UDC (504.05 +504.06) 622.692.4

CALCULATION OF STEEL PIPELINE CORROSION DEPTH FOR VARIOUS CONDITIONS OF ELECTROLYTE SOLUTIONS IN CRACKS

Stepova O.[1], DSc (Engineering), Full Professor;
Stepovyi Ye.[1]

[1]National University «Poltava Polytechnic named after Yury Kondratyuk»,
Poltava, Ukraine

On the basis of the electrochemical corrosion mathematical pipeline model in the insulating coating crack under the action of an aggressive electrolytic medium towards the pipeline metal, the dependence was obtained that allows to calculate the corrosion depth of the pipeline wall during the work of macro-galvanic corrosion couples in the conditions of stable and periodic stay of the aggressive solution in the damaged zone. The advantage of this model is the ability to predict the development of corrosion over time regardless of the corrosive electrolyte chemical composition, the possibility of obtaining necessary design parameters for operated structures. The developed dependencies of the pipeline section corrosion depth 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 evaluate the bearing capacity of structures that operate in conditions of aggressive medium with cracks

Keywords*:* steel oil pipeline, electrochemical corrosion, galvanic element, corrosion rate.

The long-term operation of pipelines, starting from the transport and storage of pipes, causes various types of damages to them, namely: damage to insulation, corrosion damages, dints in the pipe metal, cracks in welds of prolonged use and cracks near welds. Such damages in contact with external technological environments results in corrosion, mechanical and corrosion-mechanical processes leading to the destruction of pipes [1].

Being a capillary-porous material, insulating coating is a second class conductor, therefore the steel corrosion process in it can be considered from the standpoint of ordinary electrochemical corrosion of metals in electrolytes. In most cases, which can include the pipeline corrosion in the crack, the heterogeneous mechanism of the metal destruction prevails. Herewith, certain parts of the metal surface are cathodes (pipeline under the insulation layer), and the other – anodes (pipeline in the crack). The main characteristic of the electric field is the potential for which it is possible to find the corrosion current density according to the known ohm law in the differential form.

The problem of modeling the steel electrochemical corrosion in the crack of the insulating coating during the action of an aggressive metal electrolytic medium, which comes down to the determination of the heterogeneous electrode stationary electric field, is solved. The advantage of this model is the ability to predict the valve corrosion development over time, which is important in determining the reinforced concrete structure residual life.

The pipe wall thickness is one of the main parameters that affects the changes in the stress-strain state of the structure, but also, therefore, on its residual life. The pipeline cross-section changing leads to a change in the distribution of stresses in the pipeline and contributes to the development of environmentally hazardous situations. The pipe wall thickness depends on the working pressure of loads, structural characteristics and strength redundancy, including allowance to uniform corrosion loss.

In order to calculate the cross section area loss under the constant being of an aggressive electrolytic solution in the damaged insulation zone, the pipeline corrosion depth dynamics during the operation of the galvanic element "pipeline having damaged insulation – the pipeline under the insulating coating" is considered [2].

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.

The pipeline section corrosion in the crack reaches the most active phase when on its surface a moisture film is formed. Herewith, the moisture film thickness is that the anode process in it is not yet slowed down, and there are the most favorable conditions for the cathode process development in the pipeline section under the insulation coating.

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.

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

$$\frac{dD}{dt} = -rD \tag{1}$$

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

$$lnD = -rt + lna$$

where integration constant $A = \ln a$.

From the last equation after exponentiation we have

$$D = ae^{-rt} \tag{2}$$

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 (2), we obtain:: $D_0 = a \times e^{-r\times 0}$, from which $a = D_0$

Then (2) is

$$D = D_0 e^{-rt}. \quad (3)$$

To determine *r* (specific velocity of wall thickness reduction), we take logarithm of the both parts of equation (3)

$$lnD = lnD_0 - rt. \quad (4)$$

Using equation (4) it is possible to calculate the values of *r* for two known values of the cross sections *D1* and *D2*.

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

$$\Delta D = D_0 - D_0 e^{-\left(\frac{lnD_1 - lnD_2}{t_2 - t_1}\right)t},$$

Or $$\Delta D = D_0\left(1 - e^{-\left(\frac{lnD_1 - lnD_2}{t_2 - t_1}\right)t}\right) \quad (5)$$

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 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.

REFERENCES

1. Polyakov S., Klimenko A., Malkova O. (2008). Electrochemical monitoring pipelines for corrosion hazardous areas, *Fiziko-chimichna mekhnanika materialov*, No. 7, Vol. 2. P. 761 – 766.

2. Stepova O., Paraschienko I., Lartseva I. (2018). Calculation of steel pipeline corrosion depth at the work of galvanic corrosion element operating. *International Journal of Engineering & Technology*. Vol.7, No 3.2. P.431-435.