Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 12, No. 3, 2024

Research Progress of Solid Scale Inhibitors Used in Oilfield

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Abstract: Solid scale inhibitor has the advantages of long operation time, low operating cost and simple operation, and has broad application prospects in oil field production at home and abroad. In this paper, the basic components, preparation technology and common curing carrier of solid scale inhibitors are introduced, and the research and application progress of solid scale inhibitors are introduced.

Keywords: Scaling mechanism; scale inhibitor; curing carrier.

1. Introduction

With the progress of industry and science and technology, in order to solve the problem of oil well scaling, liquid scale inhibitor is usually added to oil wells, but due to the limitation of working conditions, the application area is still small, and the labor cost is high, and the addition is difficult. For gas lift oil wells and gas wells, due to the fast flow rate of produced medium and high well pressure, liquid scale inhibitor cannot be added or the retention time after adding is short, and the scale inhibition effect is not good [1]. Compared with solid scale inhibitor, solid scale inhibitor has the following advantages: This paper mainly introduces the research and application progress of solid scale inhibitor, hoping to provide reference for the development and application of solid scale inhibitor in oil and gas fields.

2. Scaling Mechanism of Oil Well

According to the analysis of scaling position in oilfield, the scaling types in oilfield can be divided into formation scale, wellbore scale and surface system scale. Fouling includes crystallization scale, granular scale, chemical reaction scale and corrosion scale. Oilfield water scaling is often caused by many reasons, and scholars at home and abroad generally believe that the scaling mechanism includes the following: fluid incompatibility theory, mechanical condition change theory, adsorption growth theory and microbial activity corrosion theory [3].

(1) Fluid incompatibility theory. In oilfield system, scaling easily occurs in wellbore or gathering system when incompatible fluids of different layer chemicals are mixed. When water injection development technology is adopted, scaling will also occur in injection well or oil layer when injected water is incompatible with produced water.

(2) Mechanical condition change theory. When the thermodynamic conditions such as temperature and pressure change, the ion equilibrium state in water changes, the solubility of scaling components decreases and crystal precipitation precipitates are precipitated. In addition, the sudden change of position, streamline, flow rate, pressure and density of flow channels such as valves and pump suction ports in oilfield systems will also occur, and the dissolution equilibrium state of scaling salts will be destroyed, resulting in scaling.

(3) Adsorptive growth theory. Pipeline and equipment wall surface is microscopic rough surface, with fluid transport, due to thermodynamic or kinetic changes, the particulate scale precipitated from the solution will be adsorbed on the wall and crystallized around it.

(4) Microbial activity corrosion theory. The temperature, pressure and water quality of oil and gas fields often change. When the production conditions are conducive to microbial activity, corrosion and scaling are easy to occur.

3. Preparation of Solid Scale Inhibitor

3.1. Scale inhibitor

The main component of solid scale inhibitor is matrix scale inhibitor, which should have the following characteristics: large molecular weight, easy grafting of structure and group, good scale inhibition performance, high freezing point; easy to cure and form, good water solubility, and good compatibility with additives and curing agents. At present, scale inhibitors mainly include five categories [4]: natural polymer scale inhibitor, phosphoric acid scale inhibitor, carboxylic acid polymer scale inhibitor, sulfonic acid polymer scale inhibitor, and green environment-friendly scale inhibitor.

3.2. Curing carrier

The solid scale inhibitors prepared by selecting different solidified carriers will show different dissolution characteristics. Therefore, the selection of carriers is particularly important. The optimized matrix scale inhibitors are combined with carriers to obtain solid scale inhibitors with different proportions after solidification. The products with good scale inhibition performance and dissolution rate can be put into use.

3.2.1. Polyvinyl alcohol

Polyvinyl alcohol (PVA) is a colorless, nontoxic, non-corrosive, biodegradable, water-soluble organic polymer. PVA has good swelling, water solubility, adhesion, softness. Therefore, PVA is widely used in textile sizing, adhesives, emulsifiers, films and other industrial fields.

3.2.2. Sodium silicate

Solid sodium silicate dissolves slowly in water and can be used as slow release material. Its solubility is affected by its own composition and external environment. Its solubility can be adjusted by controlling its modulus n/m. Adding some metal oxides can also adjust its dissolution rate in water. In addition, external conditions such as temperature and pH will also affect its dissolution rate in water[5].

3.2.3. Hydrogel

Hydrogel is a polymeric material in which abundant porosity is available to accommodate active substances and maintain high local concentrations of active pharmaceutical ingredients over long periods of time by diffusion, swelling, chemical or controlled release mechanisms based on certain environmental stimuli.

3.3. Curing method

Solid scale inhibitor should have good scale inhibition performance, easy solidification, good water solubility, good compatibility, slow release of effective ingredients and other characteristics, so it is very important to select appropriate preparation technology and process conditions [6].

