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Application of Solid Acid Plugging Removal Technology in Oilfield

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Abstract: In this paper, the cause of blockage in a heavy oil field well is analyzed, and a new solid acid plugging removal system is adopted, which achieved good plugging removal and injection effect in field application. The solid acid plugging removal system is a new type of oilfield multi-dimensional three-dimensional plugging removal system, which belongs to the polyhydroic acid system, combined with the lipophilic surfactant factor, and has various functions such as dissolution penetration, broken chain degradation, sterilization and anticorrosion, and three-dimensional dispersion. Through the evaluation of compatibility, dissolution and corrosivity of the solid acid plugging removal system, solid acids perform well. The plugging removal effect of an oilfield is remarkable, the acid system is suitable for the near well blockage or deep blockage of the heavy oil block well, which can relieve the blockage of inorganic matter, and also relieve the blockage of some organic matter and crude oil or microorganisms. Solid acids are superior to conventional acids in transportation, preparation and use, and have good application prospects.

Keywords: *Blockage; Deep acidification; Plugging removal; Solid acids*

With the extension of oilfield development time, the formation temperature and original formation pressure drop greatly, the light components of crude oil volatilized, and the heavy components such as colloid and asphaltene precipitated [1], resulting in the precipitation of condensate oil in the reservoir near the well [2]. During drilling and operation, the injection of foreign fluids may cause reservoir damage, leading to the blockage of reservoir channels [3], and prevent the normal production of oil and water Wells. In order to solve the bottleneck problem of reservoir plugging in an oilfield, the causes of reservoir plugging in an oilfield are comprehensively analyzed, and a solid acid plugging solution system suitable for the common heavy oil development block of the oilfield is selected. Through the optimization and matching of acidizing process, a well plugging solution technology system suitable for the characteristics of heavy oil blocks is initially formed, and a good plugging solution and injection increase effect is achieved after field application. **1 Analysis of plugging mechanism of Wells in an oilfield**

A heavy oil field has a multi-oil-water system with simple structure, but the reservoir has a large lateral change. The average porosity of the reservoir is 32.7%, the average permeability is 2.7μm, and the reservoir temperature is 68℃. The reservoirs are highly heterogeneous and overlapped with each other, with narrow channel deposits as a whole.

Comprehensive analysis of the causes of Wells plugging in an oilfield:

(1) Influence on the quality of injected sewage. Reinjected sewage usually contains particle impurities, solid suspended matter, organic impurities, various bacteria, microorganisms and iron scale into the formation, causing pore throat blockage. Long-term accumulation of these pollutants has a significant impact on the reinjection capacity;

(2) The expansion and migration of clay minerals and the high content of mud in oil and water Wells (20.3% ~ 41.6%), the clay minerals in the reservoir are prone to hydration expansion and migration during the production process, which leads to the blockage of the reservoir pore throat [4] and reduces the permeability near the well;

(3) Condensate oil precipitation (colloidal, asphaltene and other heavy components of organic scale) near the well is blocked, resulting in increased water injection pressure.

Conventional acidizing working fluid has great security risks in the process of transportation and storage. The acid fluid has a single function and needs to add a variety of additives, most of which are toxic and harmful. After acidizing operation, a large number of iron ions will be generated, causing formation damage [5]. Solid acid unplugging system has good corrosion performance, stable iron ion ability and low damage, and is superior to conventional acid in transportation, preparation and use.

II. RESEARCH ON PLUGGING REMOVAL TECHNOLOGY WITH SOLID ACID

A. Solid acid plugging system and technical principle

Solid acid is a new oilfield multi-dimensional and three-dimensional plugging solution system, belonging to the polyhydroacid system. Combined with oil-philic surfactant factors, solid acid has various functions such as dissolution and penetration, chain breaking degradation, sterilization and anti-corrosion, and three-dimensional dispersion. It has unique formation and process affinity characteristics, and achieves formation wetting reversal [6] without affecting the demulsification and dehydration effect.

The solid acid mainly uses sulfamic acid as the main raw material, and also contains organic phosphonic acid, citric acid, glycine, borate, organic amide, alkyl sulfonic acid and other additives, with a variety of complex functions.

