

Discussion on the relationship between iron content and corrosion rate in production fluid of oil wells

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Abstract: To provide an economical and practical technique for the application of on-line corrosion monitoring technology in oil production system, in this paper, the iron content was measured by a water quality multi-parameter tester and corrosion rate was determined by the weight loss method. Then, the quantitative relationship between the iron ion and corrosion rate could be found. On this foundation, in order to correctly describe the corrosion in the wellbore of oil wells, according to *SY/T0026-1999 water corrosion test method* standards, a mathematical relational expression between iron ion content and corrosion rate in oil wells production fluid was established. In order to verify the reliability of relational expression, the iron content in the produced fluid of 17 wells corrosion conditions before and after adding medicine were measured on the spot. Then, the relational expression entered the field application. The results show that there was the positive correlation between the iron ion and corrosion rate. The error of the calculated corrosion rate of 17 wells in the field was less than 26% compared with the measured corrosion rate. The mathematical relational expression had good effect in J45-62 well. It could reflect the corrosion trend of well bore. Thus, through the internet+ technology, the on-line monitoring system for remote corrosion could be established, and corrosion trend of wellbore pipelines could be predicted with the help of nerve net algorithm.

1. Introduction

The problem of safety and environmental protection emerges with oilfield corrosion. The corrosion online monitoring system can find out the factors of corrosion and put forward treating measures without influencing the normal production of oil field, and it has been widely used in oilfield. The commonly used monitoring methods consist of weightlessness methods, probe method, chemical analysis method and so on. Among them weightlessness is the most popular method, by contrast, the probe is more expensive. One kind of real-time and quick monitoring method is needed to come up with because of such shortcomings of weightlessness as long analysis cycle, poor real-time ability. Early research shows that the total iron content can be used as an effective corrosion evaluation method of well bore pipeline, which makes the well bore pipeline corrosion monitoring technology possible. Wei Qingxiang and others measure the concentration of iron content with spectrophotometer, analysis the corrosion degree of well bore pipeline, which saves 55% corrosion inhibitor and costs savings dramatically. Xiong Xianzhong and others measure the concentration of iron content of oil well produced water with spectrophotometer and criterion on oil well corrosion is discussed as well.^[1~11]



The above methods are very tedious which need large amount of lab experiments. This paper presents a mathematical relational expression between iron ion content and corrosion rate, which solves the problem of hysteresis of weightlessness and implements real-time monitoring of oil well corrosion.

2. Experiment

2.1 Determination of iron content

Water quality multi-parameter tester is commonly used in determination of iron content. 20mL water sample is taken, the pH value is regulated to 2.5~5.0 with 1:1 HCL. Before the capillary of KBC series is immersed into water sample, let it stand for 3~5 minutes, then break the capillary, take sample quantitatively by self-priming. Chromogenic reaction will happen in sampling process. Take out sampling tube and invert it for several times until the liquid mix homogeneously. After 3 minutes, place the sampling tube in multi-parameter tester to measure the readings. If it needs to be heated, mix the liquid homogeneously then place the sampling tube in heater for 10 min. Cool the sampling tube to room temperature for 20 min, place it in multi-parameter tester.^[12]

2.2 Determination of corrosion rate

According to SY/T0026-1999 *corrosivity of water* N80 steel plate is used. The steel plate is grinded and polished, scrubbed with absolute ethyl alcohol and petroleum ether, placed in dryer. Water produced from corroded oil well is used as testing medium. 3 parallel samples is immersed in 500mL testing medium respectively. The experimental period is 120h. Static corrosion experiment is carried out in 101A-1 constant temperature drying box.

Wash the steel plate and remove the corrosion products, dry and weight the plate. Calculate the corrosion rate by formula (1):

$$v = \frac{8.76 \times 10^4 (m - m_1)}{S \cdot t \cdot \rho} \quad (1)$$

in (1), v is corrosion rate, mm/a; m is the initial mass of steel plate, g; m_1 is the mass after experiment, g; S is the surface area of steel plate, cm²; t is the corrosion time, h; ρ is density of metal, is about 7.85g/cm³.

3. Results and analysis

3.1 Analysis of laboratory results

First, hanging patch test and iron content test at different temperature are carried on with the produced water of corroded oil well. The result is shown in Tab. 1.

