly used abroad [6], while phenolic composite of resin, poly lactic acid, acetic acid, chromium, chromium etc. are commonly used in Chinese oil fields.

3.1.2. Oily sludge plugging agent. Oily sludge is a kind of industrial waste due to its complex chemical properties. It is one of the main by-products of crude oil production. The main ingredients are water, mud, colloid, asphalt, wax etc. In general, the oil sludge is a stable suspension emulsion, which is formed by the stabilization of the system, but it is difficult to realize multiphase separation. As a particle plugging agent, it has characteristics of high yield, high oil, viscosity, fine grain, hard to dehydration, etc. Compared with other chemical agents, it has better resistance to salt and high temperature and shear resistance. It has obvious advantages in high dose injection, low cost and good effect. Furthermore, it can also solve the problem of oily sludge treatment and emission, reduce the environmental pollution and the oil sludge solidification cost, and deal with the harmful components in time.

West GuDong in Shengli oilfield in 1992 used the HPAM/chromium acetate system to test three well group, which was the earliest application of this technology in our country. A total of 155 thousand cubic meters of profile control agent, the use of 3000 mg/LHPAM and 500 mg/L chromium acetate system, water injection wells after the injection pressure profile increased by about 3 MPa on average, the cumulative increase of oil 9800 t [7]. Liaohe Oilfield used weak gel deep profile control and the effect was the best overall, the temperature is about 55 °C, reservoir depth is 1550 ~ 1700 m, 2200 mg/L mineralization, average porosity is 20%, the permeability is 1.13 D, which has significantly improved the efficiency of water flooding, valid for 3 years [8].

3.1.3. Cement plugging agent. As one of the early use of plugging agents, cement plugging agent is of low prices, big intensity, easy to adapt to the temperature environment, etc. After the solidification of cement impervious to the use of this mechanism to plug the hole, for example, the lower water, channeling water, or squeeze into the water blocking, Due to the large size of cement particles, it is difficult to enter the middle and low permeability formation, so the plugging strength and success rate are low and the validity period is short, so the application scope is limited [9]. In recent years, superfine cement and cement additive agent have been developed successfully and have broad prospects for cement plugging.

3.1.4. Resin plugging agent. The resin plugging agent is a polymer material produced by condensation of low molecular substances, with the body structure is difficult to soluble fusion. After heated by the change of nature, it can be divided into thermosetting resin and thermoplastic. Thermosetting resins such as phenolic resin, epoxy resin, sugar alcohol resin and so on are often used as non-selective plugging agents. Phenolic resins are commonly used in oil fields [10]. Will preshrinking liquid mixed with thermosetting phenolic resin curing agent into the water, suitable for formation temperature and curing agent, the crosslinking, within a certain time to form difficult to soluble phenolic resin melt, can block the formation of the layer. The advantages of Resin Plugging Agent: high strength, many kinds of pore. The cured resin is neutral, and the chemical stability is not easy to react with the underground liquid. However, before the curing of resin is sensitive to pollution, such as water, watch live agent, acid and alkali, must pay attention to detect horizon and isolation before use.

3.2. Selective water shutoff agent

Selective plugging agent is used to separate water and profile control by using the difference between oil and water, oil layer and water layer. With the rapid development, there are many methods of water shutoff, such as water shutoff agent, oil based plugging agent and alcohol based plugging agent type of different dispersion medium, water, oil and alcohol solvent, respectively.

3.2.1. Oil-based plugging agent. Oil-based plugging agent is mainly composed of thickener BCI, amphoteric polymer, diesel and other components [11]. High pressure plugging agent is injected into the oil well stratum, polymer by oil and oil flow channel of high water content and low degree of crosslinking and hydrolysis characteristics is difficult, and can avoid the emergence of gel which did not affect the flow of oil, at the same time, it can be mined with the flow of oil, into the water channel into the stratum.

3.2.2. Water plugging agent. Water plugging agent due to the variety and the lowest cost is now widely used in China's oil production. One of the most commonly used water-soluble polymers [12]. Its aqueous solution will be priority into containing high water-bearing formation, through the adsorption effect of hydrogen bonding in water layer at the grass-roots level surface to make further reserves, based on polypropylene acyl ammonia as the main raw material of the application principle of plugging agent.

3.2.3. Alcohol-based plugging agent. Alcohol-based plugging agent with resin dimer, alcohol based compound plugging agent, etc., not often used in practical production. It is commonly used to explore the possibility of selective plugging of reservoir water under the conditions of high temperature. Alcohol-based plugging agent is mainly composed of water-soluble polymer and sodium silicate aqueous ethanol solution [13].

4. Classification of oilfield water shutoff profile control technology

4.1. Mechanized water shutoff profile control technology

Mechanical water shutoff profile control technology is mainly based on the water pipe column and the relevant packer. The separator water layer will prevent water from entering the septum in the wellbore in the well. In the field practice, after entering high water cut period in mining mechanization technology is gradually to the adjustable layer technology and hydraulic adjustable two aspects of technology development, water shutoff profile control with the help of this kind of mechanization technology development will also improve the efficiency of water plugging in the actual work, also can achieve the larger goal in control water stabilizing oil production process [14].

