Non-Contact Magnetometric Diagnostics of Welded Joints of Main Gas Pipelines Susceptible to Sudden Failures

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Abstract. Currently, OJSC Gazprom pays great attention to ensuring the reliability of field welded joints of main gas pipelines (MG), both during the construction of new pipelines and in conditions of their overhaul. However, a significant number of main gas pipelines with girth welds, produced during installation, is in the long-term use (30 years and longer). Field welds are usually produced in the process of voltage welding of “closing” gas pipeline ends. Therefore, such welded joints with high level of residual stresses have a greater potential energy released in the process of their failure. The article considers non-contact magnetometric diagnostics (NCMD) of potentially hazardous MG joints susceptible to sudden failures.

Currently, OJSC Gazprom pays great attention to ensuring the reliability of field welded joints of main gas pipelines (MG), both during the construction of new pipelines and in conditions of their overhaul [1].

However, a significant number of MG with girth welds, produced during installation, is in the long-term use (30 years and longer). It is known that field girth welded joints on the MG are considerably less reliable than the factory joints. It is also known that, compared to the present period of time, 30-40 years ago methods and devices for non-destructive testing of field welded joints were not sufficiently developed. In the course of special studies during the quality control of field welded joints after the long-term MG use, unacceptable defects, both in accordance with the old and the new rejection standards are often found [2].

In addition, individual field welded joints have high level of residual stresses formed during their fabrication. Therefore, sudden failures periodically occur on MG operated for a long time. And such failures often occur on pipelines both in Russia and in other countries.

For example, failure of a buried gas pipeline with a diameter of 500 mm under pressure of 12 MPa occurred in the gas system of Poland in January 2014. Gas explosion and subsequent fire destroyed the nearby houses and other structures. Accident investigation revealed that the source of the gas pipeline failure was the field girth weld (Figure 1). At the time of the accident the gas pipeline was in operation for more than 40 years. This information was received by “Energodiagnostyka” company (Poland) employees who inspected similar pipelines in 2011 under an agreement with the Polish gas company “Gaz-System”.

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Buried gas pipeline sections were inspected by the non-contact magnetometric method using highly sensitive sensors and TSC-3M-12 instruments manufactured by Energodiagnostika Co. Ltd. (Moscow).

The experience of such inspection in combination with subsequent additional gas pipelines inspection in prospect holes by the metal magnetic memory (MMM) and ultrasonic method is presented below.

Total of 24 km of Polish company “Gaz-System” underground pipeline sections were inspected in the non-contact mode. Based on the results of non-contact magnetometric diagnostics (NCMD), the Customer was recommended to drill 10 prospect holes in zones of maximum anomalies.

In November-December 2013 Energodiagnostika company experts (Moscow and Warsaw) carried out an additional inspection of gas pipelines in prospect holes. After opening of underground gas pipeline section in all zones with identified before magnetic anomalies, based on NCMD results, field girth welded joints. Additional inspection of shells and field welded joints was carried out by the MMM method and ultrasonic testing.

According to the integrated inspection results, the state of gas pipeline metal shells after 40 years of their operation was satisfactory under the existing standards, but in 8 of 10 field butt welds the MMM method detected zones with significant stress concentration (SCZs), in which the ultrasonic method detected unacceptable defects, as a rule, in the form of poor penetration in the weld root and across weld areas with the pipe base metal.

![Fig. 1. Failure of field girth welded joint on the ∅ 500 mm gas pipeline after 40 years of operation.](image1.jpg)

**Fig. 2.** Magnetogram of non-contact inspection of the gas pipeline section: A – anomaly A022 corresponding to a welded joint with high level of stress concentration.
Figure 3 shows a fragment of the magnetogram recorded during the inspection in the non-contact mode of one of the considered gas pipeline sections. In accordance with the used technique, the magnetic anomaly \( A \), marked in figure 2, characterizes the girth welded joint location site.

Figure 3 shows the place of “trenching” (opening) of the gas pipeline section with detected magnetic anomaly \( A \).

Visual and measuring inspection of this section showed the satisfactory condition of the gas pipeline shell metal. However, the inspection of the field girth welded joint by the MMM method detected a zone with considerable distribution non-uniformity of the magnetic field and its gradient \( (dH/dx) \). Ultrasonic testing (UT) was additionally carried out in areas of maximum magnetic field gradient values corresponding to maximum stress concentration zones. Based on the results of UT in the SCZ detected by the MMM method, unacceptable defects in the form of discontinuity flaws located at different depths of the welded joint were found. Similar magnetograms with anomalies characterizing the high stress concentration were detected in prospect holes on 8 of 10 inspected field girth welds.

