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COMPLEX CORROSION PROTECTION OF TUBING IN GAS WELLS

Sofiya Pinchuk[1], Galina Galchenko[1], Aleksey Simonov[2], Ludmila Masakovskaya[2], Irina Roslyk[1, *]

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Abstract. Analysis of the efficient complex application of zinc coatings such as sherardizing on tubing surface and carbon dioxide inhibitors during the natural gas extraction on Lutsenkivske gas condensate deposit wells has been carried out. Microstructural and electrochemical investigations of zinc diffusion layer have been conducted. Existing industrial experience shows that the complex corrosion protection significantly increases the life of wells, which significantly increases the economic performance and prevents environmental pollution.

Keywords: gas tubing, gas condensate well, corrosion, sherardizing, inhibitor.

1. Introduction

Corrosion is an important common problem encountered in the gas industry, which requires using various types of equipment such as pumps, drills and tubing [1]. Stable work of the tubing, which is the main component of the operational gas-extracting column, largely determines the economic efficiency of oil and gas deposits development. Loss of column tightness, its destruction or premature failure, leads to a decrease in production volumes and increases operating costs [2]. It is known that the main cause of rapid failure of pipes is corrosion, which drastically reduces their service life and cuts production volumes, which ultimately leads to a decrease in profitability of oil and gas production. The major problems of corrosion in the gas industry is particularly found in production materials as tubing and casing are more exposed to carbon dioxide (CO_2) at a partial pressure of CO_2 more than $2\cdot10^5$ Pa and hydrogen sulphide (H_2S), and formation water can cause severe corrosion problems in gas wells [3-5].

One of the effective ways to increase the corrosion resistance of tubing is protection with special anti-corrosion coatings. The degree of protection depends on the method of application and the chemical composition of the coating, which is selected for specific operating conditions, depending on the acidity of the medium and the salt content. Anticorrosion coatings can be metals (Zn, Cr), resins, ceramics and fiberglass [3]. In the case of pipes with threaded ends, the selected coating should not only protect against corrosion but also ensure a high wear resistance and tightness of "pipe-coupling" threaded connections.

Zinc coating such as sherardizing, also known as thermal diffusion galvanizing [6], is an effective way of corrosion protection of pump tubes, both during storage and transportation and during exploitation in gas wells [7-9]. Sherardizing is a thermal diffusion coating process in which ferrous articles are heated in the presence of a sherardizing mixture consisting of zinc dust with or without an inert material. Zinc protective coating is formed on the internal and external surfaces of pipes and couplings, and on their threaded sections. After sherardizing, tubings are obtained with reliable long-term protection against corrosion-erosive effects of aggressive environment.

The unique properties of the zinc diffusion coating are due to its structure, interpenetration and uniform change in the concentration of zinc and iron in the thickness of the coating layer with a maximum content of zinc in the outer layers of the coating, which provides it with good plasticity and tread properties. External more soft layers are working as a solid lubricant, which is especially important for threaded joints of pipes, their operational durability and reliability.

The effectiveness of protective zinc coatings applied on the tubing surface and couplings was tested at the time when they were operated on Lutsenkivske gas condensate deposit wells. During operation of galvanized tubings in gas wells corrosion damage was not observed on the surface for 4–6 years, and some tubings and couplings were re-lowered into the well for further operation. After more than 7.5 years of wells exploitation, minor corrosion damage was observed on the surface of threaded connections, at the 1000–1300 m level horizon.

[1] The National Metallurgical Academy of Ukraine, Dnipro, Ukraine
[2] Limited Liability Company Research and Development Center "Quality", Dnipro, Ukraine
[*] *roslyk67@gmail.com*

Using of inhibitors is another effective way to protect the gas pipes [10-12]. Protection is carried out by introducing a protective substance into the intertube space or injecting directly into formation water.

2. Experimental

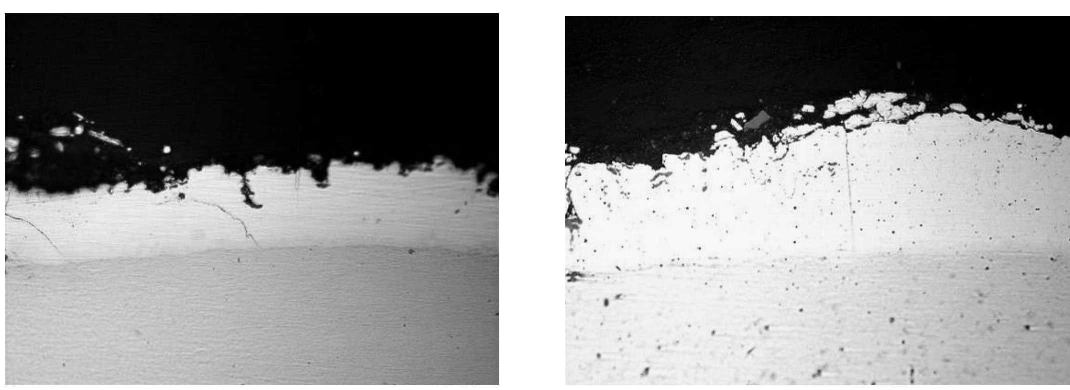
During metallographic research on the external and internal tubing surface the thickness of the applied zinc layer and the layer of zinc coating, which remained after the operation, was measured. Samples of tubes with zinc diffusion layer were fixed with acrylic resin of cold hardening to prevent the coating from being detached when grinding and dipping the edge of the sample. After polymerization of the resin, the samples were sanded by paper (P100, P240, P400, P600, P1000) and polished by diamond paste of 1 micron with chromium oxide. Estimation of the zinc coating quality was carried out on untreated samples, using a NICON Eclipse MA100 metallographic inverted microscope.

