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METAL MAGNETIC MEMORY METHOD USED FOR ANALYZING HIGH-PRESSURE GAS PIPELINES

1. INTRODUCTION

One of the most significant issues recently discussed by gas companies is the usability of alternative methods for diagnosing gas pipelines.

Pursuant to Regulation [1], the high pressure gas pipelines of diameter equal to or exceeding DN200 should be adjusted to pigging operations. In the case of newly construed high-pressure natural gas pipelines of diameter equal to or exceeding DN 400 should be designed with armature needed for fixing pig launchers. Another requirement is the zero pigging in the case of high-pressure gas pipelines of diameter DN 500 and larger prior to putting on stream. The transmission network is diversified and frequently the pipelines are not adjusted to pigging operations. Moreover, there are gas pipelines of diameter under DN200.

2. HOW ABOUT UNPIGGABLE GAS PIPELINES?

There are two options:

1) Adjust gas pipelines to pigging, which is connected with the replacement of elbow pipes, adjustment of armature and pig launcher utilities.
2) Alternative solutions, e.g. acoustic emission method (AE) or metal magnetic memory method (MMM method).

In the first case the cost is relatively high, reaching up to 80% of the cost of a new section of the gas pipeline. The inability to inspect the pipeline with the pigging device is

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connected with its life and period of exploitation. Frequently construing a new gas pipeline turns out to be more advantageous than adjusting a section of an old pipeline.

In the second case the metal magnetic memory method is of interest. This method belongs to passive non-invasive inspection methods. It is based on registering and analyzing own distributed magnetic fields generated on products and devices in the zones where stress concentrates. The MMM method makes use of the natural magnetization effect assuming the form of magnetic memory of metal when actual deformations take place, and causing structural changes in metal products and devices.

The development of the MMM method started in 1977 with the discovery of the phenomenon of self-magnetization of boiler pipes in the place of their failure. After many years of preliminary studies, in 1990 this method started to be implemented on a large scale first in power industry, then also in other branches. The first guidelines and control methods were also issued at that time. This method was worked out and implemented by a Russian scientist prof. A.A. Dubov and now is used in many countries all over the world. In 2008 and 2009 the standards specifying the conditions of measurements with the MMM method were introduced in Poland.

The gas pipelines are investigated with the MMM method in two stages.

STAGE I

Non-Contact Magnetometric Diagnostics (NCMD) lies in a walking inspection of the pipeline. In the NCMD, magnetic parameters worked out in the MMM method on the basis of standard PN-ISO 24497-1:3 [2] are used. As a result the localizations of the observed anomalous Stress Concentration Zones (SCZ) are obtained (Figs. 1, 2).

The NCMD method makes use of magnetic parameters defined according to standard [2]:

– vectors of measured magnetic field (*Hx*, *Hy*, *Hz*),
– derivative of vectors of measured magnetic field *dHp*/*dx*.

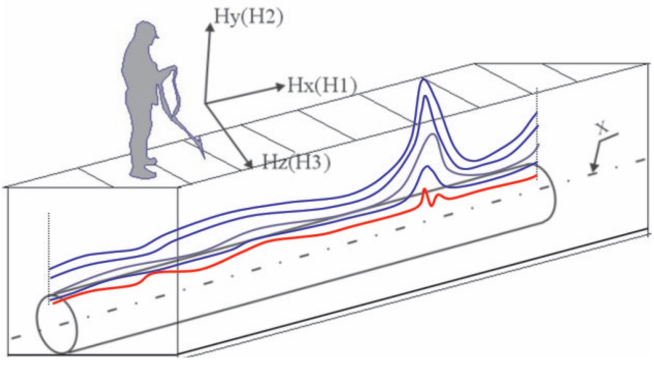


Fig. 1. Schematic of measurements performed with the NCMD method [3]

Fig. 2. NCMD measurement on the gas pipeline [2]

The character of change of measured field (*Hz* frequency, amplitude) depends on the deformation of the pipeline under the influence of technological and mounting stress, working loads, and stresses caused by self-compensation of the pipeline when the temperature changes and when the ground displaces.

Three types of SCZ were identified in the course of NCMD [3]:

Type I – numerous zones of stress and failure concentrations in the analyzed pipeline section. Zones classified as group I will have to undergo respective obligatory earth works. In the future the earth works on the analyzed pipeline section and SCZ will allow for a direct evaluation of the technical condition, on the basis of which the state of the pipeline mantle can be classified (whether or not a given pipeline section needs to be replaced, or the pipeline refurbished).