Unacceptable defects, which obviously occurred at the time of butt joints welding during gas pipelines installation, create high stress concentration in local areas of potential damages.

Here it should be noted that, according to a rough estimate, the 24 km length of gas pipelines inspected by the non-contact magnetometric method contained about 800 field girth welded joints. Only 10 areas with detected magnetic anomalies, characterizing the maximum stress concentration on girth welded joints, were recommended for opening. This makes only 1.0 to 1.2% of total number of field butt joints.

The experience of inspecting a large number of field girth welded joints on MG after the long-term operation using the MMM method is described in paper [2], which reflects the experience of 100% inspection of 12 km of 1020 mm diameter pipes on the “Parabel-Kuzbass” MG and 25 km of 720 mm diameter pipes on the “Ugra-Novosibirsk” MG.

The inspection of the above mentioned sections was performed during the MG overhaul. Using the specialized scanning devices, the MMM method in the quick control mode detected SCZs both in the pipe base metal and in girth welded joints. Then an
additional inspection by the ultrasonic and eddy-current methods was carried out in individual zones with maximum stress concentration.

The results of this integrated inspection of LLC “Tomsktransgaz” MG also showed that the number of field girth welded joints with unacceptably high levels of stress concentration makes a small percentage of the total number of inspected welded joints. It is important to know the MG sections with location of butt joints susceptible to sudden failures.

A number of papers [3, 4] noted many times the necessity of MG stress-strain state (SSS) control. However, till date the MG SSS control is not performed in the general practice, both in operating conditions and during their overhaul. It is known that in-pipe diagnostics of MG is aimed at detection of developed defects. At present there are no in-pipe flaw detectors for SSS control. During gas pipelines overhauls with insulation replacement inspection of residual stresses (RS) in the welded joints is not carried out either, despite the existing problems of damaging in welding heat affected zones (HAZ) and in local stress concentration zones of the weld metal.

To assess gas pipelines condition in local stress concentration zones using the MMM method, a guidance document GD 51-1–98 [5], approved by OJSC Gazprom and admitted for practical use, was put into effect as far back as in 1998. During the period from 1998 to the present time, the technique described in this GD was extensively tested in practice. LLC “Gazprom transgaz Tomsk” and LLC “Gazprom dobycha Urengoy” have the most significant experience of its application during quick sorting of used gas pipelines by fit and unfit, during compressor stations process piping state assessment and during determination of potentially hazardous stress-corrosion pipeline sections.

During the inspection of MG field girth welded joints at the time of their repair (in the prospect holes after NCMD or for the purpose of MG re-insulation) it is recommended to use the “Technique for operated MG girth welded joints inspection by the MMM method”. In 2008 the technique was agreed with the Department of Gas Transportation, Underground Storage and Utilization and was tested in practical work. The technique allows to detect SCZs – sources of developing damages – on welded joints in the quick control mode.

Regulatory documents [6, 7] on pipelines NCMD based on the MMM method are also currently available. Paper [8] presents the experience of NCMD of pipelines buried under a soil layer at a depth of 2-3 m or deeper. The main objective of all diagnostic methods and means during the assessment of continuously operated oil and gas pipelines is the search for and detection of potentially hazardous areas with developing damages. The inspection results must answer the question: “Where and when to expect damages or accident?” If such a problem is solved, then the possibility of timely replacement or repair of a potentially hazardous area is provided.

Unfortunately, the widespread technology of oil and gas pipelines in-pipe inspection currently does not allow to control their SSS and to detect the areas with the highest stress concentration in the base metal and welded joints. In addition, a considerable part of gas pipelines (about 50%) is not inspected by in-pipe flaw detectors due to their unsuitability for this kind of inspection.

In absence of an alternative to NCMD in determining the most stressed gas pipeline sections susceptible to damaging, its wider practical application seems appropriate. The significant experience in application of NCMD (about 15 years) and the MMM method (about 25 years) allows stating the principal possibility to solve the problem of searching and detection of potentially hazardous gas pipeline sections in the quick control mode. At present the greatest efficiency of NCMD application is achieved during detection of the most stressed field girth welded joints on gas pipelines.
References