Tab.1 laboratory results

| Temperature (°C) | Weight loss of steel sheet (mg/L) | Corrosion rate (mm/a) | Iron content in solution (mg/L) | Error (%) |
|------------------|-----------------------------------|-----------------------|---------------------------------|-----------|
| 30 | 15.1 | 0.0568 | 16.09 | -6.91 |
| 30 | 14.5 | 0.0546 | 14.57 | -0.64 |
| 30 | 14.4 | 0.0550 | 13.40 | 7.11 |
| 50 | 23.4 | 0.0883 | 26.22 | -12.05 |
| 50 | 24.2 | 0.0911 | 22.47 | 6.95 |
| 50 | 15.2 | 0.0587 | 15.45 | -1.64 |
| 70 | 36.0 | 0.1357 | 31.68 | 11.94 |
| 70 | 33.0 | 0.1246 | 31.46 | 4.75 |

| | | | | |
|----|------|--------|-------|------|
| 70 | 34.3 | 0.1297 | 31.58 | 7.93 |
|----|------|--------|-------|------|

The results show in Tab.1: the relative error is within 12% between the total weightlessness of steel plate and iron ion content measured by multi-parameter tester. According to *SY/T0026-1999 corrosivity of water*, the corrosion rate has positive relation to total weightlessness of samples. The results can be concluded: the corrosion rate has positive relation to iron content. The corrosion rate can be characterized by iron content, so the corrosion statue can be judged.^[13~16]

3.2 Relationship derivation

According to *SY/T0026-1999 corrosivity of water*, the relationship between iron content and corrosion rate is deduced under the condition that corrosion occurring on the surface of tubing and sucker rod. See the formula (2).

$$r_{\text{corr}} = \frac{8760 \times 10(m_o - m_t)}{\sum S_o \cdot t_o \cdot \rho_o} = \frac{365 \times 10(m_o - m_t)}{S_{\text{tubing}} \cdot t_1 \cdot \rho_{\text{tubing}} + S_{\text{sucker rod}} \cdot t_1 \cdot \rho_{\text{sucker rod}}} = \frac{365 \times 10 \times c_{\text{iron, content}} \times Q_{\text{yield}}}{\rho \cdot \pi \cdot L \cdot D + \rho_{\text{sucker rod}} \cdot \pi \cdot l \cdot d} \quad (2)$$

in (2),

r_{corr} ——corrosion rate, mm/a;

m_o ——the total mass of tubing and sucker rod before corrosion, g;

m_t ——the total mass of tubing and sucker rod after corrosion, g;

S_o ——exposed area, cm^2 ;

t_o ——corrosion time, h;

ρ_o ——relative density, g/cm^3 ;

S_{tubing} ——surface area of tubing, cm^2 ;

$S_{\text{sucker rod}}$ ——surface area of sucker rod, cm^2 ;

t_1 ——corrosion time, d;

ρ_{tubing} ——tubing density; g/cm^3

$\rho_{\text{sucker rod}}$ ——sucker rod density, g/cm^3

$c_{\text{iron content}}$ ——the iron content of wellhead output fluid, g/L;

Q_{yield} ——average daily yield of single well, L/d;

L ——tubing length, cm;

l ——sucker rod length, cm;

D ——internal diameter of tubing, cm;

d ——external diameter of sucker rod, cm.

The formula is applicable to water pH value less than 7. When the pH value is less than 7, carbon steel surface can absorb vapor to form hydration film. CO_2 dissolved in hydration film makes it an electrolyte solution and the H^+ will be more and more. And that form many tiny primary batteries with the Fe is the negative pole, the carbon is positive pole and the acid water layer is electrolyte solution. Hydrogen evolution corrosion occurs on the surface of carbon steel. System's corrosion trend can be judged by iron content.

When the pH value is equal or greater than 7, O_2 dissolved in water film makes the Fe absorb O_2 , so $\text{Fe}(\text{OH})_3$ is formed on the surface of tubing and sucker rod, which is also called rust. The iron ion content decreases as the pH value increases, and the corrosion rate increases significantly. When the pH value is greater than 13.6, caustic rupture will be happened, so the iron changes can't express the corrosion rate correctly.

3.3 Relational expression verification

Samples taken from the site is tested by multi-parameter, the iron ion content changes are concluded, numerous data show that there is a quantitative relationship between corrosion rate and iron content. The corrosion's position is determined by sucker rod's length and diameter. The tubing and sucker rod's length are chosen as 1500m according to corrosion position. The tubing's density is $7.85\text{g}/\text{cm}^3$,

the tubing's diameter is 7.3cm, the sucker rod's density is 7.85g/cm³, the sucker rod's external diameter is 2.5cm. The pH value of produced fluid of oil well is 6.5. Replace the parameters into the formula (2) to obtain corrosion rate, the comparison results between weightlessness and formula (2) is shown in Tab. 2, 3.

