The Statistic Analyze of Stress-Corrosion Cracks on the Main Gas Pipeline Section

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Abstract. The information on the technical diagnostics problems for pipeline systems is given; the analysis of these problems is made. The ways of their solution are considered using non-destructive testing methods and technical means. According to the results of technical diagnostics, stress-corrosion cracks of natural (operational) wear, which arose in a section of a steel pipe cut from a gas pipeline, were investigated. Some parameters characterizing the distribution of stress-corrosion cracks on the metal surface of a steel pipe are given. The statistical dependences for the lengths of stress-corrosion cracks are obtained: 46% of cracks have a length of less than 1 mm, 50.7% of cracks have a length from 1 mm to 6 mm, and less than 3% of cracks have a length from 6 mm to 26 mm. The statistical dependences for the distribution of intervals between adjacent stress-corrosion cracks in the metal were also obtained: more than 42% of cracks are located within an interval not exceeding 1 mm, more than 52% of cracks are located within an interval varying from 1 to 3 mm and about 5% of cracks are located within an interval varying from 3 to 5 mm and more.

1. Introduction
One of the most important tasks of modern technical diagnostics is the creation of conditions for ensuring the safe operation of pipeline systems. Due to the enormous length of pipeline networks, it is not possible to overhaul and reconstruct all obsolete steel pipelines. Therefore, the most appropriate and effective means in this situation is the selective repair and reconstruction of individual sections, based on the diagnostic information obtained [1-5].

Analysis of the statistics of accidents on main gas pipelines (MGP) in Russia shows that the most common cause of MGP failures is stress-corrosion cracks [6-10]. These defects, as a rule, develop on the outer surface of a steel pipeline and therefore are poorly identified by in-line flaw detectors [11-15]. The most reliable and valid diagnostic information about the technical condition of a steel pipeline is obtained when they are detected using external-use flaw detectors [15-20].

Since stress-corrosion cracks on a pipe are arranged in groups, their spatial separation (resolution) is required for a correct assessment of their linear dimensions. This issue is currently not fully understood, so for the practice of eddy current testing of pipelines, it is important to systematize information about stress-corrosion cracks of natural origin based on the study of sections of steel pipes with operational defects. This paper is devoted to statistical studies of a group of natural (operational) stress-corrosion cracks in the section of the main gas pipeline.
2. Main part
Studies of stress-corrosion cracks of operational origin were carried out on a section of steel pipe cut from the main gas pipeline according to the results of technical diagnostics (the outer diameter of the pipe is 1,420 mm, the material is the steel of 09G2S grade).

Figure 1 shows a steel pipe section with a group of natural stress-corrosion cracks, which was localized near the longitudinal weld of the pipe.

![Figure 1. Group of stress-corrosion cracks in the body of the steel pipe.](image)

Dye penetrant inspection was carried out at this site, the purpose of the inspection was to identify stress-corrosion cracks, and then the area under study was divided into cells with an area of 1 cm². Next, measurements were made of the linear dimensions of the identified defects in the continuity of the metal in this group of stress-corrosion cracks.

Table 1 shows the obtained parameters characterizing the distribution of stress-corrosion cracks on the metal surface of the steel pipe. From these data, it follows that up to 17 stress-corrosion cracks can be located on the surface of a damaged metal in a steel pipe with an area of 1 cm².

| Parameter name                                      | Parameter value |
|-----------------------------------------------------|-----------------|
| The total number of cracks in the area of the metal under study, Ne | 3825            |
| The area of the area under study, cm²               | 228             |
| The area occupied by stress-corrosion cracks, cm²  | 221             |
| Distribution density of stress-corrosion cracks (offs / cm²) | 17              |

To determine the possibility of identifying a group of stress-corrosion cracks in a steel pipe with an eddy-current flaw detector VD-12NFP, the following statistical data were obtained at first:
- for length (l, mm) of stress-corrosion cracks in the metal;
- for intervals (dx, mm) between adjacent defects in the stress-corrosion crack group.
Table 2 shows the measured values of length, l, of stress-corrosion cracks in the body of the steel pipe (the total number of measured cracks (Ne) is 3825).