4.2. Fine chemical profile control technology

Fine chemical profile control technology is mainly targeted according to the injection Wells in high water absorption layer on the longitudinal distribution of specific characteristics to carry on the fine chemical profile control, usually used to supplement mechanical profile control technology, to improve the remaining reserves of various types of reservoir the mining efficiency through the fine adjustment of injection profile [7]. This technology has a positive effect on improving the stability of oil and water control and the potential exploitation of oil reservoirs, improving the efficiency of oilfield development and the economic benefits etc. all have positive role, and oilfield development residual oil reservoir at the high water-cut stage is effective means of profile control.

4.3. Deep profile control technology

Deep profile control technology is injected the plugging agent deep into reservoirs. In the oil field actual mining for deep reservoir area, requires a lot of chemicals to injection, a prajnaparamita normal can use the block water cut 1/4 or 1/3 of the spacing of the actual processing. For water injection well in large pores or obvious cracks is required by 1/2 and above the well spacing, in order to reach the deeper parts of the high permeability reservoir plugging water layer, the water absorption layer is reduced and the actual permeability affected area to expand, improve the recovery factor [15].

4.4. Block water shutoff in oil field

The water injection wells with more than 1/3 are selected in the oil field blocks that need to be dealt with by the reasonable profile control and water shutoff measures. According to the characteristics of the reservoir and the overall requirements of the oil field development, the auxiliary measures such as adjusting the parameters, acidizing, filling holes and other auxiliary measures are adopted to achieve the purpose of improving the overall development effect.

5. The development trend of profile control water plugging technology

At this stage the profile control technology applied in the actual production of the oil field in our country has the following trends:

- Based on the principle of molecule and the principle of design, this paper studies the water absorbing delayed expansion agent, and has good research results;
- Application in horizontal well water shutoff profile control technology research has clear progress;
- Physical simulation technology, simulation of profile control technology should pay more attention to practicality, simplicity.

- The development of new technology of environmental protection water shutoff and profile control, which is based on the selectivity of nano molecular materials, and it will be the main research field in the future.

5.1. Microbial technology applied in the profile control water plugging

Microbial profile control technology is injected into formation microorganisms or used to activate the formation source. Microbial metabolism, growth and reproduction will produce gas or bio polymer, inorganic salts, the precipitation of these substances can be used to adjust the formation of the biofilm water injection profile. For water flow channel, the breeding of microorganism in the porous media, can reduce the permeability of high permeable zone formed hyphae community, to improve recovery factor [16]. Microbial profile control technology is applied in the exploitation of oilfield remaining reserves, has brought good economic benefit, environmental protection, safety, less material consumption, wide raw material sources, and the advantages of less equipment, good application prospect.

5.2. CO₂ deposition technology applied in the profile control water plugging

Adding CO₂ in the foaming agent can increase the resistance factors of foam system, the ability of the seal steam enhanced; The resistance factor decreased with the increase of temperature, and the foam stability of CO₂ foam was good under high temperature and high pressure; The resistance factor of CO₂ foam increases with the decrease of oil saturation and the increase of formation permeability. It can be seen that the CO₂ foam can be used to block the steam channeling channel and the large pore channel [17]. CO₂ foam flooding has good adaptability and good environmental protection, but there are few applications and large space for development, which is technically feasible and economically feasible still needs further validation. CO₂ water shutoff profile control, as a new technology with cationic reaction precipitation formation water, the purpose of the change of formation permeability to water shutoff profile control, Also it is the development direction of the future.

6. Conclusion

Water shutoff profile control technology has experienced decades of development, has formed a more mature water control oil stabilization technology. It can improve water flooding development effect according to different reservoir conditions, and it should be toward the low input, high-yield, multi-function, the direction of good efficiency in the future, and for different fields, practical solutions for the reservoir in high water cut period should be developed to achieve efficient development.

The technical research and development should be carried out for different conditions of the reservoir:

- According to the specific situation of the oilfield development economy long-term new water plugging material. It is important to consider the economic feasibility of water shutoff profile control in high water cut reservoir.
- Study on how to improve the mechanism of water flooding with water plugging and profile control technology. According to the current situation of oilfield development, the establishment of physical model and the corresponding evaluation, combined with the test, correlation of the real conditions of reservoir diversion agent materials and oilfield, study new control technology for different reservoir conditions.
- Precise numerical simulation and design software research and development. Most of the oil fields in our country have been greatly changed due to the long-time of strong injection and high water cut reservoir conditions. The numerical simulation and optimization design method of the traditional seepage theory is not enough to improve the present situation of water plugging and profile control technology. In combination with the practical situation of reservoir, research and development of the corresponding numerical simulation and optimization design software, make full use of the plugging agent, and achieve the best effect of development.

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