Assessment of the Reliability of Paintwork According To Accelerated Test Data

Loganina V.I.

***Abstract*— The possibility of predicting the reliability of coatings during operation in field conditions is shown on the basis of the data of accelerated tests. It is shown, that for accelerated tests the change in the determining parameter is inherent in the acceleration. Acceleration of the process of degradation of the properties of the system depends on increasing external influences. A recalculation model is proposed. The recalculation model includes the acceleration of the parameter change and the hereditary factor**

***Index Terms*— coating, probability of failure-free operation, conversion function, hereditary factor**

I. INTRODUCTION

The evaluation of the reliability of protective and decorative coatings in the process of operation presents certain difficulties associated with the duration and laboriousness of the tests. In this connection, the problem of recalculating the reliability indices obtained under forced test conditions into a real one is very actual. However, this causes certain difficulties due to the fact that depending on the intensity of the operational factors and the test regime, there is a certain rate of resource consumption (the intensity of "failure") [1,2,3,4]. The more the intensity of the external influence and the rigidity of the test regime, the more, for a certain period of time, the system produces a greater resource [5,6,7,8].

Manuscript received May 12, 2017

Loganina V.I., doctor of technical sciences, professor, author of more than 900 publications, including 65 patents. The field of scientific interests is the development of compositions of finishing materials, the forecasting of their properties, the development of quality control methods

II. MATERIALS AND METHODS OF RESEARCH

We used lime paint. Consider the calculation of reliability using the example of limy protective and decorative coatings. As a criterion for the weather resistance of coatings, a change in protective properties was used, evaluated in accordance with GOST 6992-68 on an eight-point system. During the experiment, the protective properties of the coatings were evaluated, as well as the adhesion strength. The total number of tests was 50 operating cycles. The obtained data were compared with the data of field study.

III. RESULTS OF RESEARCHES

To obtain the conversion functions, we consider two test modes:

-functioning of the coating in the normal mode of full-scale tests $-I_n(t)$;

-forced cycling tests - 4 hours freezing at a temperature of -40^{0}C, 2 hours thawing in air at a temperature of 40^{0}C and relative humidity of air of 60%, 2 hours humidification at a temperature of 18-20^{0}C and relative humidity of 60-70%$-I_f(t)$;.

Let us denote $\varepsilon_f(t)$ and - the rates of change in the value of the determining parameter (for example, the adhesion strength) in the indicated regimes. In accordance with the physical principle of reliability N.M. Sedyakin

$$\int_0^t \lambda_f(z)dz = \int_0^{x(t)} \lambda_n(z)dz \quad (1)$$

$$\int_0^t \varepsilon_f(z)dz = \int_0^{x(t)} \varepsilon_n(z)dz\,, \quad (2)$$

where $x(t)$ - the function of recalculating time of trouble-free operation from mode $I_f(t)$ to $I_n(t)$ mode;

$\lambda_n(t)$ and $\lambda_f(t)$ - the failure rate, respectively, for full-scale and forced trials.

In [9,10,11] it was shown that for accelerated tests the change in the determining parameter is characterized by an acceleration due to the acceleration of the process of degradation of the properties of the system with increasing external influences. The presence of the acceleration of the change in the parameter is a necessary condition for the distribution of the time to failure of the product in different modes to be different.

Solving the system of equations (1 and 2), one can find

$$x'(t) = \frac{\varepsilon_f(t)}{\varepsilon_n(x(t))}, \quad (3)$$

$$\varepsilon_n(x(t)) = \frac{\varepsilon_f(t)}{x'(t)} \quad (4)$$

$$\lambda_n(x(t)) = \frac{1}{x'(t)}\lambda_f(t), \quad (5)$$

where $x(t)$ is the conversion function.

Thus, it is possible to predict the reliability of coatings when operating in full-scale conditions on the basis of data from forcing tests. For this need to know:

-Law of change of the determining parameter in the regime $I_f(t)$;

-Conversion function $x(t)$;

-Law of distribution of uptime in mode $I_f(t)$.

Consider the calculation of reliability using the example of limy protective and decorative coatings. The results are shown in Fig.1.

The results of the studies show that the change in protective properties in full-scale tests corresponds to an exponential dependence of the form

$$Y(t) = A\exp(-\alpha t) \quad (6)$$

Then the rate of change is

$$\varepsilon_f(t) = -\alpha \cdot A\exp(-\alpha t) \quad (7)$$

For the limy coating under consideration A=7,96; α=0,02.