**Table 2. The length of stress-corrosion cracks in the metal.**

| Length l, mm | Number of cracks, N | N/Ne,% | Length l, mm | Number of cracks, N | N/Ne,% |
|--------------|---------------------|--------|--------------|---------------------|--------|
| < 1 мм       | 1782                | 46.59  | от 13 до 14 мм | 0                   | 0      |
| 1 мм         | 694                 | 18.14  | от 14 до 15 мм | 1                   | 0.03   |
| от 1 до 2 мм | 647                 | 16.92  | от 15 до 16 мм | 1                   | 0.03   |
| от 2 до 3 мм | 283                 | 7.4    | от 16 до 17 мм | 0                   | 0      |
| от 3 до 4 мм | 173                 | 5.52   | от 17 до 18 мм | 1                   | 0.03   |
| от 4 до 5 мм | 70                  | 1.83   | от 18 до 19 мм | 0                   | 0      |
| от 5 до 6 мм | 74                  | 1.93   | от 19 до 20 мм | 0                   | 0      |
| от 6 до 7 мм | 31                  | 0.81   | от 20 до 21 мм | 0                   | 0      |
| от 7 до 8 мм | 32                  | 0.84   | от 21 до 22 мм | 2                   | 0.05   |
| от 8 до 9 мм | 14                  | 0.37   | от 22 до 23 мм | 0                   | 0      |
| от 9 до 10 мм | 6                   | 0.16   | от 23 до 24 мм | 0                   | 0      |
| от 10 до 11 мм | 9                  | 0.24   | от 24 до 25 мм | 0                   | 0      |
| от 11 до 12 мм | 1                  | 0.03   | от 25 до 26 мм | 1                   | 0.03   |
| от 12 до 13 мм | 3                  | 0.08   |               |                     |        |

Figure 2 shows the distribution of the length value, l, of stress-corrosion cracks in the body of the steel pipe. The values above the bars of the diagram correspond to the number of cracks which length is equal to the value below the bar of the diagram.

**Figure 2. The distribution of the stress-corrosion crack length, l, in the body of the steel pipe.**

It follows from these data that:
- More than 46% of stress-corrosion cracks in the body of the steel pipe have a length l < 1 mm;
- More than half (50.7%) of stress-corrosion cracks in the body of the steel pipe have a length, l, from 1 mm to 6 mm;
- An insignificant part (less than 3%) of stress-corrosion cracks in the body of the steel pipe has a length, l, from 6 mm to 26 mm.

Table 3 shows the measured values of the intervals dx (in mm) between stress-corrosion cracks in the body of the steel pipe (the total number of measured cracks (Ne) is 601).
Table 3. Intervals between stress-corrosion cracks in the body of the steel pipeline.

| Interval dx, mm | Number of cracks, N | N/Ne,% |
|-----------------|---------------------|--------|
| до 1 мм         | 255                 | 42.43  |
| от 1 до 2 мм    | 231                 | 38.44  |
| от 2 до 3 мм    | 84                  | 13.98  |
| от 3 до 4 мм    | 24                  | 3.99   |
| от 4 до 5 мм    | 7                   | 1.16   |

Figure 3 shows the distribution of the intervals dx (in mm) between stress-corrosion cracks in the body of the steel pipe. The values above the bars of the diagram correspond to the number of cracks, the interval between which is equal to the value below the bar of the diagram.

It follows from these data that:
- More than 42% of stress-corrosion cracks in the body of the steel pipe are located within an interval dx not exceeding 1 mm;
- More than half (more than 52%) of stress-corrosion cracks in the body of the steel pipe are located within an interval dx varying from 1 to 3 mm;
- An insignificant part (about 5%) of stress-corrosion cracks in the body of the steel pipe is located within an interval dx varying from 3 to 5 mm and more.

Based on the results of statistical studies concerning the group of natural stress-corrosion cracks, samples with groups of artificial defects (ADSs) were made from flat plates (material - structural steel 09G2S) using a milling method. The grooves (simulated cracks) were rectangular in shape and of equal width (cutter thickness was 0.2 mm) on one metal surface; individual cracks had a depth (h, mm) of 1 mm and 2 mm, respectively, groups of three cracks had the same depth equal to 1 mm. The design of a sample with groups of artificial defects, as well as its appearance are shown in Figures 4 and 5, respectively.
In the future, it is planned to investigate the possibility of identifying the spatial resolution of a group and determining the depth of stress-corrosion cracks in the body of a steel pipeline by means of eddy current testing. For this purpose, it is planned to investigate the fabricated samples with the help of eddy current flaw detector VD-12NFP using detachable eddy current transducers.

3. Conclusions
1. Statistical dependences of the length distribution (l, mm) of stress-corrosion cracks in a steel gas pipeline are obtained. From them, it follows that 46% of cracks have a length of $l < 1$ mm, 50.7% of cracks have a length, $l$, from 1 mm to 6 mm and less than 3% of cracks have a length, $l$, from 6 mm to 26 mm.

2. The statistical dependences for the distribution of intervals (dx, mm) of stress-corrosion cracks in the body of a steel gas pipeline between adjacent stress-corrosion cracks are obtained. It follows from those dependencies that more than 42% of cracks are located within an interval dx not exceeding 1 mm, more than 52% of cracks are located within an interval dx varying from 2 to 3 mm and about 5% of cracks are located within an interval dx changing from 3 to 5 mm and more.

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