RESEARCH ON THE ELEMENTAL SULPHUR DEPOSITION MECHANISM IN HIGH SULPHUR GAS RESERVOIR BY NMR

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ABSTRACT

Using nuclear magnetic resonance (NMR)and physical simulation, high-sulphur gas reservoirs elemental solid sulphur deposition mechanism and the main influencing factors were studied in this paper. The results show that:elemental sulphur was deposited mainly in large pores than in little pores. With the sulphur deposition in large pore, the saturation of natural gas is reducing and the T2 number is growing. The amount of the sulphur deposition in large pores has been displaced by the follow-up of gas with the pressure reducing and the cumulative gas production increasing. As long as the volume of gas production is large enough and gas flow velocity is high enough, sulphur deposition in question will be resumed without heavily damage.

Key words： sour gas; nuclear magnetic resonance; sulphur deposition; damage; mechanism

FOREWORD

The element sulphur was always dissolved in high sulphur gas reservoir in the beginning. The solubility equilibrium will be broken with pressure decline, and the solubility of sulphur will reduce. Then the sulphur will begin to crystallize when its concentration is higher than its solubility. The depositional sulphur may be liquid or solid and will occupy or even block the pores, change the structure of pore throats, decline the permeability of layer, and finally affect the output of gas wells.

Overseas, Kennedy and Wielend[1], and Roof[2] researched the solubility of sulphur in H_2S through experiments. Swift[3], Brunner.E.[4, 5], Woll [6] and Kennedy et al. [1] researched the solubility of sulphur in fourteen different mixed gases with different ratios of H_2S, CO_2, C_1~C_4. P.M.Davis[7], Brunner E., Swift S.C.[3] and Kunal Karan[8] et al. researched the solubility of sulphur in pure H_2S and dry gas from different angles. Using

Brunner E. and Woll W.'s experimental data, Chrastil[9], Tomcej R.A[10] and Bruce E.Roberts[11] et al. established the constant coefficient empirical relationship about the solubility of sulphur in acid gas, which was usually used to calculate the sulphur's solubility in high sulphur gas reservior. Kunal Karan[8], Elsharkawy and Adel [12] and Al-Awadhy [13] researched the relationship between flow rate and sulphur deposition, then came up with the critical velocity of sulphur by means of core flow tests. Nicholas Hands[14], Shedid A.S. and A.Y. Zekri[15] analysed the effect of natural gas and sulphur deposition on permeability, and gave a formula.

In China, the earliest research on solubility of sulphur in different gases, started by Gu Mingxing[16, 17] et al. was completed in 1993. Zhong Taixian[18], Sun Changyu[19], ZengPing[20] et al. had researched the mechanism of sulphur dissolved in natural gas through simulating the sulphur's solubility in natural gas. These research methods mostly concentrate on the mathematical development, having no support by experiments. The process of sulphur deposition and crystallization lacks enough experimental data, and the mechanism explaining it is unclear. This leads to an uncertain judgment on the types of sulphur deposition (organic, inorganic, elemental).

1 RESEARCH CONTENTS

This paper introduces how to test the depositional location of sulphur and the affecting factors in high sulphur gas reservoirs. It surveys the change of pore volume, the effect on the mass of depositional sulphur by gas flow rate and cumulative production. We try to explain the affecting level on the output of high sulphur gas reservoir caused by sulphur deposition through this research.

2 TEST METHODS

NMR can test the distribution of fluid in pores, with the T2 number reflecting the change of fluid saturation in the pores. Based on this theory, we tested the sulphur deposition in the cores by means of NMR. The gas saturation will reduce after sulphur crystallizes, so where sulphur deposits can be answered by measuring the change of gas saturation before and after sulphur deposition. The measurement of T2 is non-invasive, so there is no alteration of the core.

3 RESULTS AND DISCUSSION

3.1 Research on the Depositional Location of Sulphur

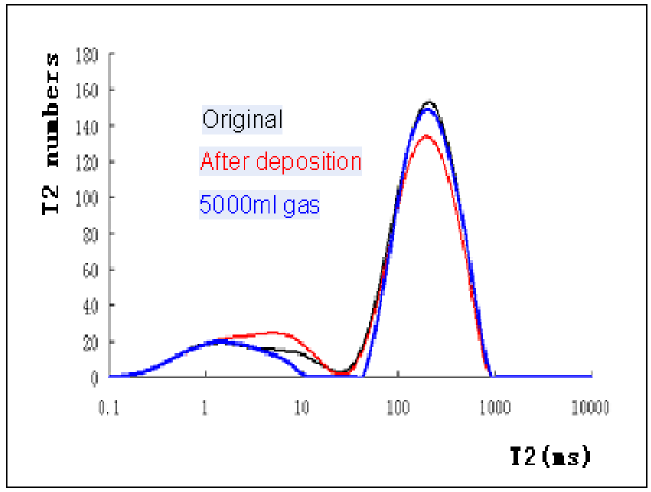

Fig 1: T2 spectral changes for Sulphur deposition after gas production

The sulphur deposited in large or small pores will have a direct effect on the output of gas reservoirs. We measured T2 before and after sulphur deposition in order to make sure where the depositonal location is. We compared T2 before and after sulphur was deposited through experiments. By holding the temperature constant, the fluid state did not change, so only sulphur deposition could change T2. Finally we measured T2.

According to the material balance theory, the reduction of fluid content in large pores will certainly make an increase in other pores. From Fig. 1, sulphur primarily deposited and reduced the natural gas content in large pores, but increased the natural gas content in part of small pores. That was similar to the microscopic profile modification. We continued the experiment after sulphur was deposited, and we found that T2 kept changing with increased flow rate, and the natural gas content recovered to the original state. That means the damage caused by sulphur deposition can be recovered.

