АССОЦИАЦИЯ
СПЕКТР-ГРУПП
МОСКВА

NANOLEVEL SYSTEM OF NON-DESTRUCTIVE DIAGNOSING OF ARTERIAL PIPE LINES

Evgenii A. Deulin
Bauman Moscow State Technical University,
bldg. 5, 2nd Baumanskaya St., Moscow, 105005,
Russian Federation

Abstract

The presented diagnosing method of non-destructive arterial pipe lines is based on SIMS analysis usage that experimentally allows to detect the dissolved hydrogen concentration increasing
at a depth of 1 … 20 mm in the pipe wall after any period of operation. The hydrogen is being dissolved in the pipe wall from a gas flow component in result of friction process on nano scale level.

I. INTRODUCTION

It was presumed, that the gas flow is accompanied with a process of gas dissolution in a pipe wall material of a gas-main pipeline, according to the theory [1]. It was experimentally shown with SIMS analysis [6], that the concentration of dissolved hydrogen increases in 100 … 300 times at a depth of 1 … 20 mm after 20 year of pipeline operation due to this process.
The presented paper is devoted to the new method of gas-main pipeline diagnosis. Other methods used at present time include the following:
1) an ultrasonic flaw detection [8];
2) a method of electromagnetic acoustic analysis of a pipe wall material [4];
3) a method of electrometric inspection of pipe material [10];
4) a method of radiographic flaw inspection of a pipe wall [9];
5) methods of radiographic, chemical and spectral analysis of a pipe wall material [5, 11].
All methods listed in clauses 1 through 4 are nondestructive diagnostic techniques, and meet the requirements to diagnostic method. Though interpretation of diagnosis results remains to be a complex problem as before. But we have showed, that results of SIMS analysis can be used to predict a gas-main pipeline destruction caused by hydrogen illness. Hydrogen dissolution in the wall of the gas pipeline is caused by dry wall friction
of the gas traveling near the surface of the pipe wall [1, 2, 7]. The gas flow allows making an adequate estimate of hydrogen dissolution in a material of pipeline wall [6]
.

II. BASICS OF THE METHOD

A. Theoretical Footing

The purpose of this work is study of corrosive and "hydrogen illness" of gas-main pipeline pipes. The experiments implemented using "CAMECA-4" installation show, that the developed method of pipe protection can limit hydrogen and deuterium dissolution. The theoretical treatment of hydrogen (deuterium) dissolution process is based on the idea, that it is similar to penetration
of these gases via metal surfaces caused by dry wall friction of the gas flow [8].

Methodology Aspects

An "in-situ" method of study of H and D dissolution in the pipe walls is discussed taking into account the significance of the gas-main pipe life cycle diagnosis problem. SIMS method provides opportunities that can be utilized in the proposed device.
It is well known [3], that SIMS analysis allows taking measurements of concentration of dissolved gases including H2 and D2 with the accuracy of about 0.0001%, at a depth down to 1 … 10 μm.
The method of SIMS analysis helped the author before to predict [1] and then discover [2, 7] the role of dry friction in the process of hydrogen dissolution that raised the hydrogen concentration in steel up to catastrophically high level.
The aims of the proposed method are following:
1) application of the high-accuracy SIMS method to analysis of the dissolved gases;
2) overcoming 1 … 10 μm limitation of depth of the SIMS method and ensuring 1 … 30 mm depth SIMS analysis
of a pipe wall;
3) implementing a nondestructive inspection with the invented diagnostic technique;
4) ensuring reliability of scheduled nondestructive inspections of a gas-main pipeline implemented every 1-3 months;
5) creating an opportunity for a nondestructive inspection of gas-main pipelines in the zones, where the pipe condition is analyzed by pipe wall samples cut from a typical pipeline operated at the same conditions. Such zones correspond to pump stations where the samples are cut during routine maintenance;
6) conversion of the qualitative results of SIMS analysis into quantative values.
The following technique of the invented diagnostic method was designated to meet the above listed requirements:
1) a representative sample of the pipe is chosen to ensure reliability of SIMS analysis of the pipe wall material;
2) the original sample is cut into "elements" for SIMS analysis according to a layout shown in Fig. 1. The proposed layout takes into account difference between the depth of SIMS analysis (x1 = 1 … 10 μm) and the thickness of the pipe wall (x2 = 1 … 30 mm);
3) the results of SIMS analysis are converted from qualitative form into quantative values by means of ion implantation of H and D in analyzed samples;
4) the analyses are implemented periodically to accumulate empirical data about diffusion of hydrogen into the gas-main pipeline pipe wall material.