Tab.2 Experimental data of seventh wells before adding medicine

| wells | Iron content in solution (mg/L) | Calculated corrosion rate (mm/a) | Actual corrosion rate (mm/a) | Error (%) |
|---------|---------------------------------|----------------------------------|------------------------------|-----------|
| Y63-38X | 3.1 | 0.0021 | 0.0025 | -16.47 |
| Y63-43X | 0.96 | 0.0006 | 0.0005 | 20 |
| C12-201 | 11.8 | 0.0185 | 0.0179 | 3.44 |
| Q2-20X | 7.95 | 0.0067 | 0.0058 | 15.94 |
| Y9-24X | 17.3 | 0.0543 | 0.0652 | -16.73 |
| Y60-41X | 21.6 | 0.0348 | 0.0286 | 21.61 |
| C19-201 | 24.5 | 0.0917 | 0.086 | 6.57 |
| C33-28 | 30 | 0.0623 | 0.0685 | -8.98 |
| C80-42 | 12.6 | 0.0273 | 0.028 | -2.41 |
| Q2-1 | 20.45 | 0.0312 | 0.0313 | -0.26 |
| Q2-7 | 25.2 | 0.0293 | 0.0288 | 1.75 |
| Q2-10X | 36.7 | 0.0581 | 0.0481 | 20.75 |
| Q2-14 | 31.4 | 0.0277 | 0.0307 | -9.66 |
| Q2-25 | 24.5 | 0.0615 | 0.0492 | 25.07 |
| C79-18 | 48.9 | 0.1524 | 0.13 | 17.26 |
| Q2-27 | 40.9 | 0.1271 | 0.1548 | -21.77 |
| Q2-47 | 48.8 | 0.1268 | 0.1105 | 14.73 |

Tab.3 Experimental data of seventh wells after adding medicine

| wells | Iron content in solution (mg/L) | Calculated corrosion rate (mm/a) | Actual corrosion rate (mm/a) | Error (%) |
|---------|---------------------------------|----------------------------------|------------------------------|-----------|
| Y9-24X | 2.41 | 0.0076 | 0.0065 | 16.36 |
| Y60-41X | 3.54 | 0.0057 | 0.0048 | 18.75 |
| C19-201 | 0.7 | 0.0026 | 0.0022 | 19.03 |
| C33-28 | 2.2 | 0.0046 | 0.0054 | -15.33 |
| C80-42 | 1.2 | 0.0026 | 0.0022 | 18.29 |
| Q2-1 | 2.34 | 0.0036 | 0.003 | 19.07 |
| Q2-7 | 3.4 | 0.004 | 0.0035 | 12.96 |
| Q2-10X | 4.2 | 0.0066 | 0.0056 | 18.7 |
| Q2-14 | 5.6 | 0.0049 | 0.004 | 23.66 |
| Q2-25 | 4.2 | 0.0102 | 0.0082 | 19.81 |
| C79-18 | 3.88 | 0.0121 | 0.01 | 20.96 |

| | | | | |
|-------|------|--------|--------|--------|
| Q2-27 | 3.25 | 0.0135 | 0.016 | -18.79 |
| Q2-47 | 6.28 | 0.0163 | 0.0175 | -6.77 |

As is shown in Tab.2, the iron ion contents of oil wells Y63-38X、Y63-43X、C12-201、Q2-20X are between 0.96~11.8mg/L, the corrosion rates calculated are between 0.0006-0.0185mm/a, the data tested are between 0.0005-0.0179mm/a, which belong to low corrosion oil wells. The iron ion contents of oil wells Y9-24X、Y60-41X、C19-201、C33-28、C80-42、Q2-1、Q2-7、Q2-10X、Q2-14、Q2-25 are between 12.6-36.7mg/L, the corrosion rates calculated are between 0.0273-0.0917mm/a, the data tested are between 0.028-0.086mm/a, which belong to middle corrosion oil wells. The iron ion contents of oil wells C79-18、Q2-27、Q2-47 are between 40.9-48.9mg/L, the corrosion rates calculated are between 0.1268-0.1524mm/a, the data tested are between 0.1268-0.1524mm/a, which belong to high corrosion oil wells. The iron ion content decreases significantly after dosing. The corrosion rates of high and middle corrosion oil wells are both below 0.025mm/a, which belong to low corrosion oil well. It's also has good corrosion inhibition effect, and the corrosion inhibition rate is 82%. As it's shown in Tab2, 3, the relative error between formula method and weightlessness is within 26%. So the correct relationship between iron ion content and corrosion rate can be obtained from formula (2), which is the judgment basis of wellbore pipeline corrosion.

4. Field applications

The iron ion content of oil well J45-62 is 16.29mg/L, average daily yield of single well is 20.7 m³, the corrosion rate calculated is 0.034 mm/a, which belongs to middle corrosion oil well. The iron ion content decreases to 0.62 mg/L and corrosion rate calculated is 0.001 mm/a after dosing. The maintenance period of pump wells prolong to 1424 days from 90 days, and the corrosion inhibition rate is 90%. As is shown in Figure 1, the tubing surface becomes smooth after dosing.



Fig.1 Comparison of corrosion morphology of pipes before and after adding medicine: a) before adding medicine, b) after adding medicine

5. Conclusions

The on-line monitoring method using iron ion and corrosion rate can truly respond the corrosion degree on spot. It can not only save cost but also reduce the tedious work. Together with remote monitoring system of corrosion the neural network algorithm will forecast corrosion trend of well bore pipeline. ^[17~18]

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