Analysis of the causes of tube blocking in Jingbian gas field

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Abstract. A large number of blockage appeared in gas wells and pipeline appeared, which caused plugging, corrosion and the increasing of wellbore pressure difference, and seriously affect the normal production of gas well of problems. In this paper, the water quality over the years and natural gas production of the JB1# well in the Jingbian gas field were analyzed, also include the composition of blockage with the chemical volumetric method (CVM), X-Ray Diffraction (XRD) and x-ray fluorescence (XFS) method. Meanwhile, the blockage powder was leached in simulated acid work solution, and then the leaching solution was analyzed with CVM. The experimental results show that the produced water in the JB1# well has unstable water quality, high salinity, high Cl- content, and low pH value, high H2S and CO2 content in natural gas, so easy to produce corrosion and carbonate scaling. The main component of the blockage is a mixture of corrosion product Fe2O3 and a small amount of CaCO3 scale. The corrosion product Fe2O3 is mainly generated by the mixture of dissolved oxygen, H2S and CO2 content in natural gas, so easy to produce corrosion and carbonate scaling. The main cause of blockage in the JB1# well is the deposition of Fe2O3 and CaCO3 scales caused by the corrosive effects of dissolved oxygen, H2S and CO2.

1. Introduction

With gas development entered the new stage, a mixing layer development had been more observed. The nature of the field produced water became more and more complicated, but due to a mount of scaling ion exists in produced water, when the changes in the conditions such as temperature, pressure and contact with the other horizon produced water, the scale ion would be easily deposited on the inner wall of the wellbore or the pipeline, formed some crystallization or non-crystallization precipitation. After a long time of accumulation, the phenomenon of plugging throttling, wellbore and pipeline would be seriously. At present, the common types of scaling blockages are mainly composite blockages caused by solid phase and corrosion inhibitor, sulfur deposition blockages, salt deposition blockages and hydrate blockages. At present, there are more than 100 Wells in Jingbian gas field, which seriously affected the normal production of gas wells due to the presence of a large number of blockage in trunk lines and pipelines, pipeline blockage and corrosion, pipeline perforation and equipment damage and failure, etc. All would result in the increase of pressure difference in the wellbore, the decrease of output, and even the shutdown of the well.

At present, scholars at home and abroad are mainly concerned with the study of scaling mechanism, influencing factors of scaling, prediction model of scaling trend and analysis of scaling rate in the
process of gas field exploitation\(^{[5-6]}\). The severe cases of single well was selected as the research object, single well water quality of produced water was analyzed, also include the composition of blockage with the chemical volumetric method, x-Ray Diffraction (XRD) and x-ray fluorescence (XFS) method. Meanwhile, the blockage powder was leached in simulated acid work solution, and then the leaching solution was analyzed with the chemical volumetric method. On basis of these results, the causes of gas well blockage in Jingbian gas field was analyzed, which provide the basis for field implementation solution blocking and prevention, extend the service life of gas well and increase production capacity.

2 Materials and method

2.1 Material and medium

Reagents: petroleum ether, hydrochloric acid, sodium hydroxide, silver nitrate, barium chloride, sodium chloride are all analytically pure.

Instrument: ICP (HK-8100 inductively coupled plasma emission spectrometer, Beijing Huaco Itong analytical instrument co., LTD.), XFS (XRF-1800, Shimadzu, Japan), XRD (X-ray diffraction D/MAX-2400, Science Corporation, Japan).

2.2 Analysis of produced water quality

According to the petroleum industry standard "Methods for Analysis of Oil and Gas Field Water" (SY/T 5523-2016)\(^{[7]}\), using ICP (HK-8100 inductively coupled plasma emission spectrometer, Huaco Itong, Beijing) to analysis of the quality of the produced water in the single well of JB1# in Jingbian gas field.

2.3 CVD and XFS analysis of blockage

The blockage was dried at 105 \(^\circ\)C for 2 hours, and the water content was measured. The chemical composition of the blockage after drying was analyzed by XFS (XRF-1800, Shimadzu, Japan). After drying, the sample is finely ground in a mortar, and a certain amount is weighed and extracted with petroleum ether, and the solid phase is dried to determine the oil content. Then take a certain amount into a muffle furnace to calcine for 2 h at 550 \(^\circ\)C and 950 \(^\circ\)C respectively, and determine the calcination reduction of each temperature section. The blockage after calcination was dissolved in 1+1 HCl and filtered. The filtrate was made up to 500 mL, and the cation content was measured. The filter residue was used to determine the acid insoluble matter.

