Problems of metrological support of methods for determining the corrosion rate of offshore platforms with insufficient source data

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Abstract. Offshore stationary platforms are used in the extraction of resources on the shelf (oil, gas, coal, steel and etc.). Offshore platforms are exposed to corrosion, which can lead to the destruction of the structural elements of the platforms. To assess the value of corrosion losses, ultrasonic measurement of the wall thickness of platform elements is used, which gives an understanding of their actual wear. In some cases, there is no initial information on the wall thickness of the platform elements. The absence of this information does not allow the calculation of the corrosion rate of platform elements and the determination of its residual life. The article proposes a method based on probability theory, which allows you to calculate the initial wall thickness of the platform elements in the absence of initial data on the initial thickness.

1. Introduction

Russia has significant offshore oil and gas resources located on offshore and oceanic shelves. Oil and gas production takes place in difficult conditions, accompanied by various negative impacts [1-20]. Extraction is actively conducted on the shelves of the Caspian, Baltic, Sakhalin and other regions. In 2014, our country gained access to the existing and prospective offshore oil and gas fields of the Black Sea, the production of which is carried out using offshore hydraulic structures, which are also called offshore oil and gas facilities (OOGF). These structures are fixed offshore platforms (FOPs) of the "jacket" type for various purposes. Fixed offshore platforms are actively used for oil and gas production on offshore fields around the world. So, for example, in the Gulf of Mexico alone, approximately 4,500 such structures are used. Actively offshore stationary platforms are used by Norway, Azerbaijan, Iran, a number of Gulf countries, China, Brazil, the USA and many other countries. Those. it can be confidently said that these structures are widespread and play an important role in the extraction of oil and gas resources on the shelf. Since FOPs operate in adverse marine conditions, characterized by high corrosion activity, they undergo significant corrosion wear (figure 1 and figure 2). In this regard, the study of the corrosion processes of offshore stationary platforms is an urgent and timely task.
Figure 1. Corrosion through an element of the offshore platform

Figure 2. Complete corrosion damage to the offshore platform element

Briefly describe the factors that influence the intensity of corrosion processes under conditions of sea oil and gas fields. Primarily on the intensity of corrosion processes affected by temperature. With increasing of the temperature the rate of electrochemical corrosion increases, due to the emergence of termogalvanic facilities vapor due to the difference in temperature of separate areas of the same structural element of FOPs. Heated under the influence of solar radiation to a higher temperature surface plot feature of FOPs is the anode and is subjected to more intense corrosion in contrast to the underwater zone with small temperature variations of structural elements. A significant impact on the rate of corrosion has dissolved in seawater salt, which turns sea water into the electrolyte with a high degree of electrical conductivity. It should also be noted that the corrosion damage of the support block begin as a result of disruption of systems of protection against corrosion. Analysis of reports of diagnostic tests of offshore platforms located on the Black sea, clearly points to the fact that corrosion processes occur most intensively in areas with damaged paint coating (or other insulating material). The weak adhesion of the paint coating or no caused serious corrosion damage even in the presence of active electrochemical protection systems. In addition, the authors would like to emphasize the fact that mechanical damage structural elements of the support unit, such as nicks or burrs, greatly accelerates the corrosion process. Also important is the factor of marine fouling, which plays a crucial role for the elements located in the underwater zone. The fouling of structures by organisms with a hard shell slows down corrosion, by limiting oxygen access to the metal.

2. Methods

During operation, offshore platforms undergo comprehensive diagnostics to assess their actual technical condition with subsequent calculation of the residual resource. The criterion for assessing this state is to determine the amount of wear of the elements of metal structures and calculate their residual life by corrosion rate. According to the results of a comprehensive technical diagnosis, the data of ultrasonic thickness measurement with a number of some measurements \( x_i \) are analyzed. The average depreciation of the platform elements is determined by the formula:

\[
\Delta_{av} = \frac{x_0 - x_{av}}{x_0}
\]  

where: \( x_0 \) is the initial wall thickness of the element (design thickness), \( x_{av} \) is the average wall thickness according to n measurements (mathematical expectation) for the measured value \( x_i \):

\[
x_{av} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]

where: \( n \) is the number of measurements.
Maximum depreciation is determined by the formula:

$$\Delta_{\text{max}} = \frac{x_0 - x_{\text{min}}}{x_0} \cdot 100\%$$  \hspace{1cm} (3)

where $x_{\text{min}}$ is the minimum value from a series of measurements $x_i$.

Residual resource $R$ by corrosion rate $V$ is determined by the formula:

$$R = \frac{x_0 - a_{\text{ext}}}{V}$$  \hspace{1cm} (4)

where: $x_0$ and $a_{\text{ext}}$ are the nominal and minimum acceptable (from the strength conditions) values of the wall thickness, and the corrosion rate $V$ is determined by the formula

$$V = \frac{x_0 - x_{\text{min}}}{T}$$  \hspace{1cm} (5)

where: $T$ – time elapsed from the start of operation to the moment of inspection, and the rest are the same as in formulas (1-4).

