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CALCULATION OF STEEL PIPELINE CORROSION DEPTH FORVARIOUS CONDITIONS OF ELECTROLYTE SOLUTIONS IN CRACKS

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Ukraine has a developed network of main oil pipelines, petroleum product pipelines and gas pipelines, the average life of which is more than 30 years. The first built oil pipelines have been operating for more than 48 years [1, 2]. The long-term interaction of the metal pipe with the environment leads to the intensification of corrosion processes, to the degradation of the wall material physical and mechanical properties of the steel pipe [3].

The lifetime of Ukrainian main gas and oil pipelines system is in many cases approaching the planned one. The numerous corrosion damage of the outer surfaces of pipes has been found that aggravates the problem of further reliable and safe operation.

Oil pipelines operate under influence of various factors, which include temperature fluctuations, corrosive – aggressive media with a wide spectrum of their parameters, dynamic loads, etc. The most negative influence on the life of pipelines is corrosion - aggressive media [4, 5, 6]. Corrosion-hazardous sections regardless of the medium corrosive aggressiveness indicators and the presence of earth currents include: floodplain; irrigated land; swamps and waterlogged soils; underwater transitions; industrial and household drains; rubbish and slag dumps; field warehouses of mineral fertilizers [7]. Corrosion may be aggravated by the occurrence of galvanic couples in the case of alternation of different composition soils under the influence of temperature factors, technology-related human activity, due to the development of microbiological organisms.

The main role under providing the environmental safety of pipeline operation in the development of corrosion damage (cracks) belongs to the study of corrosion depth and dynamics.

The frequency of penetration into the crack of an aggressive solution will affect the hourly average current strength of the galvanic couple, and hence the steel corrosion rate in the crack. The hourly average current strength increases with the increase in the frequency of penetration aggressive solution into a crack, but until the cathodic limitation of the process occurs, as solution saturation stops the oxygen inflow.

On the basis of the above said it is possible to assume that the steel corrosion process in the cracks of insulating coatings is a special kind of electrochemical corrosion, where the features of both atmospheric and electrochemical corrosion of steel which is completely immersed in a liquid electrolyte are manifested.With regular periodic moisturization, it is possible to predict further steel losses proceeding from the next calculation.

The instantaneous wall thickness loss $V = \Delta D / \Delta t$ is defined as the limit of the average velocity, provided that the time interval Δt is unlimited, that is,

$$V = \lim_{\Delta t \to 0} \frac{\Delta D}{\Delta t} = \frac{dD}{dt}. \qquad (1)$$

Thus, the velocity of change in the pipeline wall thickness is the time derivative of the initial wall thickness size. It is also clear that the rate of change in the wall thickness will be proportional to its size. Consequently, the dependence of the change in the wall thickness of the pipeline section from time *t* can be regarded as a derivative in time

$$\frac{dD}{dt} = -rD, \qquad (2)$$

where r – is the relative rate of wall thickness decrease, which depends on the grade of steel, the original wall thickness aggressiveness of environment.

After integration we get

$$\ln D = -rt + \ln a,$$

where integration constant $A = \ln a.$

From the last equation after exponentiation we have

$$D = ae^{-rt} \qquad (3)$$

If the initial thickness of the wall of the pipeline $D = Do$ is known at the initial time $t = 0$ (at the beginning of the structure operation), then substituting these values in (3), we obtain:: $D_0 = a \times e^{-r \times 0}$, from which $a = D_0$

Then (3) is

$$D = D_0 \times e^{-rt}. \qquad (4)$$

To determine r (specific velocity of wall thickness reduction), we take logarithm of the both parts of equation (4)

$$\ln D = \ln D_0 - rt. \qquad (5)$$

Using equation (5) it is possible to calculate the values of r for two known values of the cross sections $D1$ and $D2$.

The thickness $D1$ is determined at the time of the tests t_1 at the maximum current of the galvanic couple (when moistening), and the thickness $D2$ is determined by the time t_2 before the next wetting when the stable minimum value of the galvanic couple current is reached

$$D_2 = D_0 \times e^{-rt_2}. \qquad (6)$$

Then: $\ln D_1 = \ln D_0 - rt_1$, $\ln D_2 = \ln D_0 - rt_2$. (7)

We subtract the second equation of system (15) from the first one

$$ln\, D_1 - ln\, D_2 = -rt_1 - (-rt_2) = r(t_2 - t_1),$$

from which

$$r = \frac{\ln D_1 - \ln D_2}{t_2 - t_1}. \quad (8)$$

Consequently, the formula (8) can be written as follows:

$$D = D_0 \times e^{-(\frac{\ln D_1 - \ln D_2}{t_2 - t_1})t}. \quad (9)$$

The pipeline wall thickness in the crack after the time interval t_1 is

$$D_1 = D_0 - \frac{2KI_1}{7{,}87\pi D_0 a_y} t_1. \quad (10)$$

Similarly, it is possible to find the wall thickness the over time t_2

$$D_2 = D_0 - \frac{2KI_2}{7{,}87\pi D_0 a_y} t_2. \quad (11)$$

The residual wall thickness of the pipeline at any time t from the operation beginning or preliminary examination is

$$\Delta D = D_0 - D_0 e^{-\left(\frac{\ln D_1 - \ln D_2}{t_2 - t_1}\right)t}, \quad (12)$$

or

$$\Delta D = D_0 (1 - e^{-\left(\frac{\ln D_1 - \ln D_2}{t_2 - t_1}\right)t}).$$

In the case of irregular periodic moisturization of the structure, steel corrosion calculations are also performed according to the average value of the galvanic couple current. On the basis of the sample data of the measurements, the average current value, the mean square deviation, are found, and further, assuming that the law of the sample data distribution is normal, with a probability of 0,997, according to the rule of «three sigmae», the mean value of scattering limits is obtained:

$$\varepsilon = \bar{I} \pm 3\sigma,$$

where: I –is the average value of galvanic couple current; σ-is the mean square deviation.

On the basis of the developed mathematical model of the galvanic corrosion element work in the steel pipeline section, the dependence is obtained that allows us to calculate the corrosion damage depth of the pipeline section with a constant and periodic penetration of an aggressive electrolytic solution into the area of damaged insulation.

Dependencies make it possible to predict the development of corrosion in time, regardless the aggressive electrolyte chemical composition, the possibility of obtaining the required calculation parameters from the structures which are used. By studying the dynamics of the pipeline section loss in the crack of the insulating coating, it is planned to develop a methodology for assessing the residual life of the pipeline sections for bearing capacity and suitability for further operation.

Based on the mathematical model of the work of a local corrosion element, the dependence has been developed that allows calculating the loss of the cross-sectional area of the steel pipeline in the crack of the insulation coating under different conditions of the aggressive solution penetration. Dependencies are based on real parameters obtained by a non-destructive method during the structure examination. The calculation study of the cross-sectional area relative loss of the steel pipe during its corrosion in the crack of the insulating coating showed that direct corrosion tests are compliant with the current values of the macro-galvanic couples.

The developed dependencies of the pipeline cross-section area losses make it possible to plan rationally the repair work, to predict the real terms of the structure work, to review the operation mode, etc. The obtained results allow us to more reliably estimate the bearing capacity of cracked structures operating in aggressive media conditions.

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