3.2 Effect of Natural Gas Production on Sulphur Deposition

We took the T2 cutoff value as a cutting point, divided the fluid distribution in pores reflected by T2 number into two parts, and thought the pores with a greater T2 number than cutting point as large pores. Based on this, we analyzed the change of the T2 number, same as the natural gas content, when continuing the production after sulphur was deposited. (Fig.2)

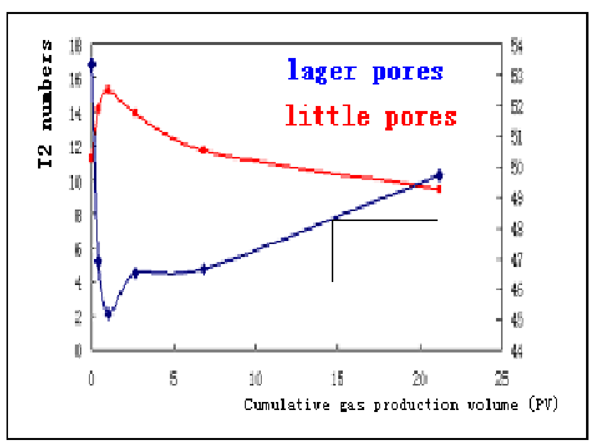

Fig 2: T2 change in differrent cores after gas production with sulfur deposition

From Fig.2, the NMR signals of small pores became weak with the output of the gas increasing, and that of large pores became strong. That meant the depositional sulphur in large pores was displaced out by succeeding fluid, so the signals became stronger with the injection volume of natural gas increasing. The natural gas content of small pores declined with the gas moving to large pores under the pressure difference caused by depositional sulphur decline and pressure decrease. When the output of the gas was large enough, the depositional sulphur in large pores was nearly displaced, then the signals became the same slowly.

3.3 Effect of Natural Gas Flow Rate on Sulphur Deposition

We tested the effect on sulphur deposition caused by natural gas flow rate, and the result is in Fig.3. The elemental depositional sulphur in pore throats was displaced, and the T2 number recovered to the original state gradually with the output of depositional sulphur increasing. So, the problems caused by sulphur deposition will be worked out, as long as the output of the gas increases enough and flow rate is fast enough.

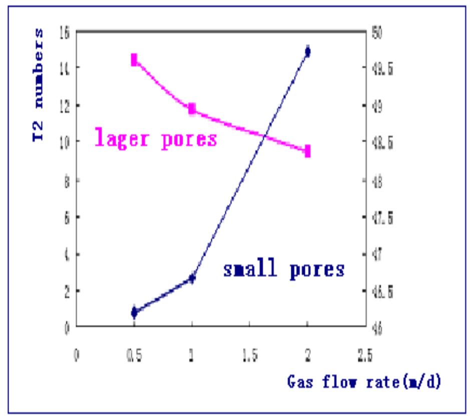

Fig 3:T2 changing with gas flow rate after sulfur deposition

3.4 Size Distribution of Sulphur

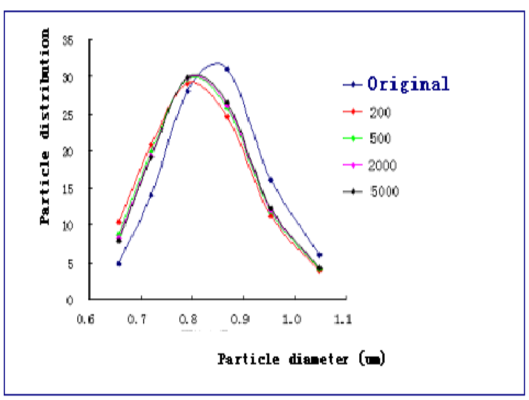

Fig 4: Particle size of sulfur changing under different volume of gas production

We tested the size distribution of elemental sulphur particles displaced out under different output of gas by means of granulometer (Table1 and Fig.4). According to the figure and table, there was some change to the size distribution, showing that the normal distribution of elemental sulphur particles shifted to smaller particle size. Because the large pores were choked and the sulphur particles were not able to move; with the output of gas increasing, some of the sulphur particles were displaced out, and the damage extent declined. That meant the damage was reversible.

Table 1 Sulphur particles diameter distribution at different gas cumulative production

Sulphur Particle Diameter (um)	Cumulative Gas Production (ml)				
	0	50	200	1000	5000
0.657	4.820	10.447	8.805	8.310	7.929
0.721	14.040	20.772	19.841	19.449	19.101
0.791	28.074	29.031	29.645	29.804	29.909
0.869	30.935	24.588	25.727	26.143	26.494
0.954	16.083	11.259	11.859	12.087	12.285
1.047	6.046	3.903	4.123	4.208	4.282

In a word, elemental sulphur probably deposits inside the layer, especially in large pores, but most of the depositional sulphur can be displaced out by succeeding natural gas, and has no great harm to the layer.

4 CONCLUSIONS

(1) The deposition of solid sulphur will choke and damage the layer, but most can be displaced out as production continues, so the damage caused by elemental sulphur can be recovered.
(2) Elemental sulphur mostly deposits in large pores, so it is very important to maintain the production of natural gas before the large pores are blocked off.
(3) Sulphur deposition and movement will happen through the whole production process, so it is necessary to take both of them into consideration and increase the output of gas wells as possible against the blockage caused by sulphur deposition.

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