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ESTIMATION OF GAS AND OIL PIPELINES CONDITION BASED ON THE METHOD OF METAL MAGNETIC MEMORY

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Abstract

Ageing of oil- and gas-trunk pipelines places the task of their functioning safety and reliability assurance in the list of the most important state problems. At present the general length of trunk pipelines in Russia is over 300 thousand kilometers. And about 40 % of gas pipelines and 60% of oil pipelines have been in operation for more than 20 years.

The accident rate analysis shows that already after 15 years of operation the intensity of pipelines failures starts growing abruptly. Thus, practically all trunk pipeline systems nowadays require performing of diagnostic investigations and recovery repairs. It should be noted that the conditions of the pipeline metal operation are particularly specific and differ from operation in other steel structures by the whole number of factors.

The article considers the abilities of the method of metal magnetic memory (MMM method) to estimate stress-strained state (SSS) of gas and oil pipelines directly on equipment and to trace the development of metal fatigue failure process in these zones. Based on 100% equipment inspection using the MMM method it is suggested to detect all potentially dangerous zones with developing defects and to timely remove them during the repairs. Thus, an opportunity is offered to assess the real equipment life.

Keywords: non-destructive testing, metal magnetic memory, pipeline, stress concentration, stress-strained state.

Introduction

A number of outer flaw detecting scanners was developed and manufactured on the instructions of GAZPROM JSC during the period of 2004-2006 for application at diagnostics of gas pipelines in the course of re-isolation and other repair works.

Multi-channel scanning devices (SD) for large-diameter (530÷1420 mm) pipes inspection by the metal magnetic memory method supplied as a set with the TSC-type instruments (Tester of Stress Concentration) were developed for the same purpose.

According to ISO 24497-1:2007 (E) t**he method of metal magnetic memory** (MMM method) – is a non-destructive testing method based on the analysis of self-magnetic leakage field (SMLF) distribution on components' surfaces for determination of stress concentration zones (SCZs), imperfections and heterogeneity of metal structures and welded joints.

Self-magnetic leakage field (SMLF) is a magnetic-leakage field occurring on the component's surface in the zones of stable slip bands of dislocations under operational or residual stresses or in the zones of strong material microstructure heterogeneity.

Reading of **SMLF** provides a unique possibility to integrally assess in the quick testing mode the actual equipments state taking into account structural inhomogeneity, distribution of residual stresses and macrodefects.

1. A specific features of the MMM method and its ability to assess gas and oil pipelines condition by special scanning devices.

At present Energodiagnostika Co. Ltd. uses three types of multi-channel SD for large-diameter (530÷1420 mm) pipes inspection by the metal magnetic memory method:

- with full coverage of the entire pipe diameter and with the number of the magnetic field measurement channels from 24 to 32;
- with half-perimeter coverage of the pipe (up to 24 measurement channels);
- with partial pipe coverage on the perimeter length of 300-400 mm (12 measurement channels).

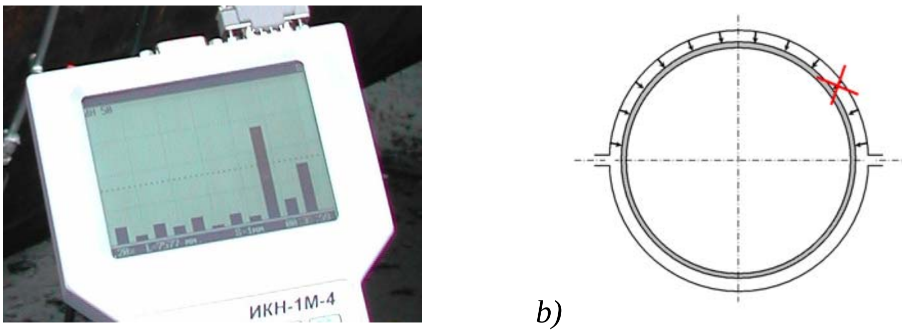
When these SDs are used, the inspection of the entire pipe surface can be carried out at an average scanning speed of 10 m/min. At the same time isolation removal and pipe surface dressing are not required. The method uses natural magnetization of the metal formed in the course of operation (the magnetic memory of metal). A flaw detecting scanner represents a device consisting of two rings, being attached to each other, on which from 24 to 32 flux-gate sensors are installed. These sensors are integrated with the wheels allowing the operator to move the SD quickly along the pipeline. Papers [1, 2] present the general view of the SD covering the entire pipe perimeter. SDs with partial coverage of the pipe surface along its perimeter gained wide practical application. The SC with 12 measurement channels of the magnetic field for inspection of the most damaged pipe area, located near the longitudinal weld at a distance of 200-300 mm to different sides of the weld, can serve as an example of this.