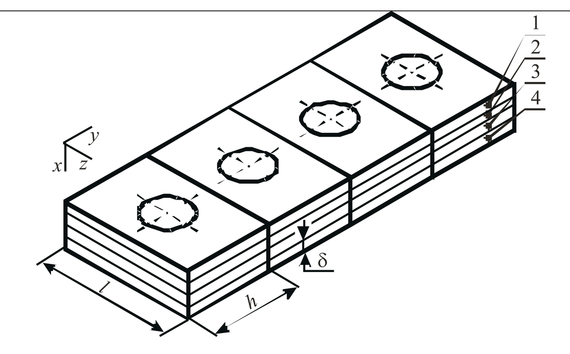

Fig. 1. A layout for cutting the original sample into "elements" for SIMS analysis. Element numbers increase starting from the outer surface of the pipe.

The collected data show, that the hydrogen concentration varies in different samples of the pipe wall.
The sample element number being cutted from the original sample, Fig.1 corresponds to the surface distanse from the inner tube wall being contacting with the moving gas flow (4-near inner tube wall, 1- near outer tube wall).
The measured hydrogen concentration would satisfy the analytical expression (1):

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

, where CH is a hydrogen concentration through the wall thickness; CsurfH is a hydrogen original concentration on the work surface of the pipe wall; Ci is an initial hydrogen concentration in the metal lattice; D is a diffusion constant; x is a distance from the surface of the pipe wall; t is operating time.

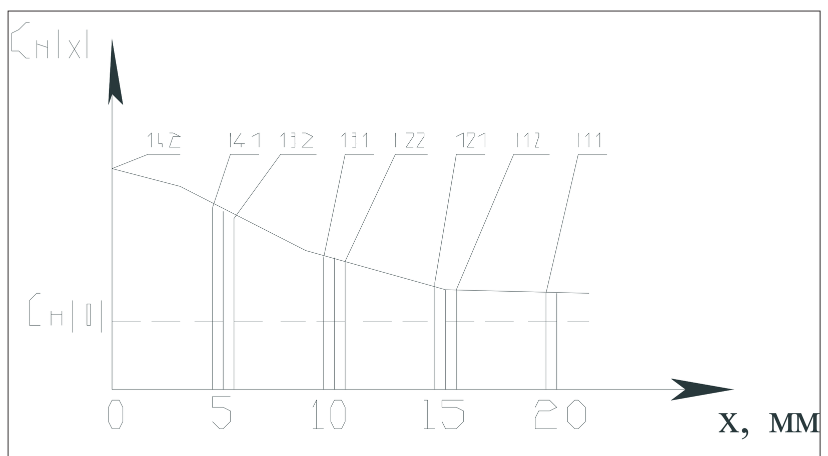

Fig. 2. The graph of the theoretically calculated hydrogen concentration distribution in the tube wall according equation (1)

The Fig.2 shows, that the theoretically hydrogen concentration in the sample №1 after 20 year period of the tube work close to the original hydrogen concentration CsurfH in the material of the pipe tube. From the another side Fig.2 shows, that the hydrogen concentration in the sample № 4 after 20 year service according equation(1) must be increased more then 300 times, because of distance x close to 0.