Electrochemical inhibitors tests were carried out according to manufacturer's recommendations by adding inhibitors to the system in the amount of 30–40 g inhibitor in commercial form per 1000 m^3 of gas, calculated in accordance with well production.

Corrosion behavior was investigated by polarization potentiodynamics. Polarization curves were determined by IPC-Pro potentiostate apparatus (with built-in microprocessor and access to a personal computer) at scan rate of 5 mV/s. Polarization curves determined the potential and current density. The potential was recorded in comparison with the chloride silver electrode, translating data into a standard hydrogen scale. As an auxiliary electrode, a platinum electrode was used. During the experiment, the mixing of the solution was carried out using a magnetic stirrer MM-5.

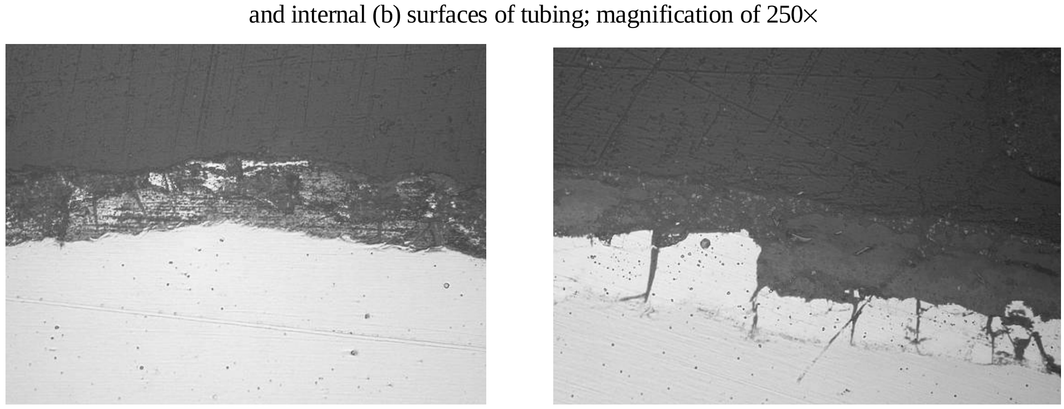
3. Results and Discussion

Investigations of tube with zinc diffusion layer before and after operation in the well for four years have been carried out. The microstructure of zinc diffusion layer is shown in Figs. 1 and 2. Distribution of thickness of zinc diffusion layer on tube surfaces is reported in Table.



a) b)

Fig. 1. Conditions of zinc diffusion layer before exploitation on external (a) and internal (b) surfaces of tubing; magnification of 250×



a) b)

Fig. 2. Conditions of zinc diffusion layer after 4 years exploitation on external (a) and internal (b) surfaces of tubing; magnification of 250×

Distribution of thickness of zinc diffusion layer on tubing surfaces

Characteristics	Before operation		After operation	
	External	Internal	External	Internal
Number of measurements	182	251	154	244
Mean thickness, $\bar{X}$, μm	44.7	58.70	22.8	27.8
Standard deviation, *S*, μm	12.1	15.11	6.0	8.5
Minimum value, μm	18.3	24.75	13.1	19.7
Maximum value, μm	87.2	102.45	37.5	49.3
Coefficient of variation, %	27.07	25.72	26.32	30.58

The mean and minimum thickness of the external zinc diffusion layer is slightly less than that of the internal one. This may be due to the technological features of the coating process and does not affect the reliability and duration of tubing operation in gas well.

Long-term tubing operation with zinc diffusion layer is due to the high corrosion resistance of the iron-zinc phases of diffusion zinc coating (primarily due to participation in the passivation of the surface) together with ZnO oxide, zinc ferrites ($ZnFeO_2$, $ZnFe_2O_4$), and also complex salts on zinc basis. Fig. 3 shows the external tubing surface with zinc diffusion layer after its operation in the gas well. Light areas of a surface are the layer of metal zinc and iron-zinc phases, dark areas are products of corrosion.

