Identification of the causes of non-uniformity of the condensate collector metal of the main gas pipeline

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Abstract. The complex of negative effects of hydrogen on metal, leading to destruction of metal structures, is commonly called hydrogen corrosion. The object of the study was a sample of steel A 516-55 condensate collector of the main gas pipeline, which was subjected to hydrogen stratification. The aim of the work was to establish a link between the non-uniformity of the metal and its tendency to hydrogen stratification. The work solved problems that were aimed at studying the physical and mechanical properties and microstructure of the analysed metal. X-ray fluorescence analysis was carried out to identify the causes of discontinuities within the metal. A light microscopy method was carried out to study the microstructure of the test sample taken from the focus zone of the condensate collector destruction. The microstructure was examined using the "METAM RV - 22 type EU LOMO metallographic microscope. An X-ray fluorescence analysis was carried out to determine the causes of the discontinuity within the metal. Tests were performed on a EDX-800HS spectrometer at various X-ray tube operations. It has been found that the inhomogeneities are due to the uneven distribution of manganese in the metal body.

1. Introduction
The problem of hydrogen embrittlement has been studied quite intensively for several decades due to the large role this process has on the strength and life of main gas pipelines. Hydrogen brittleness is caused by imperfections of the crystal lattice of metals [1-3]. The presence of hydrogen in the metal increases the brittleness of all metals without exception [4-7].

At the same time, two directions of research of the problem of hydrogen embrittlement can be noted: the first is connected with further study of fundamental foundations and disclosure of micromechanical systems and interaction of processes of hydrogen embrittlement and aging of metals; The second direction is related to the development of models and methods for prediction of kinetics of stress-strain state change and evaluation of durability of structures subjected to hydrogen embrittlement.

In the simplest case, the reaction of hydrogen with metal can be represented as a number of steps: adsorption, dissolution, diffusion, volume exit to the surface, desorption [8, 9]. Solubility is one of the most important characteristics, as the physicochemical perceptions of the mechanism of decarburization and hydrogen brittleness of steel are largely based on available data on the forms of hydrogen existence in metals, the mechanism of its dissolution, and the locations of hydrogen in the crystal lattice.
Hydrogen does not form chemical compounds (hydrides) with iron [10]. It causes increased strength and decreased fracture resistance, metal delamination and hydrogen bubble formation (blister). Hydrogen corrosion caused by molecular hydrogen and hydrogen corrosion caused by atomic hydrogen are distinguished.

2. Experimental procedures

2.1. Materials

The object of the study was a sample of steel A 516-55 condensate collector of the main gas pipeline subjected to hydrogen stratification, shown in figure 1. Samples were made to study the causes of stratification of the test metal. The sample subjected to the strongest stratification of 40x13x5 mm is shown in figure 1.

![Figure 1. Studied steel sample.](image)

Chemical composition of steel according to GOST 19282-73 is shown in table 1.

| C, %  | Si, %  | Mn, %  | Cr, %  | Cu, %  | P, %  | S, %  | N, %  | Ni, %  | As, %  |
|-------|--------|--------|--------|--------|-------|-------|-------|--------|--------|
| 0,12  | 0,5-0,8| 1,3-1,7| 0,3    | 0,3    | 0,035 | 0,04  | 0,008 | 0,3    | 0,08   |

2.2. Experiment Techniques

Hydrogen corrosion is a complex of negative effects of hydrogen on steel, resulting in destruction of metal structures. This type of corrosion does not occur on the boundary "metal-corrosion medium," but in the volume of metal [1]. Hydrogen accumulates in traps (vacancies, dislocations, grain boundaries, non-metallic inclusions). Segregation of carbon and other impurity atoms at grain boundaries enhances iron's ability to capture hydrogen. Atomic hydrogen from electrochemical reactions (hydrogen depolarization corrosion, cathodic protection, galvanic processes) penetrates the steel at normal temperature [2, 11-14]. In view of the above, the purpose of the work was to establish a link between the non-uniformity of the metal and its tendency to hydrogen stratification.

In order to achieve this goal, the following objectives were achieved: study of physical and mechanical properties and microstructure of the investigated metal; X-ray fluorescence analysis is performed to detect the causes of discontinuities within the metal.

A widespread method of light microscopy (often referred to as metallographic) was carried out to study the microstructure of the sample under study taken from the focus zone of condensate collector destruction. The plane of the sample was ground with GOI polishing paste, in which the main active substance is chromium oxide. Metal polishing was carried out by means of soft tweed to obtain absolutely smooth surface and mirror state. Then pickling with picric acid was carried out to create a relief and to detect the structure of the test sample. In etching, the acid primarily affects grain boundaries.

X-ray fluorescence analysis was performed to identify the causes of non-uniformity within the metal. The tests were performed on a spectrometer EDX-800HS figure 2.
3. The results of studies and their discussion

The microstructure was examined using the "METAM RV - 22 type EU LOMO metallographic microscope. The results are shown in figures 3 and 4, respectively.

Figures 3 and 4 show that the steel sample under study has a ferritic-pearlitic structure in which inhomogeneities are observed. The figures show that the ferritic-pearlitic structure has different perlite content at different measurement points.
X-ray fluorescence analysis was performed to identify the causes of non-uniformity within the metal. Various X-ray tube operations produced the various results shown in tables 2-3.

**Table 2.** Results of a research.

| Element | Result   | Standard deviation | Way of calculation | Line  |
|---------|----------|---------------------|--------------------|-------|
| Fe      | 98.19 %  | (0.114)             | Cal-FP             | FeKa  |
| Mn      | 2.12 %   | (0.016)             | Cal-FP             | MnKa  |
| Cu      | 0.13 %   | (0.008)             | Cal-FP             | CuKa  |
| V       | 0.06 %   | (0.005)             | Cal-FP             | VKa   |
| Ge      | 0.06 %   | (0.004)             | Cal-FP             | GeKa  |

X-ray fluorescence analysis revealed that irregularities within the alloy were due to the uneven distribution of manganese in the metal body. This is probably due to a disruption in the metal production process.

**Table 3.** Results of the X-ray fluorescent analysis.

| Measurement condition |
|-----------------------|
| Device: 800HS2        |
| Atmosphere: Air       |
| Rotation: It is switched off |

| Analyte | TG kv | mkA | FI | Time(s) | D. T. (%) |
|---------|-------|-----|----|---------|-----------|
| Na-Sc   | Rh 15 | 56-Auto | ---- | Live-100 | 25        |
| C-U     | Rh 50 | 8-Auto | ---- | Live-100 | 25        |

4. Conclusions
As a result of the work done, it has been shown that there are gaps in the composition of the metal. Gaps were revealed through microstructural analysis. A metallographic microscope revealed different perlite content in the metal structure. This can be explained by the fact that at the centre of the sample there is a liquor strip formed in the production of the steel sheet. X-ray fluorescence analysis revealed that the discontinuities were due to the uneven distribution of manganese in the metal body.

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