3.3.1. Technique of high-temperature melting

The solid scale inhibitor is prepared by mixing scale inhibitor and synergistic agent with good scale inhibition effect, loading into a container, placing into a high temperature reaction furnace, reacting at high temperature, cooling and forming.

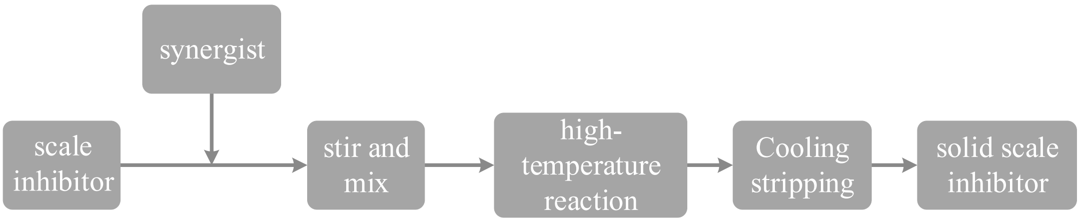

Figure 1. Process flow chart of technique of high-temperature melting

3.3.2. Adsorption impregnation

Select a substance with good adsorption or use a material that can form a gel and consolidate as a carrier, mix it evenly with the scale inhibitor, heat it at a certain temperature for dehydration, and form it to finally form a solid scale inhibitor.

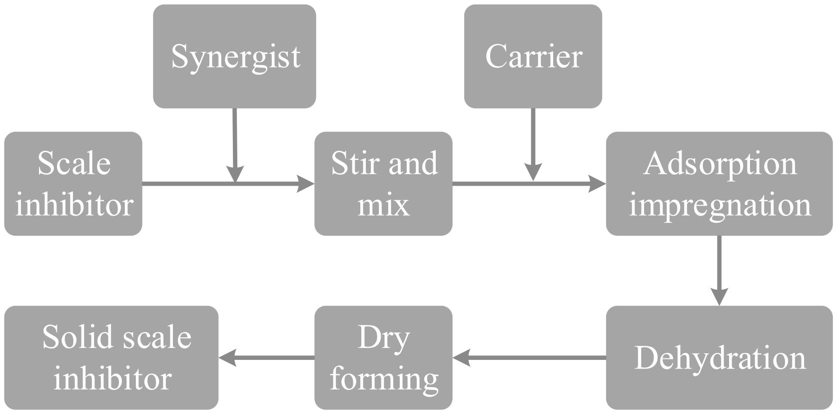

Figure 2. Process flow chart of adsorption impregnation

3.3.3. Capsule coating method

The scale inhibitor is coated with a high-density slightly water-soluble or microporous material to make capsules or coatings, or the scale inhibitor can be dissolved or dispersed in a polymer matrix to form a matrix-type micro-spherical skeleton, thereby making a slow-release scale inhibitor.

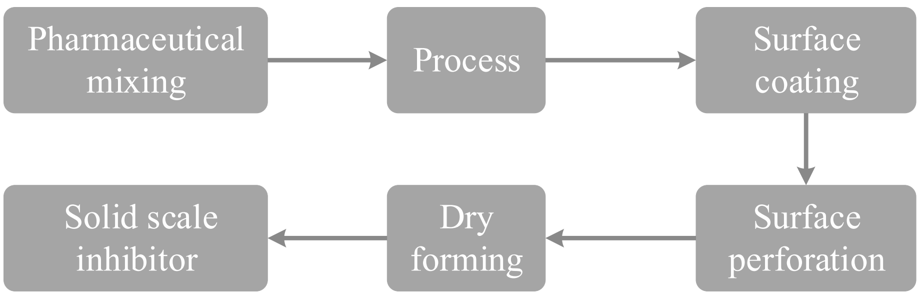

Figure 3. Process flow chart of capsule coating method

3.3.4. Cementing method

The scale inhibitor, synergist, filler and other agents are mixed according to a certain proportion, and an appropriate amount of binder is added, which is put into a mold for pressure molding, and finally dehydrated and dried to obtain a solid slow-release scale inhibitor.

