THE RESIDUAL RESOURCE ASSESSMENT OF A OIL PIPELINE WITH A SURFACE DEFECT UNDER THE LOAD AND ENVIRONMENTAL FACTORS

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The authors proposed a mathematical model for estimating the timespan life of an oil pipeline with a surface semi-elliptical microcrack under the turbulent flow of oil in a soil-corrosive environment, which leads to the degradation of the pipe material. A two-frequency load models the effect of the turbulent flow of oil on the pipe wall. The energy basis approach is helping to obtain a nonlinear differential equation with respect to the function of crack opening in the refracture zone with variable coefficients. The equation and the initial and final conditions of crack propagation constitute a mathematical model for determining the residual life of the pipe. The remaining service life of the oil pipeline made of X70 steel was estimated.

Keywords: oil pipeline, degradation, energy approach, two-frequency loading, crack opening function

Introduction. Most of the oil pipelines are buried in the ground and are often operated with damaged outer insulation. Therefore, they are mainly destroyed from the outer surface where corrosion caverns and cracks occur as a result of the degradation of their material and the load. For the safe operation of pipes, it is important to assess their remaining service life.

Formulation of the calculation model. An oil pipeline pipe with an inner radius of 710 mm and a wall thickness of 18.7 mm made of X70 steel with an external surface semi-elliptical crack, along which a turbulent flow of oil with a pressure of $p = 9$ MPa moves with a fluctuation due to turbulence $\Delta p \approx 0.25$ MPa is under analyzing. The pressure in the pipe changes according to the two-frequency law and the surface of the pipe is exposed to soil corrosion, which contributes to the degradation of the material. The remaining lifespan should be calculated, by the number of low-frequency load cycles $N = N_*$, upon reaching which the crack contour will reach the inner surface of the pipe and its depressurization is occur. The direct solution of such a problem has a hidden pitfalls with led to significant mathematical difficulties. To avoid them, we use the method of equivalent areas, by means of which the rate of change of the area S of such a crack under uniform tension depends slightly on the configuration of its contour (in this case, the surface one). Therefore, we replace the contour configuration with a semicircular radius ρ with an initial area equal to the original defect. In the future, we apply the energy approach formulated earlier and the δ_k-model known in the literature by V.V. Panasyuk, as a result of which the problem was reduced to the following mathematical ratios.

$$d\rho/dN \approx \{\alpha(1-R_\delta)^2[\sigma_t[[1+N_1(1-R_{1\delta})]\delta_{t\max}-\delta_{scc}]^2]+ \\ +\eta(\delta_{t\max}-\delta_{scc})\}\cdot[\sigma_t\delta_{fC}-\sigma_t\delta_{t\max}]^{-1}, \tag{1}$$

$$N=0, \rho(0)=\rho_0=\sqrt{a_0b_0};\ N=N_*,\ \rho(N_*)=h\ .$$

δ_{tmax} is the maximum opening value of a semicircular crack in a cycle; $R_\delta = 0.1$, $R_{1\delta} = 0.94$ – cycle asymmetry coefficients for low and high-frequency loads; $N_1 = 1100$. Material characteristics δ_{fC}, δ_{scc}, α, η as a result of its degradation will change and depend on time t. Based on the results of the work [1], kinetic diagrams of crack growth V–δ_t were constructed for X70 steel for stock pipe and degraded after 30 years of operation. Referring to the dependence of the characteristics on the time t of the load was assumed to be linear, since during this period they changed slightly [1]. Hence, we present them in the form of functions: : $\delta_{fC}(t)=7{,}9\cdot10^{-5}–3\cdot10^{-7}t$; $\delta_{scc}(t)=8{,}4\cdot10^{-7}–1{,}43\cdot10^{-8}t$; $\alpha(t)=9{,}7\cdot10^{-2}+0{,}0141t$; $\eta(t)=4{,}9\cdot10^{-6}–6{,}6\cdot10^{-9}t$.

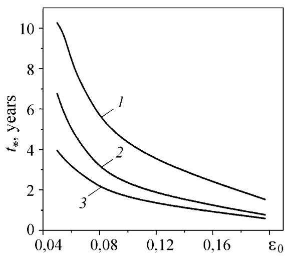

Fig. 1. Dependence of the residual resource of the pipe on the initial size of the defect.

Substitute these functions into equation (1) together with the numerical values of the parameters of the pipe geometry and its load. Based on the solution of the mathematical problem (1), the dependence of the residual resource of the pipe on the initial size of the defect was constructed (Fig. 1). It is shown that if the changes in material characteristics are not taken into account (curve 1) during operation, the real resource is overestimated (curve 2). At the same time, a similar dependence (curve 3) is given for the state of the material that degraded over 10 years. The presented results indicate the correctness of the proposed approach to estimating the residual resource of oil pipelines, taking into account the degradation of their material

Conclusions. Based on the formulated mathematical model, it was established that failure to the residual service life of the pipe leads to its overestimation if determined by the characteristics of the original material, and to underestimation, if calculated by the characteristics of the degraded material (after 30 years of operation).

1. *Andreikiv O.E., Hembara O.V., Tsyrul'nyk O.T. and Nyrkova L.I.* Evaluation of the residual lifetime of a section of a main gas pipeline after long-term operation // Mater. Sci. – 2012. – 48, № 2. – P. 231–238.