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Corrosive wear forecasting of steel elements on the basis of mathematical modeling methods

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Abstract. Life Extension and resistance increase of metal materials and constructions to the corrosion destruction processes is the most important scientific and technical problem. To solve this problem it is necessary to develop complex scientific research to study the corrosion phenomena, along with practical actions against corrosion directed to selecting new corrosion resistant metal materials and methods of their protection. This research is carried out for searching mathematical model which could predict corrosive wear in metal constructions with a certain accuracy taking into account design and the type of corrosion process.

1 Introduction

Damage assessment of bearing constructions and determination of their residual resource is an important task [1,2]. Corrosion destruction is one of basic reasons of steel structures durability decrease. Researches in the field of durability increase and improvement of anticorrosive protection of building constructions are conducted in complex and include: on-site investigations, experimental and theoretical developments.

When studying development results of corrosion processes it is necessary to analyse a large number of factors. Handling of considerable amount of information and determination of common factors of damage formation due to corrosion require the use of modern computing devices and corresponding mathematical models [3]. Mathematical models development is impossible without clear idea of process mechanism, experimental data characterizing the influence of different factors on process kinetics and reliability control of the forecast methodology in natural conditions. It particularly concerns corrosion processes which are multistage. Stages can proceed in consecutive, as well as in parallel in case of various combinations of internal and external factors. Chemical composition of metal and alloy, metal surface condition, protective coatings type and condition, operation mode, hostile environment characteristics belong to such factors [4, 5-8].

2 Main Part

In the pilot study process of corrosive wear of different metalwork it is necessary to carry out the analysis of corrosion damage nature, as well as quantitative indices of wear in long

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operational conditions. In this paper the installation for hydrochloric acid acceptance and pouring of the galvanic shop was chosen as a research object. The installation represents three level metal framework consisting of 8 racks (a square pipe 200x7) connected by platform beams (channel No. 14) at which boards from corrugated steel are put. On the upper platform (mark. +11.000) there were tanks with hydrochloric acid. All the constructions are made of S 235 steel (Russian standard - VSt3kp2 GOST 380-71*). Installation service life is 42 years in conditions of moderately aggressive environment [5]

During on-site investigation residual elements thickness was measured: i.e. stay braces (4 pieces) and beams (4 pieces). Forty measurements in various section points were performed on each element. The total number of measurements was 320. Survey allowed to determine the type and nature of corrosion damages. Common uneven corrosion was inherent for all the elements. In particular, pitting and localized were found on certain sites. Hence, it is possible to state that corrosion process caused the damages formation of chaotic character on the surface of studied elements. And they can be described statistically. When analyzing statistical data, the measured values are most likely, to submit to lognormal distribution law as corrosion destructions happen owing to a large number of arbitrary factors. It means that accidental process is stationary, normal and can be described by means of the least significant moments of probabilities distribution. Mean square deviation value and points deviation dispersion from the average line belong to these very probabilities. These two values describe distribution function of geometrical sizes of construction elements damaged by corrosion (thickness). Long-term practice of scientific research conducted in the field of studying of corrosion wear influence on construction showed that a true mathematical wear size distribution model of steel elements of a framework is lognormal distribution [7].

To detect distribution nature of spreading depth on the elements surface and to determine construction wear value let us carry out the statistical analysis to draw distribution curves of wear values. (Fig. 1)

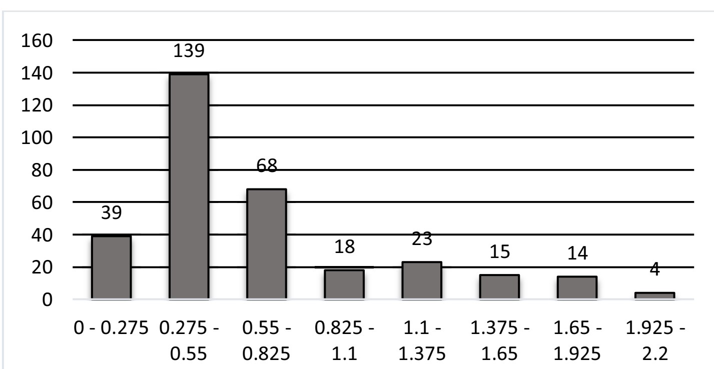

Fig. 1. Histogram of results distribution of corrosion wear measurement of elements thickness -Δt, mm. Δt=t0-t, where t0 – the initial thickness of elements, mm; t – the measured thickness of elements, mm.