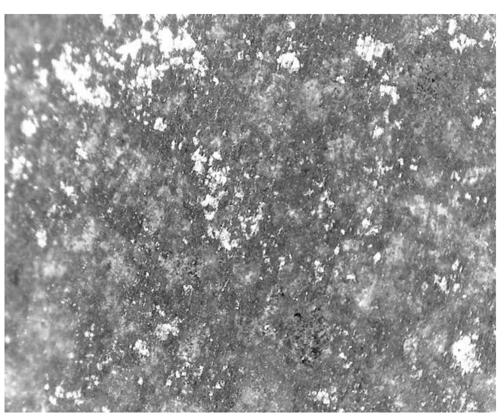


Fig. 3. Zinc diffusion layer appeared on the tubing surface after operation in the well for four years

The metallographic studies have shown (Figs. 2 and 3) that during long-term exploitation of sherardizing tubing in gas wells dense layers of zinc corrosion products and iron are formed on their surfaces, the protective properties of which prevent the destruction of deeper layers, that is, the effect of self-protection of the pipe surface is detected.

To create an effective anti-corrosion protection system when operating gas condensate wells, it is necessary to consider the corrosion activity of formation water, which significantly affects the destruction of the tubing surface. One of the methods for reducing the corrosive activity of formation water is the use of inhibitors, namely, carbon dioxide inhibitors.

The properties of carbon dioxide corrosion inhibitors of 27 world producers have been studied and comparative electrochemical investigations have been carried out under exploitation conditions on Lutsenkivske gas deposit wells, namely, when using as electrolyte sample of formation water from the gas well.

Anodic polarization curves of steel samples with zinc diffusion layer in formation water with addition of 5% methanol inhibitor solution are shown in Fig. 4. The highest protective properties (*curves* 2 and 3) have been detected for formation water with inhibitor compared to those obtained using formation water without inhibitors (*curve* 1).

So, the addition of 5% methanolic solutions of all investigated inhibitors into the formation water (Fig. 4) significantly stifles corrosion processes and decreases current density by 2.15–2.5 times.

For the determination of well corrosion state, iron and zinc ion contents in formation water were regularly monitored. Application of complex protection tubing, namely, the zinc diffusion coating and the carbon dioxide inhibitor, significantly reduces the corrosion rate. Thus, there is a decrease in the number of iron ions in the samples of formation water even from 200 to 0 mg/l, and the content of zinc ions – from 30 to 0.5 mg/l.

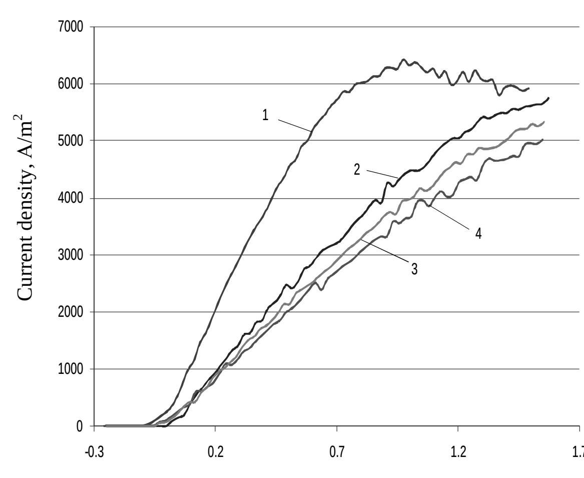


Fig. 4. Anodic polarization curves of steel sample with zinc diffusion layer in formation water: without (1) and with addition of 5% methanol inhibitor solution AMDOR IC-7 (2), INCORPAR 7920-M (3) and INCORGAS 111 (4)

4. Conclusions

Using of applied set of methods for tubing corrosion mitigation in gas production, in particular, complex application of sherardizing and corrosion inhibitors, allows to significantly (up to 7 years or more) extend reliable lifetime of gas wells, reduce the number or even eliminate the possibility of accidents, prevent this contamination of the environment, as well as significantly improve the economic performance.

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КОМПЛЕКСНИЙ ПРОТИКОРОЗІЙНИЙ ЗАХИСТ НАСОСНО-КОМПРЕСОРНИХ ТРУБ В ГАЗОВИДОБУВАЮЧИХ СВЕРДЛОВИНАХ

Анотація. *Проведено аналіз ефективності комплексного застосування термодифузійного цинкового покриття на поверхні НКТ та інгібіторів вуглекислотної корозії при видобутку природного газу у свердловинах Луценківського газоконденсатного родовища. Наявний промисловий досвід показує, що комплексний протикорозійний захист дає можливість суттєво збільшити строк експлуатації свердловин, що суттєво підвищує економічні показники і запобігає забрудненню навколишнього середовища.*

Ключові слова: *насосно-компресорна труба, газоконденсатна свердловина, корозія, цинкове покриття, інгібітор.*