We believe that during the tests in the forced mode, there is an acceleration of the process of changing the protective properties, i.e.

$$\varepsilon_f(t) = -\alpha A\exp(-\alpha t) + \beta t \quad (8)$$

Then, according to (1), the recalculation function $x(t)$ can be determined from expression

$$x(t) = -\frac{1}{\alpha}\ln\{\exp(-\alpha t) + \frac{\beta t^2}{2A}\} \quad (9)$$

In accordance with the theory of reliability, the probability of failure-free operation of *P (t)* can be determined by the exponential dependence

$$P(t) = e^{-\lambda t} \quad (10)$$

However, earlier studies [7,8,9] indicate, that aging model of coatings should take into account the components that characterize the hereditary factor.

$$P(t) = e^{-\lambda t - e^{\beta t} + 1}, \quad (11)$$

And the failure rate in the regime $I_f(t)$ in this case

$$\lambda_f(t) = \lambda + \gamma e^{\gamma t} \quad (12)$$

Performing the recalculation of the reliability function from the forced mode to the actual operating conditions using formula (5), we obtain

$$\lambda'(t) = \frac{A\exp(-\alpha t) - \beta t^2/2}{A\exp(-\alpha t) + \beta t/2}(\lambda + \gamma\exp\gamma) \quad (13)$$

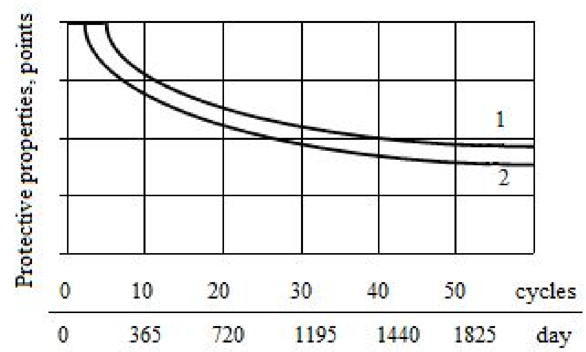

Fig. 1. Change in the protective properties of the lime coating in the process of aging
1 - forced test mode; 2 - full-scale tests

Table 1 shows the calculated data on the probability of failure-free operation obtained according to formula (13), the data obtained are in good agreement with the experimental data.

Table 1.Probability of failure-free operation of the lime coating

Day since the beginning of operation	The probability of failure-free operation of the lime coating in normal operation	
	Calculation of the experimental data in the mode $I_n(t)$	Calculation with predictions based on test data in the mode $I_f(t)$
100	0,896	0,895
180	0,801	0,796
460	0,681	0,696
1095	0,599	0,602

1825	0,503	0,507

IV. Conclusions

Thus, the proposed models allow a more reliable prediction of the service life of coatings.

References

[1] L.P.Orentlicher, V.I.Loganina. Protective-decorative coatings of concrete and stone walls. Reference. Moscow : Stroiizdat, 1993.136p
[2] Kanevskaya E.A, I.V.Elisavetskaya, Yu.N.Mikhailovsky. Forecasting of light fastness of paint and varnish coatings in natural conditions according to short-term tests. - In: Abstracts of the scientific and technical meeting "Protection of building materials and structures against corrosion - Kiev, 1973, p. 57.
[3] E.A.Andrushenko. Lightfastness of paint and varnish coatings. - Moscow: Chemistry, 1986, 186 p.
[4] GOST 6992 - 68 Materials for paint and varnish. Method for determining the stability of the coating in atmospheric conditions.
[4] M.I.Karyakina. Physico-chemical basis of the formation and aging of coatings. Moscow: Chemistry, 1980, 216 p.
[5] G.Gardner. ASTM's new coatings test method addresses interactive effects of weathering and corrosion. //JPCL. 1998. September. P. 50–62.
[6] M.A.Frizzi, E.Aragon. Correlation between natural and artificial weathering anticorrosive paints. //JPCL. 2002. September. P. 58–62.
[7] O.O.Knudsen, U.Steinsmo, M. Bjordan., S.Nijjer. Accelerated testing: correlation between four accelerated tests and years offshore field testing.// PCE. 2001. December. P. 52–56.
[8] SSPC-PS 36. Editorial Revision. November 1. 2004. P. 6-159–6-165.
[9] G.M. Bartenev Strength and mechanism of destruction of polymers - Moscow: "Chemistry", 1984, 280 p.
[10] V.I.Loganina.. The Kinetics Model of Coverings' Properties with Consideration of the Heredity Factor. Contemporary Engineering Sciences, Vol. 8, 2015, no. 2, 85-89HIKARI Ltd, www.m-hikari.com http://dx.doi.org/10.12988/ces.2015.412257
[11] V.I.Loganina. Model of Aging Coatings Based on Hereditary Factors Contemporary Engineering Sciences, Vol. 8, 2015, no. 4, 165 -170 HIKARI Ltd, www.m-hikari.com http://dx.doi.org/10.12988/ces.2015.518

Loganina Valentina Ivanovna
Loganina Valentina Ivanovna - doctor of technical sciences, professor, author of more than 900 publications, including 65 patents. The field of scientific interests is the development of compositions of finishing materials, the forecasting of their properties, the development of quality control methods.