2.4 XRD analysis of blockage

The composition of the blockges was analyzed by XRD (X-ray diffraction D/MAX-2400, Science Corporation, Japan).

3 Results and discussion

3.1 Historical water quality and basic situation of detection well

The water quality composition of JB1# well and the basic situation of gas well production in 2018 are shown in Table 1 and Table 2.

### Table 1 Compositions of the liquid phase

| Date   | pH  | Cl\(^-\) | HCO\(_3\)- | Mg\(^{2+}\) | Fe\(^{3+}\) | Ca\(^{2+}\) | Na\(^+\)+K\(^+\) | salinity |
|--------|-----|---------|-----------|------------|-----------|-----------|----------------|----------|
| Jul-15 | 5.64| 38534.15| 576.64    | 7106.54    | 306.65    | 10188.34  | 3754.41        | 56712.32 |
| Mar-16 | 5.00| 16941.56| 80.11     | 0.00       | 16.55     | 6484.34   | 4011.62        | 23522.56 |
| Aug-16 | 5.33| 81031.61| 298.39    | 2649.79    | 91.31     | 25120.14  | 25561.87       | 109191.24|
| Jan-17 | 5.60| 29743.44| 198.39    | 1674.96    | 29.60     | 9559.08   | 7399.75        | 41205.47 |
| Aug-17 | 6.32| 100646.10| 410.05   | 4436.33    | 1619.08   | 3239.45   | 23352.89       | 139503.01|

### Table 2 Basic situation of JB1# wellbore production

| Oil pressure (Mpa) | Casing pressure (Mpa) | Gas production (10^4 m^3/d) | Water production (m/d) | H\(_2\)S (mg/m^3) | CO\(_2\) (%) | Total salinity (g/L) |
|-------------------|-----------------------|-----------------------------|------------------------|------------------|-------------|----------------------|
| 3.20              | 8.15                  | 3.50                        | 1.49                   | 1400.89          | 5.52        | 113.38               |
From the Table 1 and Table 2, the JB1# well has unstable water quality, low pH, high content of Cl⁻, H₂S and CO₂ (5.52%), which is prone to corrosion and carbonate scaling.

3.2 CVD and XFS analysis of blockage

The original blockage of the JB1# well was dissolved in 1+1 HCl as it was, with less bubbles and a pungent smell of rotten eggs, indicating a small amount of carbonate and a certain amount of H₂S. The appearance of the plug after calcination at 550 °C and 950 °C is as shown in Fig. 1, and the appearance of the solution and the filtered acid insoluble matter after the plugged material is dissolved in 1+1 HCl after calcination is shown in Fig. 2.

![Fig. 1 Comparison of appearance before and after calcination of blockages](image)

(a) Original blockage (b) 550°C (c)950°C

![Fig. 2 Appearance of the solution after HCl dissolves and HCl insoluble matter](image)

(a) The solution after HCl dissolves (b) Appearance of HCl insoluble matter

As shown in Fig. 1 and Fig. 2, both calcination and HCl dissolution have a red appearance, indicating that the plug may contain iron compounds. The original blockage contains a certain amount of H₂S, which may cause H₂S corrosion.

Chemical composition analysis of the blockage was conducted by CVM and XFS, the results are shown in Table 3 and Table 4.

| Table 3 CVM analysis results of blockage | Unit: w/w, % |
|-----------------------------------------|--------------|
| indicators                              | HCl insoluble matter | HCl soluble matter |
| water                                   | organics      | Ca²⁺  | Mg²⁺  | Ba²⁺  | Sr²⁺  | ∑Fe  |
| Content(w/w, %)                         | 0.87          | 18.95 | 12.60 | 0.57  | 0.25  | 0.30  | 0.16  | 38.01 |

| Table 4 XFS analysis results of blockage | Unit: w/w, %, based on oxide mass fraction |
|------------------------------------------|-------------------------------------------|
| matter                                   | CaO SiO₂ CaO SiO₂ MgO MoO₃ Al₂O₃ P₂O₅ CuO NiO MnO Cr₂O₃ ZnO |
| Content (w(M)/10⁻², %)                   | 34.44 61.93 0.53 0.05 0.66 0.73 0.08 0.05 0.18 0.03 0.02 0.01 0.37 0.51 0.41 |