Table 1: Components of solid acid plugging system

Serial number	constituent	use
1	Sulfamic acid	Solution penetration
2	Organophosphonic acid	Polyhydroacid, chelating agent
3	Citric acid	Complexing agent
4	borate	Oxidant, chain break degradation
5	Organic amide	Sustained-release agent, anti-corrosion
6	Alkyl sulfonic acid	Surface activator, stereodisperse
7	glycine	Fungicide

Sulfonic acid, the main component of solid acid, can react with inorganic substances such as metal oxides and calcium and magnesium compounds respectively, mainly dissolving inorganic substances. Meanwhile, other components contain organic acids, mainly producing mixed fatty acids and aromatic acids, which can dissolve organic substances in the formation and dissolve some inorganic substances [7]. Compared with hydrochloric acid, hydrofluoric acid and soil acid, the reaction speed is fast, the action distance is short, and the sand production will be serious in the formation with loose cement. Sulfamic acid is a medium strong acid, which reacts slowly with rocks and does not damage the formation skeleton, so deep acidification can be carried out [8].

（1） React with metal oxides

$Fe_3O_4 + 8NH_2SO_3H \text{—} Fe(NH_2SO_3)_2 + 2Fe(NH_2SO_3)_3 + 4H_2O$

$Fe_2O_3 + 6NH_2SO_3H \text{—} 2Fe(NH_2SO_3)_3 + 3H_2O$

$FeO + 2NH_2SO_3H \text{—} Fe(NH_2SO_3)_2 + H_2O$

（2） Reaction with calcium and magnesium compounds (limestone)

$CaCO_3 + 2NH_2SO_3H \text{——} Ca(NH_2SO_3)_2 + H_2O + CO_2\uparrow$

$MgCO_3 + 2NH_2SO_3H \text{——} Mg(NH_2SO_3)_2 + H_2O + CO_2\uparrow$

$Mg(OH)_2 + 2NH_2SO_3H \text{——} Mg(NH_2SO_3)_2 + 2H_2O$

$Ca_3(PO_4)_2 + 6NH_2SO_3H \text{——} 3Ca(NH_2SO_3)_2 + 2H_3PO_4$

B. Evaluation of solid acid laboratory experiment

(1) Compatibility test [9]

A solid acid solution with a mass concentration of 5% was prepared and mixed with reinjection water in water injection Wells according to different volume ratios (1:9, 2:8, 3:7, 4:6, 5:5), and then heated at 70℃ for 2 hours at constant temperature to observe the water quality changes. It can be seen from the data in Table 2 that the solid acid solution is well compatible with reinjection water in injection Wells.

Table 2: Compatibility experiment data table

Ratio of solid acid solution to reinjection water	Room temperature 20℃	Constant temperature 70℃	remark
0:10	clarification	clarification	Reinjection water
1:9	clarification	clarification	
2:8	clarification	clarification	
3:7	clarification	clarification	
4:6	clarification	clarification	
5:5	clarification	clarification	
10:0	clarification	clarification	Solid acid solution

(2) Corrosion test [10]

A solid acid solution with a mass concentration of 5% and 10% was prepared respectively, and the scale sample of a plugged well of about 2g was weighed and heated at 90℃ for 4h[11]. Parallel experiments were conducted to compare the two groups, and the residual scale sample mass after reaction was weighed and the scale dissolution rate was calculated. It can be seen from the data in Table 3 that the scale dissolution rate of the two concentrations of solid acid solution is more than 90%, and the blockage removal system has a good corrosion ability for the scale samples of the blocked well.

Table 3 Scale dissolving experiment data (normal pressure, 90℃, scale dissolving time 4 hours)

Serial number	Concentration %	Solid acid solution mass g	Scale sample Mass g	Paper, dish quality g	Mass g after filtration and drying	Residual mass g	Scale dissolution rate %
1	10.00	200	2.0060	54.2842	54.3308	0.0466	97.67%
2	10.00	200	2.0058	49.3818	49.4170	0.0352	98.24%
3	5.00	200	2.0061	54.699	54.8960	0.1970	90.18%
4	5.00	200	2.0065	49.7413	49.9279	0.1866	90.70%

(3) Corrosion test

According to the evaluation standard of corrosion inhibitor for acidification [12], corrosion test was conducted on N80 steel sheet. It can be seen from Table 4 that the corrosion inhibitor added to solid acid is difficult to meet the requirement of corrosion rate less than 5g/m·h. When 0.25% acid inhibitor was added to solid acid, the corrosion rate decreased significantly. The average corrosion rate of the solid acid system on the N80 steel sheet is 0.84g/m·h, which meets the requirements of the national industry standard.