The operator moves the scanner along the outer pipe surface using a distance bar. The operator can be directly on the pipe or near the pipe (at a distance of 5-6 m), walking together with another operator, who watches the inspection results on the screen of the specialized TSC-type instrument (Tester of Stress Concentration, Certificate of the Russian Technical Regulation body RU.C.34.003.A No.22257). The scanning device can be used as a set with a laptop-based instrument.

The basic diagnostic parameter during the inspection of the outer surface of pipes using the MMM method is the gradient dH_p/dx of the magnetic field intensity (or the intensity of its variation), which is recorded in the zones of developing defects occurring due to stresses and strains concentration. While assessing the state of the pipeline metal, it is necessary to know the limiting field gradient, corresponding to the ultimate strength of the metal. These limiting values are determined in the course of industrial and laboratory investigations. From the positions of fracture mechanics, meeting the limiting state by the metal does not depend on the type of defect causing this state. It is characterized by the integral diagnostic parameter – the density of the mechanical and, accordingly, the magnetic energy on the surface and in the volume of the pipe body [3].

The magnetic field gradient, detected automatically in the course of scanning, is displayed on the instrument screen as columns with binding to the number of the sensor on the scanning device (see fig.1, *a*) as soon as it crosses the defected zone.

When the limiting gradient of the field, set up beforehand at the instrument adjustment, is exceeded on any of the measurement channels, the operator stops, saves this zone in the instrument memory and tells another operator to make the corresponding mark in the logbook or directly on the pipe surface (see fig.1, *b*).



a) *b)*

Fig.1. *Display of inspection results on the screen of the instrument (a) when the scanning device moves along the pipe surface and marking of the defected zone in the pipe logbook (b).*

The Methodical Guideline (MG) on carrying out the inspection of large-diameter (∅530÷1420 mm) pipelines using the specialized scanning devices were developed. This MG specifies the limiting field gradients for the above mentioned diameters of pipes. These gradients characterize the limiting state of the metal by the strength conditions, as well as the initial development of cracks.

The existing experience in inspection using the metal magnetic memory method, the TSC-type instruments and the scanning devices, which do not require any pipe surface preparation, demonstrates the following: pipes, located on the same gas pipeline segment and being in the long-time operation under identical conditions, are in a distinctly different state. If in the course of the inspection no magnetic anomalies are displayed on the screen, it indicates that the pipe metal's state is satisfactory and there are no developing defects on it. At that the inspection speed is not higher than 2 min per 10 m of the pipe length. In case the zones with the magnetic field gradient value higher than the limiting values are detected, all these zones are marked in the pipe logbook according to the described above technique. Then the qualifying inspection using the eddy-current instruments and UFD is carried out in these zones.

It is appropriate to carry out the described above diagnostics of pipes using the scanning devices in the field or factory conditions during the planned replacement of insulation, on open above-ground pipeline segments, during grading of used pipes, as well as before laying of new pipes into trenches.

