

The analysis of repeated failures of pipelines in Kal'chinskoe oil field

E N Shavlov^{1,2}, O V Brusnik^{1,3}, V G Lukjanov^{1,4}

¹National Research Tomsk Polytechnic University, 30, Lenin Ave., 634050, Tomsk, Russia

²shavlov@tpu.ru, ³brusnikov@tpu.ru, ⁴lukjanov@tpu.ru

Abstract. The paper presents the chemical analysis of oilfield water and hydraulic analysis of the liquid flow in Kal'chinskoe oil field pipeline that allow detecting the causes of the internal corrosion processes. The inhibitor protection is suggested to reduce the corrosion rate in the pipelines of Kal'chinskoe oil field. Based on the analysis of the pipeline failures, it is suggested to replace steel pipes by fiberglass pipes.

1. Introduction

The system of oil gathering and transportation depends on the natural climatic conditions (continental climate, bogginess); cluster-well development; method, amount, and rate of the oil production; water-cut oil; physico-chemical properties of oil, gas, water and parameters of the reservoir production [1].

Kal'chinskoe oil field was found in 1990 and is today the southmost field in the Tyumen region. The field site lies within the Middle-Ob' Plain and is represented by a dissected lacustrine-alluvial plain. The hydrographic network of this oil field includes the Irtysh basin and its feeders. Owing to the proper drainage of surface and groundwater, a thick forest is found nearby the river valleys. The bogginess is 81% of the area, including 4% of open bogs. The peat bog layer achieves 6-8 cm. The field site is represented by loams, clayey and sandy soils of different size. In accordance with the SNiP 2.01.01-82, the field site refers to the 1st climatic area, D subarea. And in accordance with the SNiP P-7-81 'Seismic construction', it refers to a seismic area with the earthquake intensity of 6. The main volume of oil extracted from Kal'chinskoe field, falls to Achimovskaya band.

Kal'chinskoe oil field is characterized by 86% water-cut oil. Oilfield waters of Kal'chinskoe oil field are represented by complex solutions comprising inorganic salts, gases, soluble organic substances. Among the substances dissolved in oilfield water organic salts predominate, such as chlorides, sulfates, and alkali and alkali-earth metal carbonates. Gas dissolved in oilfield water mostly contains methane. The total composition of salts dissolved in oilfield water is called mineralization. Oilfield waters of Kal'chinskoe oil field relate to the sodium bicarbonate type of water. The water mineralization ranges between 12.21 and 14.21 g/l upon the average [1].

2. Hydraulic analysis of the liquid flow in Kal'chinskoe oil field pipeline

Table 1 presents the original data on the physical properties of fluids pumped through the pipeline and its hydrodynamic parameters. Using these data, the fluid flow rate and the critical rate of transition from stratified to non-stratified oil-water flows were obtained for the pipeline section in Kal'chinskoe oil field.



The condition of corrosion resistance is satisfied in case the flow rate is higher than the critical rate. If this condition is not satisfied, intense localized corrosion frequently occurs on the metallic surface of the pipeline [2].

The calculations are carried out in compliance with the methodology given in *The Design and Operation Manual for Corrosion-Resistant Protection of Pipelines in West Siberian Oil Fields* (Regulatory Document 390147323-339-89-R) with a view to determine the modes of fluid control and the maximum rate of corrosion.

Table 1. Physical properties of controlled fluid and hydrodynamic parameters of Ø114 pipeline

| Original data | |
|--|-------------|
| Parameters | Values |
| Average pressure, [Pa] | 1060000 |
| Volumetric flow rate, [m ³ /day] | 212 |
| Inner diameter of pipeline, [m] | 0.098 |
| Oil delivery temperature, [K] | 316 |
| Gas factor, [m ³ /m ³] | 45 |
| Water content, [%] | 72 |
| Oil/water interfacial tension, [N/m] | 0.03 |
| Oil dynamic viscosity, [Pa*s] | 0.008 |
| Saturation pressure, [Pa] | 11300000 |
| Oil density, [kg/m ³] | 884 |
| Density of bottom water, [kg/m ³] | 1005 |
| Ion composition of bottom water | |
| Parameters | Values |
| Cl, [g/l] | 3.3 |
| HCO ₃ , [mg/l] | 2554 |
| Ca, [mg/l] | 3.3 |
| pH | 7 |
| Design values | |
| Parameters | Values |
| Oil density at delivery temperature, [kg/m ³] | 869.4732 |
| Volume flow rate, [m ³ /s] | 0.002453704 |
| Volume flow rate in operation conditions, [m ³ /s] | 0.002450865 |
| Volume gas discharge in operation conditions, [m ³ /s] | 0.002739484 |
| Volume flow rate of oil-gas-water mixture in operation conditions, [m ³ /s] | 0.005190349 |
| Consumption gas content | 0.527803418 |
| Density of oil-in-water emulsion, [kg/m ³] | 908.2 |
| Oil dynamic viscosity in operation, [Pa*s] | 0.006968444 |

