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Evaluation of the Destruction of the Coating Depending on its Thickness

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Abstract: The study covers the probabilities of cohesive and adhesive fracture of coating, depending on its thickness. The formulas for calculating the critical thickness of coating, at which the probabilities of cohesive and adhesive fracture are equal are cited. Particular cases of use of the proposed calculation formulas are examined.

Key words: Paint, coatings, the thickness of the coating, the probability of breakage, Russia

INTRODUCTION

When testing paints on a cement backing three types of fracture are observed at the same time cohesive, adhesive and mixed. This makes it difficult to obtain reliable data on the mechanism of the coats fracture, to predict the behavior of the coat while in operation, etc.

The property values of the coats on a cement backing are known to be variable and depend on a number of factors (the roughness and porosity of the backing, technological factors, etc.) (Loganina, 2014a, b; Bartlett, 1997; Song *et al.*, 2005; Loganina and Fokin, 2016). The probability of this or that type of fracture (adhesive or cohesive is defined by a combination of these factors.

Taking into account the cement backing structure characteristics, it should be borne in mind that the coat thickness on the surface is uneven which undoubtedly has an impact on the coat properties distribution. In connection with this while testing there is a possibility of conflicting results about the nature of the coat fracture. We believe that the coat thickness should be taken into account when preparing samples for testing, its value is determined in accordance with the following.

MATERIALS AND METHODS

The study used polyvinyl acetate cement PVAC paint. The coating thickness was measured with a micrometer. Totally we have performed 50 measurements. Samples of the films were tested for tensile on testing machine brand IR 50-57 to set the speed of the traverse of 87.5 m sec^{-1}. The 1×1×5 cm samples were fixed in the clips of the tensile machine so that their longitudinal axis was in the direction of stretching and the force was applied equally all over the sample section. The tests were carried out at the temperature of 20°C and relative air humidity of 60%. The ultimate tensile strength estimation was carried out for not less than four samples of each compound. The ultimate tensile strength R_{kog} for each sample was calculated by Eq. 1:

$$R_{kog} = \frac{F_{Pi}}{S_{Oi}} \quad (1)$$

Where:
F_{Pi} = The stretching loading at the time of a rupture (N)
S_{Oi} = The initial cross-sectional area of a sample (mm^2)

RESULTS AND DISCUSSION

The condition of cohesive fracture has the form:

$$R_K < R_a \quad (2)$$

where, R^k, R^a is the respective values of cohesive strength and adhesive strength of the coat. Let’s consider the probability of the cohesive type of fracture P (R_k<R_a) provided that the coat thickness takes random values equal to h:

$$R_K = A \cdot h^{-\frac{1}{n}} \quad (3)$$

Where:
h = The thickness of the coat
A, n = Coefficients dependent on the type of the coat

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The value is random and in general (with the cumulative impact of many factors) follow the normal distribution law (Pugachyov, 1968; Loganina and Fokin, 2016). Therefore, the value of h is also random. We will make the following transformation to determine the law (and functions) of its distribution on the coat surface according to the distribution of the cohesive strength The law of distribution R_k is as follows:

$$f(R_K)=\frac{1}{\sqrt{2\pi}\sigma_{R_K}}\cdot e^{-\frac{1}{2}\frac{(R_K-\bar{R}_K)^2}{\sigma^2_{R_K}}} \quad (4)$$

Equation 2 is a monotonically decreasing function, therefore, the coat thickness distribution density h can be determined by the Eq. 5:

$$f(h)=f[\psi(h)]\cdot|\psi'(h)| \quad (5)$$

Where:
$f[\psi(h)]$ = Function of the Eq. 3
$\psi(h)$ = Right-hand side of Eq. 2

Substituting (Eq. 2 and 3) into (Eq. 4) we obtain:

$$f(h)=\frac{\left|-\frac{A}{n}\cdot h^{\frac{-1-n}{n}}\right|}{\sqrt{2\pi}\sigma_{R_K}}\cdot e^{-\frac{\left(A\cdot h^{-\frac{1}{n}}-\bar{R}_K\right)^2}{2\cdot\sigma^2_{R_K}}} \quad (6)$$

The distribution function, respectively will be:

$$F(h)=\int_0^h f(h)dh \quad (7)$$

Thus, the distribution law and function of h are determined by coefficients A and n and also parameters of the distribution $\bar{R}_k$ and σ_{R_k} the cohesive strength of the coat.

The comparison of Eq. 1 and 2 shows that the cohesive type of fracture takes place, if the coat thickness h exceeds some critical value h_{kr} in which R_c = R_a. Therefore, substituting the value of R_a instead of R_c in Eq. 1 and having made transformations, we can calculate the value of h_{kr} as follows:

$$h_{Kp}=e^{\left[(-n)\cdot\ln\left(\frac{R_a}{A}\right)\right]} \quad (8)$$

The probability of the cohesive type of fracture is calculated by the equation:

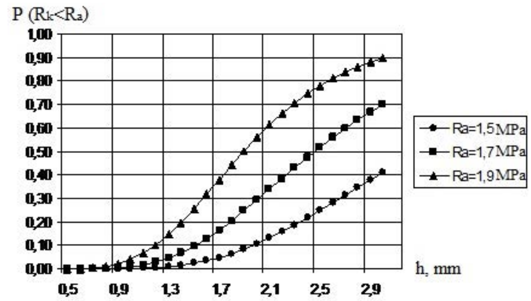

Fig. 1: The dependence of the cohesive fracture on the coat thickness h

$$P(R_K<R_a)=\int_{h_{Kp}}^{\infty} f(h)dh \quad (9)$$

Let's consider the practical application of the above mentioned results using polyvinyl acetate cement PVAC coat. At the stage of experimental research dependence (Eq. 2) has been found) for PVAC coat:

$$R_K = 2.5\cdot h^{-\frac{1}{2.33}}$$

The average value of the cohesive strength MPa and standard deviation MPa of the cohesive strength of PVAC coating have been also determined. The distribution law (Eq. 5) takes the form:

$$f(h)=\frac{\left|-\frac{2.5}{2.33}\cdot h^{\frac{-1-2,33}{2,33}}\right|}{\sqrt{2\pi}\cdot 0.308}\cdot e^{-\frac{\left(2.5\cdot h^{-\frac{1}{2.33}}-2.1\right)^2}{2\cdot 0.308^2}}$$

According to (Eq. 8) the cohesive fracture probability P (R_k<R_a) depending on h will be described by the curve shown in Fig. 1.

The experiment results revealed that the average value of the adhesion strength is MPa. By the Eq. 7 the critical coat thickness for the cohesive fracture pattern is mm. The probability of the cohesive fracture by Eq. 8 or Fig. 1 is: P (P_k<R_a) = 0.097. This implies that only on 9.7% of the coat surface area the cohesive fracture pattern may occur. However, to get only the adhesive fracture pattern the probability of the cohesive fracture must be P (P_k<R_a) = 0.00.

On this basis, we have calculated the coat thickness of PVAC $h_{Kp}=2.45$ (only adhesive type of fracture will be observed). The elimination of the cohesive fracture pattern is followed by high values of cohesive strength and predetermine the development of coat crack resistance of optimum thickness.

CONCLUSION

The approach can be applied to the development of the coat quality control.

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