2. Results of gas and oil pipelines testing by the MMM method and appropriate scanning devices.

In 2005 experts of Energodiagnostika Co. Ltd. carried out inspection in winter route conditions of 1695 pipes (∅1020×11mm), operated on the segment of 141-170 km of the Parabel-Kuzbass gas-main pipeline, and 1796 (∅1020 mm) pipes, with thickness of 9,5 and 10,5 mm on the foundry-production section (FPS) in Urga. In 2006 the same method way applied at various objects of Tomsktransgaz Co. Ltd. for inspection of about 3000 pipes with the diameter of 1020 and 1220 mm. The pipes had been in operation for 20 years and longer.

The pipes, on which no unacceptable defects and stress concentration zones – SCZs (the sources of damages) – were detected, were accepted as ready for further operation. The wall thickness of these pipes was within the acceptable limits.

The pipes with the limiting gradient of the magnetic field *dH/dx* in SCZs, containing various defects (pits on the internal and external surface, lamination of the metal, mechanical damages, etc.) and wall thinning in individual zones by more than 15÷20% were considered as unsuitable for further operation.

As an example, fig.2 and 3 show the magnetograms, characterizing various states of the metal of individual pipes. The magnetogram, shown in fig.2, characterizes the unsatisfactory metal's state of the pipe #46n. On this pipe in the zone, where the values of the leakage field gradient *dH/dx* are higher than 15×10^3A/m^2, the developing defects in the form of corrosion pits were detected. Fig.3 shows the magnetogram, characterizing the satisfactory metal's state of the pipe #22n.

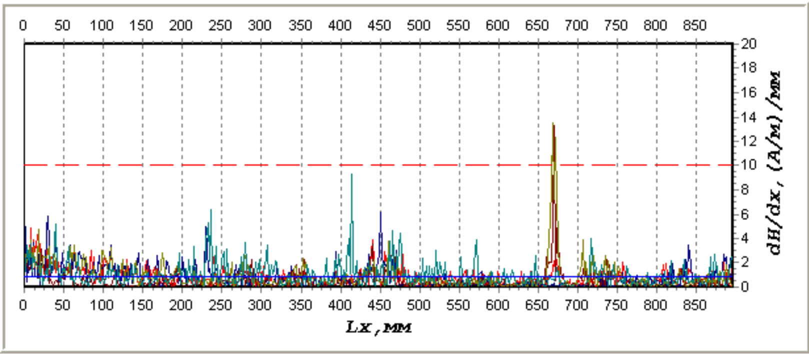


Fig.2. *The inspection results of the pipe #46n with pit-like defects (141-170 km of the Parabel-Kuzbass GMP).*

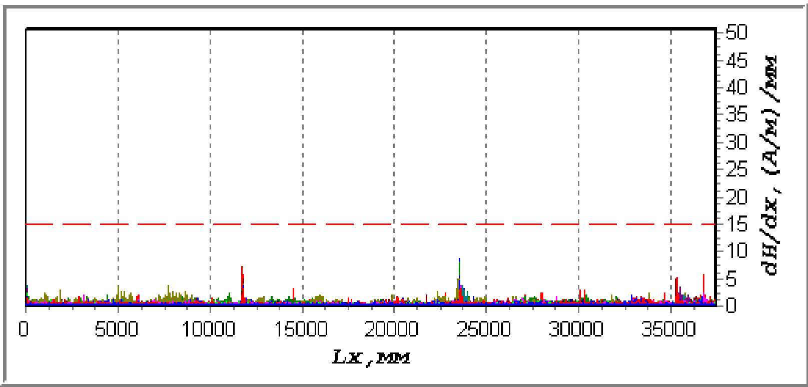


Fig.3. *The inspection results of the defect-free pipe #22n (141-170 km of the Parabel-Kuzbass GMP).*

It should be noted that on the above mentioned objects the inspection was carried out with application of the described above scanning devices without removal of the old insulation and without any pipe surface preparation.

In the course of inspection in route conditions 1131 (about 70%) of the inspected 1695 pipes were accepted as ready for re-operation. The obtained results of the quick inspection without insulation removal were further confirmed by other NDT methods after the pipes were cleaned in the course of their laying and re-insulation.

