Corrosion properties of the deposited coatings of the system Fe-15Cr

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Abstract. Coating of machine parts and mechanisms operating in a corrosive environment is an important task of modern engineering. The surfacing of working surfaces by chromium steels has wide possibilities for the formation of corrosion-resistant coatings. The basis of most of these steels is the system Fe-Cr. For surfacing of corrosion-resistant coatings it is efficient to use economically alloyed flux-cored wire of the system Fe-15Cr. At the same time, the corrosion resistance of the deposited metal of such a system has not been studied. In connection with the above, the purpose of the work was to study the corrosion properties of the metal deposited by chromium flux-cored wire of the Fe-15Cr system. Tests for general corrosion were carried out in a salt fog chamber (SFC) at a temperature of 50±1 °C while spraying copper-acetic acid salt solution (neutral brine with the addition of dihydrated copper chloride (CuCl₂ + 2H₂O) and crystalline acetic acid) for 3 hours every 1 hour. The evaluation of the corrosion behavior in a salt fog chamber of the metal deposited by flux-cored wire PP-Kh15 was carried out in comparison with the metal deposited by standard wire Sv-20Kh13. It is established that the properties of the metal deposited by wire PP-Kh15 at the initial stage of corrosion behavior, estimated at the time until the first signs of corrosion appear, exceed the properties of the metal deposited by standard wire Sv-20Kh13 in 4.8 times, and for long-term corrosion resistance in 1.49 times. The low-alloyed flux-cored wire PP-Kh15 can be recommended for surfacing coatings on parts of equipment used in production, transportation and storage of oil operating in slightly aggressive environments under conditions of slight abrasive wear.

1. Introduction
Coating of machine parts and mechanisms operating in a corrosive environment is an important task of modern engineering [1]. Wide opportunities for the formation of corrosion-resistant coatings is surfacing of working surfaces with chromium steels [2]. The basis of most of these steels is the system Fe-Cr [3]. For deposition of such steels, surfacing by solid flux-core wires of the Fe-13Kh system is widely used. These are such wires as Sv-12Kh13, Sv-20Kh13, Sv-30Kh13, etc. The study of such wires for surfacing wear-resistant coatings was considered in a number of works [4–6].

2. Statement of a problem
At the same time, for surfacing corrosion-resistant coatings, it is efficient to use economically alloyed cored wire of the Fe-15Cr system. Such flux-cored wire can be used for surfacing parts of the equipment of oil production, transportation and storage systems operating in slightly aggressive environments under conditions of slight abrasive wear. The main reason for the failure of such equipment is hydrogen sulfide and carbonate corrosion [7, 8]. At the same time, the corrosion resistance of the deposited metal of the Fe-15Cr system in such environment has not been studied.
In connection with the above, the corrosion properties of the metal of the system Fe-15Cr were investigated.

3. Theory
The object of the study was the coating metal deposited by flux-cored wire PP-Kh15.
Surfacing was carried out on plates of steel St3 with a size of 200×50×10 mm using experienced flux-cored wire with a diameter of 2.4 mm in argon in three layers. Surfacing mode: current 230 A; voltage 24 V; surfacing speed of 20 m/h.
Tests for general corrosion were carried out in a salt fog chamber (SFC) at a temperature of 50±1 °C while spraying copper-acetic acid salt solution (neutral brine with the addition of dihydrated copper chloride (CuCl₂+2H₂O) and crystalline acetic acid) for 3 hours every 1 hour, which provides 1.5-2 ml/h of precipitation of salts. The concentration of the solution is 0.26±0.02 g/l, pH from 3.1 to 3.3. The duration of stay in the conditions of the influence of copper-acetic salt fog was 2400 hours.
The evaluation of the corrosion behavior in a salt fog chamber of the metal deposited by flux-cored wire PP-Kh15 was carried out in comparison with the metal deposited by standard wire Sv-20Kh13.

Metallographic studies of the deposited metal were carried out on an optical microscope Axio Observer A1m (Carl Zeiss).