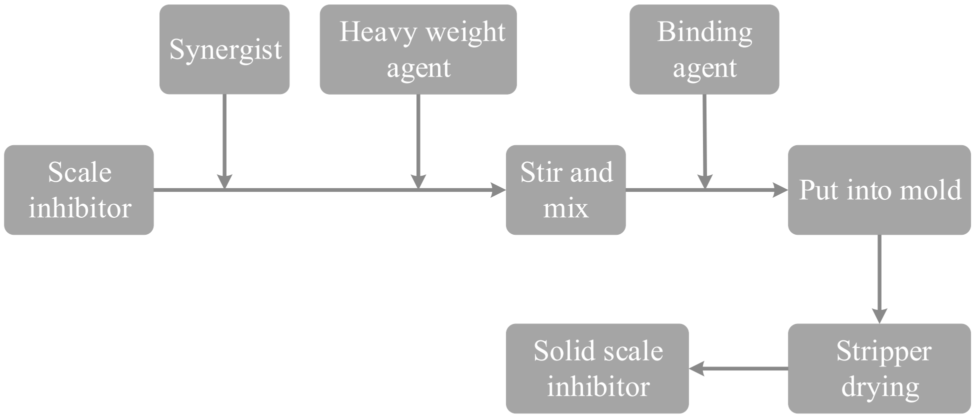

Figure 4. Process flow chart of cementing method

4. Research Progress of Solid Scale Inhibitor

Using polyvinyl alcohol as carrier, the preparation of solid scale inhibitor by cementing method is low cost and easy to operate, so it is the method adopted by most researchers at present. Han Xiaoqian [7] prepared three series of long-acting slow-release solid scale inhibitors with seven different structures based on the synthesis of macromolecular scale inhibitors. The slow-release solid scale inhibitors were prepared with PVA1788 with polymerization degree of 1700 and alcoholysis degree of 88% as the carrier, and the scale inhibition rate of calcium carbonate scale was as high as 90%. Luo Gang [8] Through orthogonal experiment, the optimal compound system of MSV, MAH, EDTMPS and PESA was used as the matrix scale inhibitor, and PVA1788 with polymerization degree of 1700 and alcoholysis degree of 88% was used as the carrier to prepare the slow-release solid scale inhibitor. The release rate of effective agent was 2.70mg/h, and the scale inhibition rate was over 90%.

Yu Liu Jie [5] took sodium silicate with modulus of 1.8 as curing carrier, added effective component M, and added proper amount of auxiliaries such as ZnO and Al_2O_3, and after high temperature reaction, cooled to obtain solid corrosion and scale inhibitor. At 50°C, the dissolution rate of the sample in the produced fluid is 14.57 mg cm-2 d-1, and the dissolution period is as long as 314d d. When the concentration of the sample in the produced fluid is 30mg/L, the scale inhibition rate of the sample to the two produced fluids is as high as 96.1% and 95.8%, respectively, and the corrosion inhibition rate is 46.1%.

Guo Kai [9] prepared a solid scale inhibitor with polyaspartic acid as the main scale inhibitor and transparent soap base as the carrier, and the scale inhibition effect was the best when the mass ratio was 1:3. When the prepared solid slow-release scale inhibitor was released for 5h, the scale inhibition rate of the simulated scaling solution could reach 90.24%.

Guo Liang [10] and others developed new corrosion and scale inhibitors HZ-1, HZ-2 and HZ-3, and HZ-2 was selected as the main agent of the corrosion and scale inhibition rod. Combined with the skeleton material, the solid corrosion and scale inhibition rod was successfully prepared by mixed pressing method. The dissolution rate of solid corrosion and scale inhibition rod is 0.06 ~ 0.08g/(cm2·m3), and the scale inhibition rate of calcium carbonate is 90% and the corrosion inhibition rate is 92.1% at 60℃.

Xiao Yan [11] and others studied and synthesized a series of scale inhibitors NCP-X(X=0,3,5) with low dissolution rate by melting at high temperature. The experimental results showed that NCP-X could be released slowly and evenly in circulating cooling water, and the higher the aluminum content, the lower the dissolution rate. In the temperature range of 30 ~ 70℃, NCP-X has good scale inhibition performance.

Wang Yangyang [12] synthesized eight new types of hyperbranched polymer scale inhibitors by Michael addition and amidation reaction, and filled the best scale inhibitor into porous ceramsite to prepare a slow-release hyperbranched polymer scale inhibitor. Under static and dynamic conditions for 60 days, the scale inhibition rates of $CaSO_4$ and $CaCO_3$ were 95.6% and 92.1% respectively, and 93.2% and 89.8% respectively.

Liu Tong [13] et al. mixed low-phosphine solid anti-corrosion and scale inhibitor, sulfur remover, carbon dioxide neutralizer and bactericide in a certain proportion by adhesive, then dried and solidified to prepare a solid corrosion and scale inhibition system, which was put into a special oil pipe to prepare a corrosion and scale inhibition pipe. The average pump inspection period was increased from 41 days to 210 days, and the effect was very remarkable.

5. Summary

(1) Compared with liquid scale inhibitors, solid scale inhibitors have the characteristics of stable composition, simple operation and long application cycle, which greatly reduces the scale inhibition cost and shows broad application prospects.

(2) The curing method of solid scale inhibitor is determined by the selected agent, and most of them choose the cementing method, which is easy to realize and has a high success rate.

(3) In the research of curing carrier, polyvinyl alcohol is the most commonly used, but other new carriers also show certain advantages, so there is still a lot of room for development in carrier selection.

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