From the Table 3 and Table 4, the content of HCl insoluble matter in the blockage of JB1# well is low, while the content of Fe in HCl soluble matter is high and contains a small amount of CaCO₃ scale, so it is mainly caused by the clogging of inorganic substances caused by corrosion products generated by corrosion. The XFS analysis showed that the main elements were sulfur and iron oxide. Combining with Fig. 1 and Fig. 2, it was found that the blockage after calcination was reddish, and the main components
may be iron oxides ($\text{Fe}_2\text{O}_3$ and $\text{Fe}_3\text{O}_4$) depending on the color and the magnetic testing (A little of blockage has the magnetism, which is $\text{Fe}_3\text{O}_4$). In addition, it also contains a small amount of zinc, manganese, aluminum, chromate, silicate, trace amounts of magnesium, barium, molybdenum, phosphate and other substances.

3.3 XRD of blockage

The chemical composition of the plug was analyzed by XRD, and the results are shown in Fig. 3.

![Fig.3 XRD analysis results of blockage](image)

From the Fig. 3, the main component of the blockage is $\text{Fe}_2\text{O}_3$, and a certain amount of $\text{SiO}_2$. Where $\text{Fe}_2\text{O}_3$ comes from $\text{CO}_2$ and $\text{H}_2\text{S}$ produce corrosion.

3.4 Plugging mechanism

The results of blockage analysis in JB1# well indicate that the main cause of blockage was the eposition of $\text{Fe}_2\text{O}_3$ generated by the corrosion of $\text{CO}_2$ and $\text{H}_2\text{S}$. When $\text{CO}_2$ is dissolved in water, it is extremely corrosive to steel\cite{8}, a galvanic cell is formed on the surface of steel, and oxygen corrosion occurs under dissolved oxygen conditions. The reaction process is as follows\cite{8-11}:

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \tag{1}
\]

Anodic reaction: $2\text{Fe} \rightarrow 2\text{Fe}^{2+} + 4\text{e}^-$ \hspace{1cm} \tag{2}

Cathodic reaction: $\text{O}_2 + \text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ \hspace{1cm} \tag{3}

Total reaction: $2\text{Fe} + \text{O}_2 + \text{H}_2\text{O} \rightarrow 2\text{Fe(OH)}_2$ \hspace{1cm} \tag{4}

The generated $\text{Fe(OH)}_2$ is very unstable and oxidized into magnetite ($\text{Fe}_3\text{O}_4$) and $\text{Fe(OH)}_3$ under the action of dissolved oxygen:

\[
4\text{Fe(OH)}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{Fe(OH)}_3 \downarrow \tag{5}
\]

\[
\text{Fe}^{2+} + 2\text{FeOOH} \rightarrow \text{Fe}_3\text{O}_4 \tag{6}
\]

The generated $\text{Fe(OH)}_3$ was dehydrated to form $\text{Fe}_3\text{O}_4$:

\[
2\text{Fe(OH)}_3 + \text{nH}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3 \cdot \text{nH}_2\text{O} + 3\text{H}_2\text{O} \tag{7}
\]

The corrosion products of $\text{CO}_2$ on steel are $\text{Fe}_2\text{O}_3$ and $\text{Fe}_3\text{O}_4$, which form a layer of a protective film on the metal surface, however, due to uneven or broken film formation, local corrosion such as etch pits, rim corrosion, and mesa corrosion often occur, the presence of $\text{Cl}^-$ will interferes with the formation of this protective film, causing corrosion to continue and accelerating the scrapping of the pipe. When
dissolved oxygen, H$_2$S and CO$_2$ or other corrosive impurities are present in the system, the corrosive effect on the metal will be more serious.$^{[12-13]}$

4 Conclusions

The JB1# well in the Jingbian gas field has unstable water quality, high salinity, high Cl$^-$ content, and low pH value, high H$_2$S and CO$_2$ content in natural gas, so easy to produce corrosion and carbonate scaling. The main component of the blockage is a mixture of corrosion product Fe$_2$O$_3$ and a small amount of CaCO$_3$ scale. The corrosion product Fe$_2$O$_3$ is mainly generated by the mixture of dissolved oxygen, H$_2$S, CO$_2$ and other corrosion effects. The main cause of blockage in the JB1# well is the deposition of Fe$_2$O$_3$ and CaCO$_3$ scales caused by the corrosive effects of dissolved oxygen, H$_2$S and CO$_2$.

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