4. Results of the experiments and discussion
The results of the evaluation of the corrosivity of the investigated coating compositions at the initial stage of testing in the salt fog chamber are shown in Table 1.

| Composition | The time of the first signs of corrosion, h |
|-------------|------------------------------------------|
| PP-Kh15     | 576                                      |
| Sv-20Kh13   | 120                                      |

It is established that at the initial stage of corrosion behavior, the time until the first signs of corrosion appear for a deposited metal by wire PP-Kh15 is 4.8 times longer than for a deposited metal by standard wire Sv-20Kh13. At the same time, there is a qualitative difference in the development of corrosion on the surfaces of the investigated compositions.
The results of the evaluation of the state of the surface on the metal of samples taken after long-term tests at 2400 hours are shown in Table 2 and in Fig. 1 and Fig. 2.

| Composition | Surface condition on metal specimens after testing |
|-------------|-----------------------------------------------|
| PP-Kh15     | 46% covered by corrosion products              |
| Sv-20Kh13   | 100% covered by corrosion products             |

As it can be seen after long-term tests in the salt fog chamber, the surface of the metal deposited by wire Sv-20X13 is covered by a continuous layer of corrosive compounds and cavities (Fig. 1). Corrosion products on the surface of the metal deposited by wire PP-Kh15 are much smaller (Fig. 2). For metal deposited by wire Sv-20Kh13, the depth of corrosion damage reached 0.85 mm, while for metal deposited by wire PP-Kh15, it reached 0.63 mm.
Figure 1. Sample (a) and the surface of the metal (b), deposited by Sv-20Kh13 after 2400 hours of testing for general corrosion.

Figure 2. Sample (a) and the surface of the metal (b), deposited by PP-Kh15 after 2400 hours of testing for general corrosion.

The results of the evaluation of the state of the metal surface of test samples are correlated with the results of their corrosivity shown in Table 3.

The results can be attributed to the concentration of carbon in the deposited metal. The chemical analysis of the deposited metal performed on the sulfur and carbon analyzer METAVAK CS-30 (Table 3), shows a direct dependence of the increase in the tendency to general metal corrosion on increasing the carbon concentration in its composition, which is also noted in other works [1, 9]. At the same time, a higher tendency to general corrosion of the metal deposited by wire the Sv-20Kh13 can be explained not only by the high carbon content, but also by the low chromium concentration [10].

Table 3. Content of carbon and sulfur in the deposited coatings

| Composition | Carbon, % | Sulfur, % |
|-------------|-----------|-----------|
| PP-Kh15     | 0.1899    | 0.0211    |
| Sv-20Kh13   | 0.2439    | 0.0142    |

At the same time, the corrosion properties of the metal are also associated with the characteristics of the microstructure [11]. Metallographic studies have established a different degree of etching of the microstructure of the surfaces of the investigated coating compositions (Fig. 3, 4).
As can be seen on the metal surface of the coatings obtained by surfacing PP-Kh15, there is no strong etched microstructure, apparently due to the higher chromium content in the matrix. In the metal coating Sv-20Kh13, uniform etching of all structural components is observed.

The total corrosion resistance from an area of 120 mm² at the time of removal from the tests (2400 hours) is given in Table 4.

Table 4. The results of the weight loss of metal samples of the investigated compositions after corrosion tests

| Composition | Weight loss, g | Relative Corrosion Resistance $\varepsilon_{\text{tot}}$ |
|-------------|----------------|-----------------------------------------------------|
| PP-Kh15     | 0.9008         | 1.49                                                |
| Sv-20Kh13   | 1.3392         | 1                                                   |

From table 4 it follows that the weight loss of the metal obtained by surfacing PP-Kh15 as a result of lengthy tests is significantly less than that of the metal obtained by surfacing Sv-20Kh13. Resistance to general corrosion can be expressed as the coefficient of relative corrosion resistance $\varepsilon_{\text{tot}}$, numerically equal to the ratio of the weight loss of the coating taken per unit metal obtained by surfacing Sv-20Kh13.
to the subject metal for the same test time. In this case, the coating metal obtained by surfacing cored wire PP-Kh15 is 1.49 times longer than the coating metal obtained by surfacing Sv-20Kh13 for long-term corrosion resistance.

5. Conclusion
1. The properties of the metal deposited by PP-Kh15 wire are inferior in corrosion activity to the properties of the metal deposited by standard wire Sv-20Kh13 in 4.8 times, and in terms of long-term corrosion resistance exceed 1.49 times.

2. The low-alloyed flux-cored wire PP-Kh15 can be recommended for surfacing coatings on parts of equipment used in the production, transportation and storage of oil operating in slightly aggressive media under conditions of slight abrasive wear.

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