While preparing the conclusions of the industrial safety review and analysis of project documentation, situations of the so-called incomplete certainty of the initial data often arise. Namely, the nominal thicknesses indicated in the design are less than the actually measured values, or the design documentation has been lost. A similar situation arose after familiarizing ourselves with the measurements of wall thicknesses of metal structures presented in the Technical Report «Inspection of the Metal Structures of the Offshore Fixed Platform». (Black Sea Region). As a result of the analysis of the results obtained, it was established that according to the thickness gauge of individual elements of the offshore platform in a number of measurements $x_i$, there are values that do not correspond to the design wall thickness. For the correct determination of the wear of individual elements, it is necessary to establish the initial wall thickness of the elements, taking into account deviations from the project that were allowed in the manufacture and installation of the metal structures of the offshore platform, a solution to this problem can be found on the basis of probability theory and involves the following steps.

Initially, the initial wall thickness of the element should be determined by the formula:

$$x_0 = x_{\text{av}} + t_v \cdot \frac{\sigma}{\sqrt{n}}$$  \hspace{1cm} (6)

where: $x_0$ is the initial wall thickness of the element (design thickness), $x_{\text{av}}$ is the average wall thickness according to $n$ measurements, the ratio $t_v \frac{\sigma}{\sqrt{n}}$ is the confidence interval for the arithmetic mean $x_{\text{av}}$ measured by the value of $x_i$, which is distributed according to the normal law with reliability $\gamma$, for which, according to the Student distribution tables (see table 1) for a given value of $\gamma$ we find the value $t_v$, and the value $\sigma$ is determined by the formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} |x_i - x_{\text{av}}|^2}{(n-1)}}$$  \hspace{1cm} (7)

where: $\sigma$ is the dispersion of the linear combination of the mean square error of the arithmetic mean, $x_i$ is some measured value, $x_{\text{av}}$ is the average measured value, $n$ is the number of measurements.

**Table 1. Student distribution with a given value of reliability $\gamma$.**

| Number of measurements n-1 | Reliability $\gamma$ |
|---------------------------|----------------------|
|                           | P=68.3%              | P=95%     | P=99%     | P=99.73% |
| (1)                       | (1.8)                | (12.7)    | (64)      | (235)     |
| 2                         | 1.32                 | 4.70      | 9.9       | 19.2      |
| 3                         | 1.20                 | 3.18      | 5.8       | 9.2       |
| 4                         | 1.15                 | 2.78      | 4.6       | 6.6       |
| 5                         | 1.11                 | 2.57      | 4.0       | 5.5       |
3. Result

We give an example of calculation. Based on the results of ultrasonic thickness measurement, the wall thicknesses of the element are given in table 2. We will calculate the variance of the linear combination of measurement errors using formula (7):

\[
\sigma = \sqrt{\frac{0.416}{8-1}} = 0.2437
\]

Then the initial wall thickness of the investigated element of the supporting block of the offshore platform will be determined by the formula (6):

\[
x_0 = 18.75 + 4.5 \cdot 0.2437 = 19.84 \text{ mm}
\]

Accordingly, having received a probable initial value of 19.84 mm, we take the nearest nominal thickness equal to 20 mm.

Table 2. The residual wall thickness of the columns of the surface of the support block of the offshore stationary platform according to the results of ultrasonic thickness measurement.

| Measurement number | Measurement result \(x_i, \text{mm}\) | Arithmetic mean value \(x_{av}, \text{mm}\) | Deviation of the measured thickness from the arithmetic mean | Dispersion of a linear combination of measurement error, \(\sigma\) |
|--------------------|---------------------------------|-----------------|-----------------------------|-----------------|
| 1                  | 18.7                           | ...             | 0.125                       | ...             |
| 2                  | 19.1                           | ...             | 0.275                       | ...             |
| 3                  | 18.9                           | ...             | 0.075                       | ...             |
| 4                  | 18.8                           | 18.75           | 0.025                       | 0.2437          |
| 5                  | 18.7                           | 18.75           | 0.125                       | ...             |
| 6                  | 18.8                           | ...             | 0.025                       | ...             |
| 7                  | 18.1                           | ...             | 0.725                       | ...             |
| 8                  | 18.9                           | ...             | 0.075                       | ...             |

Having determined the value of the nominal wall thickness of the element and taking into account that from the moment of commissioning to the moment of inspection the time \(T = 15\) years has passed, we calculate the corrosion rate \(V\) is determined by the formula (5):
\[ V = \frac{20 - 18.1}{15} = 0.13 \text{mm/year} \]

It should be noted that the obtained value is 0.03 mm/year higher than the corrosion rate specified in [2].

We calculate the residual life \( R \) by the corrosion rate \( V \) at the minimum allowable value of the wall thickness of the element (from the condition for ensuring strength) \( t_{\text{ext}} \) equal to 16 mm is determined by the formula (4):

\[ R = \frac{18.1 - 16}{0.13} = 16.1 \text{years} \]

The average depreciation of the investigated element of the support block, calculated by the formula (1) is:

\[ \Delta_{\text{av}} = \frac{20 - 18.75}{15} \times 100\% = 8.33\% \]

The maximum depreciation of the investigated element of the support block, calculated by the formula (3) is:

\[ \Delta_{\text{max}} = \frac{20 - 18.1}{15} \times 100\% = 12.7\% \]

4. Conclusion

Thus, a technique is proposed in the article that makes it possible to determine the nominal wall thickness of an element of the offshore platform in the absence of data on their initial thickness. And on the basis of the data obtained, calculate the residual life of the platform elements according to the corrosion rate.

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