The hydraulic analysis of the liquid flow in the pipeline of Kal'chinskoe oil field includes the calculation of the estimated flow rate V_f and absolute critical rate V_c of oil-gas-water mixture. The estimated flow rate V_f is obtained from

$$V_f = \frac{4Q}{\pi D^2} = \frac{4 \cdot 0.005190349}{3.14 \cdot 0.098^2} = 0.69 \text{ m/s},$$

where Q is the volume flow rate of oil-gas-water mixture in operation conditions; D is the inner diameter of pipeline.

The absolute value of the critical rate V_c can be found from

$$V_c = 6.69 \frac{D_0^{0.268} \sigma^{0.171} |g(\rho_w - \rho_e)|^{0.366}}{\rho_w^{0.536} \nu^{0.073} |(-10.96\beta^2 + 9.94\beta + 1)|^{0.659}} = \frac{0.098^{0.268} 0.03^{0.171} |9.8(1005 - 908.2)|^{0.366}}{1005^{0.536} 0.000001^{0.073} |(-10.96 \cdot 0.52^2 + 9.94 \cdot 0.52 + 1)|^{0.659}} =$$

$$= 6.69 \frac{0.5365 \cdot 0.55 \cdot 12.29}{40.659 \cdot 0.364 \cdot 2.18} = 0.76 \text{ m/s},$$

where σ is the oil/water interfacial tension; g is the gravity factor; ρ_w is the density of bottom water; ρ_e is the density of oil-in-water emulsion; ν is the kinematic coefficient of viscosity; β is the consumption gas content.

The hydraulic analysis shows the stratified structure of the flow since the flow rate of the oil-gas-water mixture is 0.69 m/s, which is lower than 0.76 m/s of the critical rate and leads to the corrosion conditions.

The chemical analysis of oilfield water and the hydraulic analysis of the liquid flow in Kal'chinskoe oil field pipeline show that the localized corrosion occurs due to the oilfield water attack and corrosion processes induced by the flow conditions.

3. Corrosion inhibition of pipelines

The internal surface of pipelines is exposed to a corrosive environment. Thus, the steel pipes, welded joints and pipeline facilities must be protected from the effects of internal corrosion. At a rate of corrosive environment of 0.2 mm per year and higher, nonmetallic pipe materials should be used for the pipes with the protective internal coating. In steel pipes without the protective coating corrosion inhibitors are used to slow down galvanic corrosion processes. Corrosion inhibitors are used in pipelines in accordance with the developed technology [1].

In Kal'chinskoe oil field, the pipelines are protected by chemicals subject to such physico-chemical properties as

- name, percentage, hazard effect;
- appearance, color, smell;
- solubility;
- specific weight/density at 15-20 °C (g/cm³);
- vapor pressure at 20°C (millibar);
- pH of dilute solution (concentration, mole);
- viscosity (cS);
- flash point (°C);
- dissolving temperature (°C);

- boiling temperature (°C);
- chilling temperature (°C).