Corrosion wear was determined as difference between the initial thickness of an element and residual one according to measurements. After visual assessment of this distribution it is possible to make the assumption of lognormal distribution since form and outline quite correspond to values distribution according to Gauss's law. There are several methods of justifying assumptions about distribution law of random variable. Pearson consent criteria used in case of large amount of test samples is the most widespread and it was considered in this paper. Non-negative random variable is known to be distributed logarithmically normal if the decimal logarithm of this value is distributed according to the normal law. Values of logarithmic and normal random variables are formed as "accidental misstatements" of some "true value". The last, eventually, acts not as an average value, but as a median. Let us take the logarithms of residual thickness and draw the histogram for the given values (Fig. 2,3).

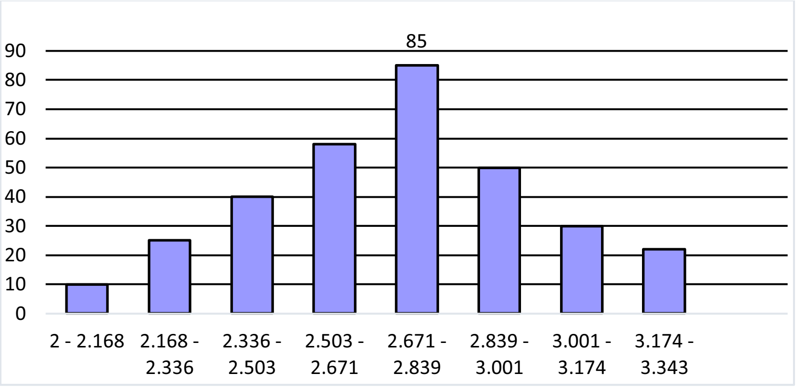

Fig. 2. Distribution type of corrosion wear values for stay braces.

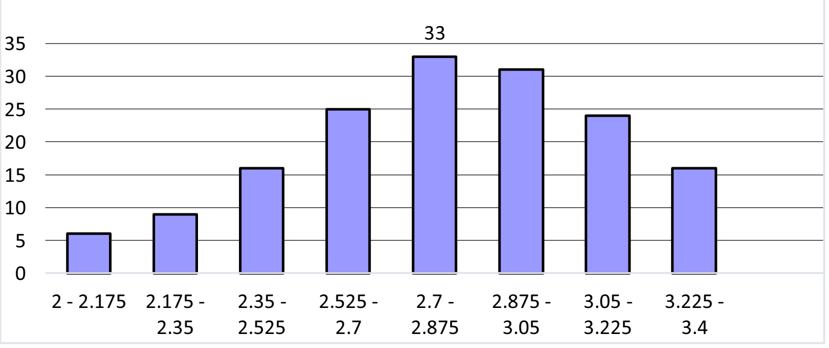

Fig. 3. Distribution type of corrosion wear values for beams.

The results received showed that values of corrosion losses of steel elements of this installation (a beam, a stay brace) are of lognormal distribution [3].

Let's figure mathematical distribution models of corrosion wear values of steel elements on the example of steel stay braces (Fig. 4).