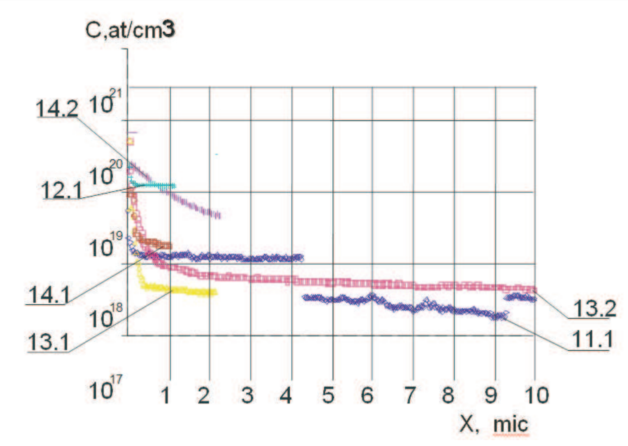

Fig. 3 The experimen6tal results of the hydrogen concentration distributions into the different "elements" of the sample after it's cutting into "elements" after 20 years service period of the pipe line tube. Element's symbols correspond to the Fig1 and 2 symbols.

The Fig.3 shows, the quantative results of the hydrogen concentration distributions in the "elements" of the sample at different distances x, from inner tube's wall which symbols correspond to Fig.1 and 2. All graphs of the CH concentration distributions at the depth x=0-0,5mic. (left parts of the graphs) show the distribution rise to x=0 becouse the hydrogen increased dissolution in the near surface material of the "elements" at the process of " original sample" cutting process into "elements".
The right parts of the same graphs correspond to the hydrogen concentration after its penetration after service period on the distance x=0,1- 20 mm from the inner surface of the pipe line tube.

I. PRIMARY RESULTS

The opportunities provided with the method of SIMS analysis are utilized in the device designed by authors to clarify the characteristic properties of mechanically stimulated dissolution process and to facilitate further research and development of a gas-main pipeline pipe protection against hydrogen dissolution and "hydrogen illness" of oil and gas pipelines
.

ACKNOWLEDGMENT

The authors want to express their heartfelt gratitude
to Ministry of Science and Education of Russian Federation for support and kind assistance in Contract П24-21 in work on this paper and to engineer E Tkacheva for her fine experimental results.

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 R.A. Nevshoupa, 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] Science & Metrology Solutions. IMS 7f High performance universal magnetic sector SIMS [cited; Advertising materials]. Available from: www.cameca.com.
[4] Алёшин, Н.П. and Г.Г. Чернышов, eds. Сварка. Резка. Контроль. Справочник. Vol. 1, 2. 2004, Машиностроение: Москва. In Russian.
[5] Антипов, А.И. and О.И. Стеклов, Определение времени безотказной работы сварных соединений трубопроводов при воздействии на них коррозионно-активной среды. Сварочное производство, 1972(8): p. 10-11. In Russian.
[6] 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.
[7] Деулин, Е.А., et al., Механически-стимулированные процессы диссоциации сорбированной тяжелой воды (D2O) и растворения дейтерия
в нержавеющей стали. Вакуумная Техника и Технология, 2003. 13(3): p. 17-22. In Russian.
[8] Ермолов, И.Н., Н.П. Алёшин, and А.И. Потапов, Акустические методы контроля Неразрушающий контроль. 1991, Москва: Высшая школа. 283 с. In Russian.
[9] Контроль неразрушающий. Соединения сварные. Радиографический метод. in ГОСТ 7512-82. 1983, Издательство стандартов. In Russian.
[10] Методика проведения электрометрического обследования подземных коммуникаций промплощадок. 2000, ВНИИСТ-ВНИИГАЗ: Москва. p. 40. In Russian.
[11] Новые методы оценки сопротивления материалов хрупкому разрушению. 1972, Москва: "Мир". 439 с. In Russian.

Contacts: e-mail: deulin@bmstu.ru