In Kal'chinskoe oil field, Azole 5010 corrosion inhibitor has found a use. It refers to nitrogen-based cationic surfactants and is used to protect steel pipes in oil-and-gas industry. Azole 5010 is produced in two types, i.e. oil-soluble A type and water-soluble B type. Additionally, the available type A and the type B inhibitor concentrates contain 60–70 and 80 % active agents, respectively. Azole 5010 inhibitor concentrates can be used to produce both commodity forms and active-matrix conservation materials and thin-film coatings to protect pipelines from atmosphere corrosion. While storing and transporting, Azole 5010 retains its aggregative stability within the temperature range from -45° to 50°C . With the constant monthly dosage of 25–50 g/t, Azole 5010 has no negative effect on commercial oil, prevents steel from corrosion cracking, inhibit the growth of sulfur reducing bacteria. The type B Azole 5010 is more efficient in oil-gathering systems and pressure pipelining. It possesses low flow rates at stratified flow patterns and also in reservoir pressure maintenance systems. The optimum inhibition dosages of Azole 5010 are 100–150 g/t (shocking) and 15–25 g/t (working). The protective effect of Azole 5010 film in oil-water emulsions comes to 85–95% [3]. Figure 3 presents the time/rate dependence of the pipeline corrosion.

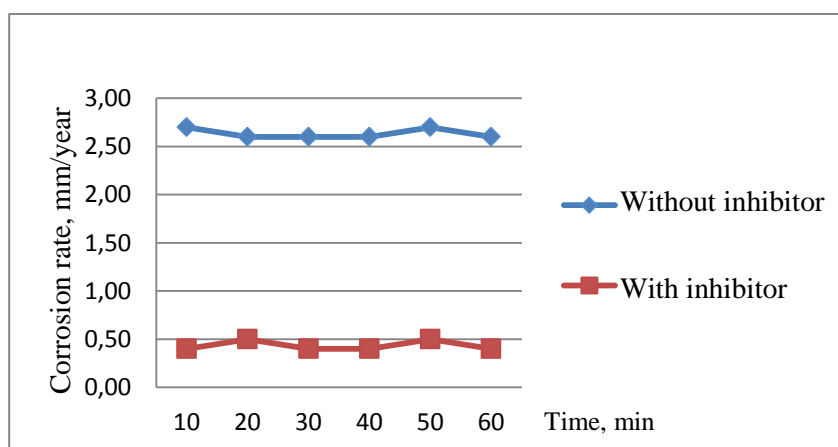


Figure 1. Time dependence of corrosion rate

4. The analysis of the pipeline failures

The operational data are used to analyze the pipeline failures in Kal'chinskoe oil field. This analysis shows that during the time period from 2011 to 2015, three failures were registered as shown in Figure 2. Despite the corrosion protection provided by inhibition, a greater number of failures are registered in the pipelines that have been in operation for not more than five years. This is probably, due to mechanical impurities presenting in the fluid that are involved in hydroerosion of the protective film formed by inhibitors.

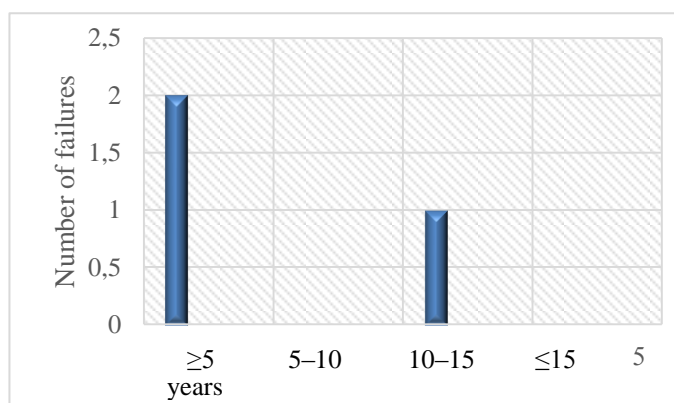


Figure 2. The dynamic failure analysis in Kal'chinskoe oil field for the years of 2011–2015

5. Conclusion

To avoid the localized corrosion processes occurring on the internal surface of pipelines, it is advisable to apply composite or fiberglass pipes. The implementation of fiberglass pipes in Kal'chinskoe oil field will prevent the pipelines from the repeated failures occurred due to the internal corrosion. The use of fiberglass pipes will provide a longer operation of the pipeline extending its service life up to 25 years that, in turn, will result in the reduction of their maintenance costs and elimination of emergencies.

References

- [1] Pipeline technology regulations for the formation pressure maintenance system of Kal'chinskoe oil field 2012 (Tyumen) (in Russian)
- [2] Regulatory Document 390147323-339-89-R The Design and Operation Manual for Corrosion-Resistant Protection of Pipelines in West Siberian Oil Fields (in Russian)
- [3] Kotlasskii chemical plant [official website] URL: <http://kchz.ru/item/azol5010>