Application of SDs and instruments by the metal magnetic memory method provides the opportunity to present the results of the quick inspection in the pipe layout logbook. Fig.4 shows the distribution of stress concentration zones (SCZs) with the field gradient value $dH_p/dx \geq 5.0\times10^3$ A/m^2. This pipe layout was obtained based on the computer processing of the inspection results using the "MMM-System" program after transferring to the PC of the data saved in the TSC instrument memory. In fig.4 the isolines of the field gradient with the field value of $\geq 5.0\times10^3$ A/m^2 are outlined with thick lines, corresponding to the boundaries of the defected zones.

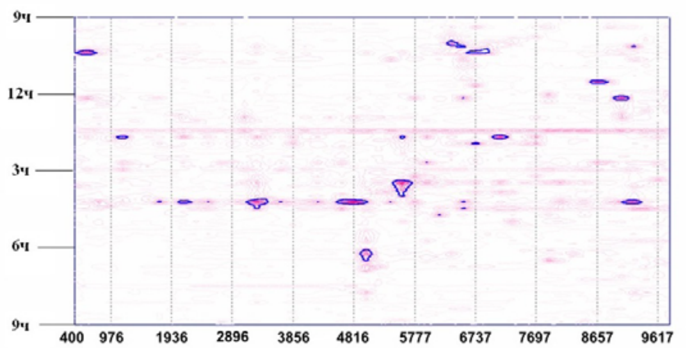


Fig.4. *Distribution of SCZs with maximum values of the H_p field gradient (dH_p/dx) on the layout of the pipe # 7321 (∅1020×12mm).*

3. Conclusion

In conclusion the following should be noted.

At present in the experimental-industrial operation of GAZPROM JSC enterprises there is already a diversity of flaw-detecting scanners by different companies. These devices use magnetic (with artificial magnetization), eddy-current and ultrasonic methods of inspection. However, to our opinion, at scanners certification the commissions of GAZPROM JSC pay insufficient attention to the most important question – **classification of recorded signals by types of defects and processing of inspection results with binding to the pipe layout**. Exactly the inspection results and their objectivity, i.e. their correspondence to actual defects, should be the basic factor when the effectiveness of various flaw-detecting scanners is compared. This is especially important because till date no standard and classification of signals by the defect type and size exist for any of the inspection types (magnetic, eddy-current, and ultrasonic) for the base metal of gas pipelines!

Based on the great experience in gas- and oil pipelines diagnostics using the metal magnetic memory method Energodiagnostika Co. Ltd. possesses such classification of defects by the parameters of the measured magnetic field and its gradient. Further they have to be normalized.

While carrying out the diagnostic works on gas- and oil pipelines during their re-insulation and performing of other repair works with the purpose of their acceptance for further operation during a long period, to our opinion, it is necessary, besides the ordinary flaw detection, to carry out the inspection of the pipes' stress-strain state (SSS) with detection of SCZs, being the potential sources of damages.

It is also necessary to carry out the inspection of pipelines' SSS Контроль in connection with putting in operation of the corresponding Russian and International standards. In 2005 based on the International standard ISO 9712 and the European normative documents the RSNDTTD introduced a new type of inspection – "Stress Control" – for the base metal and welded joints. Besides, a new national standard of Russia GOST R 52330-2005 «Non-destructive testing. Stressed-strained state test on industrial objects and transport. General requirements» was put in operation in 2005.

As it is known, the MMM method and the appropriate TSC-type inspection instruments simultaneously perform two tasks:

- inspection of pipelines' SSS with detection of SCZs (early diagnostics of damages);
- detection of already existing defects.

Application of the MMM method provides the possibility to carry out the assessment of the degree of the defect's hazard and to answer the question: "Is the defect developing or not?" Such an approach is of principal significance as well at carrying out the engineering diagnostics for risks evaluation during gas- and oil pipelines operation.

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