Table 4: N80 corrosion test (5% mass concentration, atmospheric pressure, 90℃)

Serial number	Tag number	Mass g	Corroded mass g	Lost mass g	Corrosion duration h	Corrosion rate g/m*hundefined	remark
1	8050	12.2174	12.1638	0.0536	4	5.9814	2021.3.18 14:25-18:30 Production of water
2	8051	12.5244	12.4505	0.0739	4	8.2155	
3	8052	12.5178	12.4669	0.0509	4	5.6658	

4	8053	12.6036	12.5222	0.0814	4.25	8.4839	2021.3.20 17:23-19:42 Tap water
5	8054	12.3943	12.3144	0.0799	4.25	8.3893	
6	8055	12.3497	12.2635	0.0862	4.25	9.0451	
7	8037	12.0445	12.0373	0.0072	4	0.8019	2021.3.24 17:23-19:43 0.25% corrosion inhibition Tap water
8	8038	12.7601	12.7518	0.0083	4	0.9197	
9	8039	12.0453	12.038	0.0073	4	0.8131	

III. FIELD APPLICATION AND EFFECT EVALUATION

The daily injection volume of well H in an oilfield is 440m/d, the wellhead injection pressure is 7.5MPa, and the apparent water absorption index is 58.7m/(d·MPa). This well has not carried out any measure operation since the well was transferred to the injection well, and the injection can meet the injection requirement in the early stage of the injection. With the progress of water injection, the current injection water volume fails to meet the injection requirement, and it is analyzed that there is pollution in this well, so it is necessary to unplug this well, reduce the injection pressure and increase the injection water volume. The wellhead injection pressure should not exceed 1450psi (10.0 MPa) during acid extrusion to ensure the safety of wellhead equipment and ensure that the injection pressure is lower than the formation rupture pressure of the water injection layer.

A. Plugging removal process

The solid acid plugging removal process is simple, safe and reliable, as shown in Figure 1. During construction, it is necessary to mix solid acid into an aqueous solution (2%-5% mass concentration), fresh water or seawater according to site conditions and plugging needs. The injection method of the prepared solution is referred to the conventional acid injection process [13]. The usage amount is generally designed to be 1-2 meters according to the treatment radius, and the shut-in reaction time is determined according to the process. In order to avoid the loss of the treatment fluid along the high permeability zone of the formation [14], under the pressure conditions allowed by the equipment and the formation, the tubing is injected with a high displacement as far as possible.

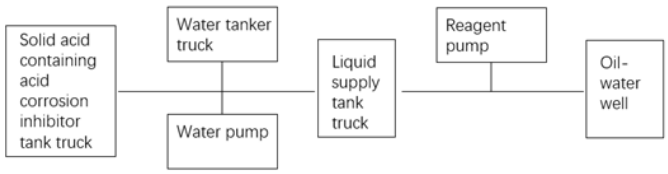
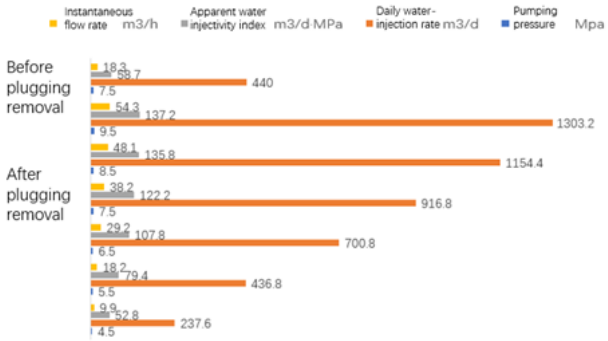


Figure 1: Offline plugging removal process flow

B. Field application effect

After the well was constructed, water injection indication test was carried out, and the measured data were shown in Table 5. It can be seen that under the action of solid acid solution, the injection pressure decreases by about 2MPa after plugging removal under the same displacement/daily injection water volume. Under the same injection pressure (7.5MPa), the daily injection water volume increased by 220%. The experimental results show that solid acid has a significant effect on plugging removal in an oilfield. The acid system is suitable for near-well plugging or deep plugging of Wells in heavy oil blocks, and can relieve the plugging of inorganic substances, as well as some organic substances, crude oil or microorganisms [15].

Table 5: Water injection indication test curve table



CONCLUSION

（1） Laboratory evaluation experiments show that the solid acid plugging removal system has good performance in compatibility, corrosion, corrosion (combined with acid corrosion inhibitor) and other aspects [16]. The acid solution with a certain concentration is well compatible with the reinjection water in the injection well, and has a good corrosion corrosion ability for a well scale sample, and can reach the national first class corrosion inhibition standard after adding corrosion inhibitor.

（2） The solid acid plugging removal system is suitable for near-well plugging or deep plugging of oil and water Wells in heavy oil blocks. It can remove the plugging of inorganic substances, and at the same time, it can also remove the plugging of some organic substances, crude oil or microorganisms.

（3）The solid acid plugging removal system was applied to well H in an oil field with off-line plugging removal technology. Under the same displacement/daily injection volume, the injection pressure decreased by about 2MPa after plugging removal. Under the same injection pressure (7.5MPa), the injection water volume increased by 220%, and the plugging removal effect was remarkable.

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