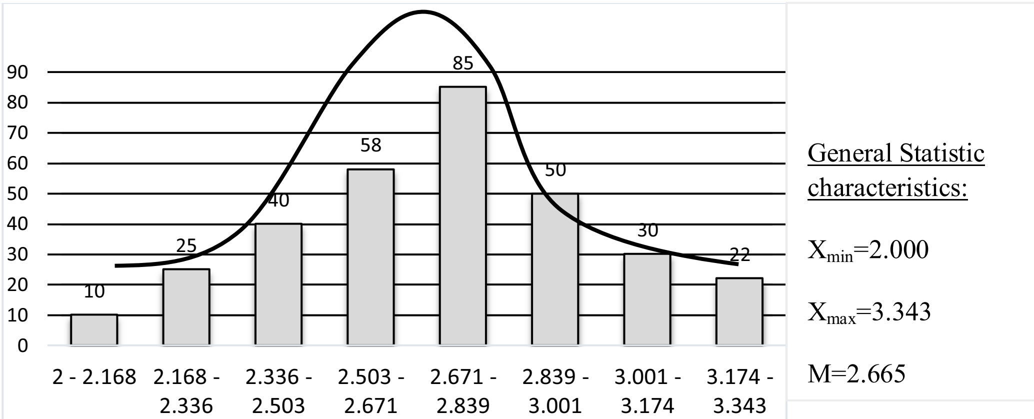

Fig. 4. A mathematical distribution model of corrosion wear of steel elements – lognormal distribution.

Lognormal distribution has its own regularities with the use of which, it is possible to define elements average wear, and also the greatest and smallest probable wear values of constructions in the given operating conditions, with a certain accuracy. Let's consider the maximum corrosion damage depth with the probability of 0,95 which is quite accepted for technical calculations. In case of lognormal distribution it will be:

$$t_{max} = 10^{m+1.65\sigma} \quad (1)$$

where m – logarithms mean value of corrosion damage depth of test samples.

For the measured stay braces:

$$m = \frac{\sum x_i}{N} = \frac{852.809}{320} = 2.665 \quad (2)$$

For the measured beams:

$$m = \frac{\sum x_i}{N} = \frac{443.81}{160} = 2.774 \quad (3)$$

where x_i – the logarithms values amount of corrosion damage depth of constructions; N – a number of measurements (N=320 – for stay braces, N=160 – for beams).

σ – root mean squared deviation of test samples logarithms is defined:

- For the measured stay braces:

$$\sigma = \sqrt{\frac{\sum (m-x_i)^2}{N-1}} = 0.462 \quad (4)$$

- For the measured beams:

$$\sigma = \sqrt{\frac{\sum (m-x_i)^2}{N-1}} = 0.409 \quad (5)$$

Thus, the maximum depth of corrosion damages, according to the statistic analysis of lognormal distribution, is equal:

For the measured stay braces:

$$t_{max} = 10^{m+1.65\sigma} = 10^{2.665+1.65\cdot0.462} = 2680\ mkm = 2.68\ mm \quad (6)$$

For the measured beams:

$$t_{max} = 10^{m+1.65\sigma} = 10^{2.774+1.65\cdot0.409} = 2818\ мкм = 2.82\ mm \quad (7)$$

Comparing these data we see that:

$$t^{st}{}_{max} = 2.68\ mm < t^{b}{}_{max} = 2.82\ (mm) \quad (8)$$

Difference in thickness value of corrosive wear of beams and stay braces shows a significant influence role of a geometrical arrangement of elements in space. Smaller corrosion losses in stay braces can also be explained by successfully chosen section form – the closed square profile since corrosion process takes place on open profiles more intensively (corners, channels, I-beams, etc.).

As a result of the conducted research it is stated that corrosion wear process of various elements is described with the help of exponential function quite accurately by means of which it is possible to determine wear value of metal elements from various constructive forms at the definite operation moment in strong and the moderately aggressive medium, thus, predicting their durability, appointing the optimum inter-repair periods and different anticorrosive actions. The law of lognormal distribution allows to view processes, to predict them with high precision and that can be used in case of real inspection of the constructions subjected to corrosion. The application possibility of this mathematical model for the long-term forecast of corrosion process can be performed by indirect verification, i.e. comparison of model and the research results of similar processes reviewed in literature.

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