CORROSION PROPERTIES OF DIFFUSION COATINGS UNDER THE CONDITIONS OF CATHODE PROTECTION

Yu. A. Puchkov and V. A. Larkin

INTRODUCTION

Cathode protection is widely used for preserving metallic structures from electrochemical corrosion. As a rule, the cathode protection is combined in this case with protection by nonmetallic (based on plastics, bitumen, etc.) coatings. The joint use of diffusion coatings and cathode protection is an effective means for increasing the service life of parts operating in an aggressive medium under conditions of friction, erosion, tensile stresses, etc. However, we could find only very scarce data from works devoted to the determination of the losses to corrosion under the conditions of cathode protection of diffusion coatings widely used in machine building. The advancement of computer technologies also requires improvement of corrosion monitoring of structures serving under the conditions of cathode protection.

The aim of the present work consists in the development of a method for computational and experimental determination of the losses to corrosion under the conditions of cathode protection of diffusion coatings widely used in machine building.

METHODS OF STUDY

We analyzed the losses to corrosion under the conditions of cathode protection of carbon and alloy structural steels with carburized, nitrided, diffusion calorized, and chromized coatings. The grades of the steels and the regimes of deposition of the coatings are presented in Table 1. The corrosion tests were performed in a P5827 potentiostat in a 3% solution of NaCl. The phase composition of the coatings was determined by the method of x-ray diffractometry using a DRON-1 device.

METHOD OF COMPUTATION

The losses to corrosion can be determined if we know the value of the density of the corrosion current [1, 2]. The density of the corrosion current depends on several parameters and can be found from the equation:

\[
I = i_{\text{cor}} \exp \left( \frac{2.303(E - E_{\text{cor}} - i \rho_c)}{b_a} \right) \times \exp \left( \frac{-2.303(E - E_{\text{cor}} - i \rho_c)}{b_c} \right) \times \frac{1}{i_d} \left[ 1 - \exp \left( \frac{-2.303(E - E_{\text{cor}} - i \rho_c)}{b_c} \right) \right] \times \frac{i_d}{i_{\text{cor}}},
\]

where \(i_{\text{cor}}\) is the density of the corrosion current, \(i\) is the density of the external current, \(E_{\text{cor}}\) is the potential of free corrosion, \(E\) is the running value of the potential, \(b_a\) and \(b_c\) are the Tafel slopes of the anode and cathode processes, \(i_d\) is the density of the diffusion (limiting) current, and \(\rho_c\) is the electrical resistivity of the electrolyte.

In addition to the density of the corrosion current the corrosion process is determined by such parameters as the Tafel slopes, the density of the diffusion current, and the electrical resistivity of the electrolyte. The program for computing the parameters of the corrosion process was written in Pascal. The block diagram for the computation is presented in Fig. 1. The initial data are the coordinates of the points \((i_i, E_i)\) of the polarization curve near the corrosion potential \(E_{\text{cor}}\), and the values of the density of the diffusion current \(i_d\) and the electrical resistivity \(\rho_c\) of the electrolyte determined experimentally with the use of the method of a rotating electrode.

TABLE 1. Parameters of the Processes of Deposition of Coatings

<table>
<thead>
<tr>
<th>Steel</th>
<th>Process</th>
<th>Medium</th>
<th>(t), °C</th>
<th>(t), h</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Chromizing</td>
<td>Chloride</td>
<td>1000</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>Calorizing</td>
<td>Chloride</td>
<td>950</td>
<td>5</td>
</tr>
<tr>
<td>St3</td>
<td>Ion carburizing</td>
<td>Hydrocarbons + argon</td>
<td>920</td>
<td>5</td>
</tr>
<tr>
<td>38Kh2MYuA</td>
<td>Ion nitriding</td>
<td>Nitrogen + hydrogen</td>
<td>520</td>
<td>10</td>
</tr>
<tr>
<td>25Kh5M</td>
<td>Furnace nitriding</td>
<td>Ammonia</td>
<td>520</td>
<td>20</td>
</tr>
</tbody>
</table>

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Corrosion Properties of Diffusion Coatings

Input: 1) of points \((i, E)\) of the polarization curve near \(E_{cor}\)
2) of the electrical resistivity of the electrolyte \(\rho_e\) and the density of the diffusion current \(i_p\)

Computation: \(i_{cor}, b_a, b_c\)

Output: points \((i, E)\) close to the potential of cathode protection \(E_{pr}\)

Computation: \(b_a, R(E_{pr} - E_{cor}), Z, K_{pr}\)

Fig. 1. Block diagram for determining the parameters of corrosion process.

and of a bridge circuit respectively [3]. Substituting the initial data into equation (1) we compute (by the method of "matching" [1]) the other parameters of the corrosion process, i.e., \(i_{cor}, b_a,\) and \(b_c\). Computing the parameters of the corrosion process including the linear losses (\(\mu m/\text{year}\)) we used data from the databank, including the atomic masses and valences of the components of the coatings and their densities.

In the second stage of the computation from the known values of \(i_{cor}, b_a, b_c,\) and \(\rho_e\) we introduce the values of the density of the external current at points close to the protection potential and close to the corrosion potential and use the method of "matching" to determine the Tafel slope of \(b_a\) averaged for the range \(E_{cor} - E_{pr}\) of the potentials and the dependence of the corrosion losses on the value of the cathode polarization \(R(E - E_{cor})\). The densities of the corrosion current used for determination of the losses to corrosion are computed by the formula

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i_{cor}(E_{pr}) = i_{cor}(E_{cor}) \exp \left[ -2.303(E_{pr} - E_{cor})/b_a \right],
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