4.3.15. NANOLEVEL SYSTEM OF NON-DESTRUCTIVE DIAGNOSING OF ARTERIAL PIPE LINES

Deulin E.A., Bredikhin I.S., Petrosyan G.A.,
Bauman Moscow State Technical University, Moscow, Russia

The proposed method pertains to diagnostics of linear parts of gas distribution and trunk lines (LPGDTL). It is based on nanometer effects on the work surface of pipes.

The described technique is based on secondary ion mass spectrometry (SIMS) analysis. It used for taking recurrent measurements of hydrogen concentration in pipe wall material (or considered rubbing element) depending on dry wall friction of the gas traveling along the inner surface of the pipe wall [1, 2].

SIMS analysis allows taking measurements of concentration of dissolved gases including H2 and D2 with the accuracy of about 0.0001%, at the depth down to 1–10 μm.

The method of SIMS analysis helped us to predict [1] and investigate [2, 4] the role of dry friction in the process of hydrogen dissolution that raised the hydrogen concentration in steel up to catastrophically high level.

The diagram of the pipe wall hydrogenation with time is shown in Fig. 1. It is plotted taking into account the equation of an unsteady-state diffusion (the second Fick's law) [3] expressed with the formula (1).

$$C_H(x,t) = (C_{surfH} - C_i)\left[1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)\right] + C_i.$$

The novelty of the proposed diagnostics technique includes the following:

1) the hydrogen concentration in pipe wall material is analyzed recurrently during preventative maintenance using SIMS method for analysis of hydrogen concentration in a gas-main pipeline through the pipe wall thickness. The results of the SIMS analysis are used for multipurpose analysis and forecast of survivability of LPGDTL after computer processing of collected data;

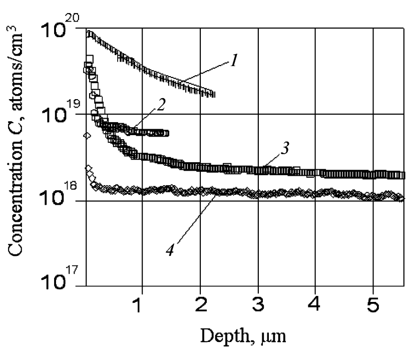

Fig. 1. The results of hydrogen concentration C_H (*x*) distribution through the depth *X* = 0.005-5.00 μm in the different specimens from a gas pipeline after 20 years of operation. The measurements on the fig.1 have taken on the various depth of the pipe:
1 – 15 mm, 2 – 20 mm, 3 – 25 mm, 4 – 30 mm

2) the studied specimens made of the same steel as the pipe wall with overall dimensions of 2×10×10 mm are placed where the result of specimen hydrogenating corresponds with the pipe wall. Hydrogenating caused by dry friction of the gas traveling along the inner surface of the pipe wall. Such places of LPGDTL are found near compressor stations and other devices subjected to preventative maintenance that allows the recurrent SIMS analysis of the check specimens.

The diagnostics technique has been chosen is such a way that allows accurate chemical analysis and taking measurements of hydrogen concentration through the pipe wall thickness at strictly defined penetration depths measured from the work surface of the pipe wall. SIMS analysis of a chemical composition of the check specimens and a dissolved gases concentration there is implemented with a thin ion beam (Ø 100 – 200 nm) that creates a cylindrical "well" in a studied material step by step to the depth of X = 1 – 10 μm. The chemical analysis is performed through this depth. SIMS analysis of the check specimen to the depth of X = 5 – 10 μm takes 2.5 – 8 working hours.

The disadvantage of SIMS analysis is that it provides only qualitative estimates. The following process sequence was developed taking into account the above features of SIMS analysis.

The proposed pipe wall diagnostics technique allows taking 50 – 200 consequent analyses during 20 – 30 years of pipeline operating time. It ensures the accurate predictive analysis of the pipeline properties and reliability

The advantage of the method described above is the ability of the SIMS analysis method to fulfill the detection of hydrogen concentration distribution in the sample at the depth 5 – 10 microns and at short time 2 – 8 hours. The method being described is based on the periodical information about «hydrogen illness» process and state of linear parts of pipe lines.

The opportunities and advantages of the described method are:

1. An opportunity to fulfill with the highest accuracy the dissolute gases analysis with help of SIMS method.
2. Overcome the depth limitations of SIMS method in the range of the analysis depth about 1 – 10 μm and to ensure the depth of SIMS analysis at 1 – 30 mm.
3. To ensure non-destructive diagnosing method with the period about 1 – 3 months.

References:

1. **Deulin E.A.** Exchange of gases at friction in vacuum. In ECASIA. 1997. Göteborg, Sweden: John Wiley & Sons.
2. **Deulin E.A. and Nevshoupa R.A.** Deuterium penetration into the bulk of a steel ball of a ball bearing due to its rotation in vacuum. Applied Surface Science, 1999. 144–145: p. 283 – 286.
3. **Бокштейн Б.С.** Диффузия в металлах. 1978, Москва: Металлургия. 248 с. In Russian.
4. **Деулин Е.А.** et al., Исследование причин появления "водородной болезни" в материале труб магистральных газопроводов и разработка вакуумных методов их устранения. Конверсия в машиностроении, 2007. 82(3): p. 32 – 36. In Russian.