Type II – single zones of stress concentration in a given section of the pipeline. Section classified as type II will undergo optional earth works. Periodical monitoring (12 to 60 months from the date of the last inspection) of the pipeline section may be recommended if no earth works were performed.

Type III – zones to be monitored in a period of 60 to 84 months from the date of the last inspection, non-invasive for the further operation of the pipeline.

An example of device used for NCMD is a highly specialized sensitive twelve-channel scanning device with integrated three-component flux-gate transducers and analogue-digital converter (Fig. 3). It is designed for non-contact magnetometric diagnostics of gas- and oil-pipelines being buried at the depth of 2–3 m. The scanning device is manufactured in the form of a telescopic bar with a rod for mounting of four three-component sensors. The rod length and the distance between the sensors depend on the diameter of the inspected pipe. The scanning device mounted on the road measuring wheel.

Fig. 3. Scanning device Type 11-12W [5]

STAGE II

At this stage the earth works are performed and SCZ (selected at stage I with the use of MMM method) are investigated and referred to ultrasonic measurements.

The following diagnostic operations are performed:

– visual assessment of the condition of the pipeline insulation,
– measurements with the MMM method to reveal the stress concentration zones,
– visual evaluation of detected stress concentration zones after the insulation was removed,
– analysis with the MMM method of the pipeline mantle and possibly welds, after the insulation was removed,
– ultrasonic tests – Ultrasonic Thickness Testing (UTT) of the pipeline mantle,
– ultrasonic Tests (UT) – analysis of welded connections.

The measurements performed on the opencast are performed with the use of devices presented in Figure 4. This type of scanning device with eight flux-gate transducers in their two-component installation for simultaneous measuring of the normal (*Hpy*) and tangential (*Hpx*) components of the magnetic field is designed for inspection of pipelines, vessels and extended welded joints. It is manufactured in form of a 4-wheel trolley with four flux-gate transducers and a length-counting device. It is possible to inspect the objects on distance of 2–5 m at the use of a specialized extension rode. It is used with TSC-7M-16 device (Fig. 5).

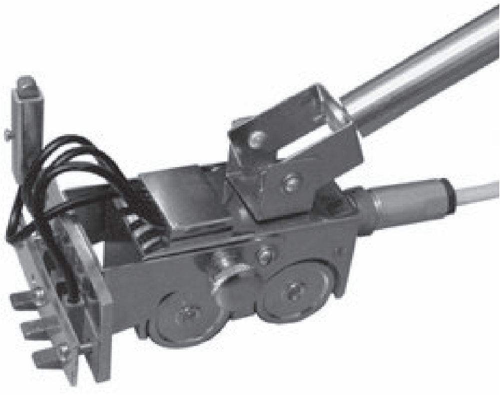


Fig. 4. Scanning device Type 1-8M [5]

Fig. 5. Tester of Stress Concentration TSC-7M-16 [5]

Signals are processed by the MMM System – program for data processing by the metal magnetic memory method (Fig. 6).

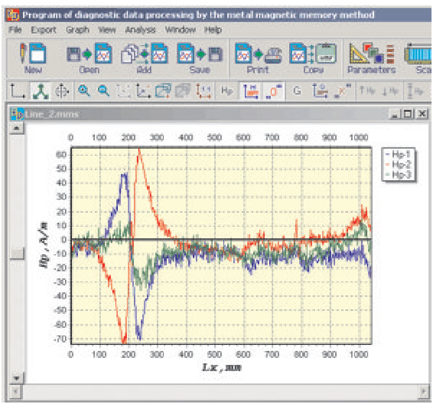


Fig. 6. Software „MMM-System" version 3.0 [5]

"MMM-System" allows simultaneous processing of several hundreds of residual magnetization distribution graphs. Diagram plotting parameters are controlled. Using the residual magnetization distribution graphs (*Hp*-graphs) the program is able to automatically plot graphs of distribution of the *Hp* function differentials and gradient (*dH*/*dx*, *dH*/*dz*, |grad *Hp*| – graphs), characterizing the level of stress concentration, and using them, according to the inspection technique, to determine the limiting stress concentration zones (damage development zones).

The measurement data are analyzed in view of occurrence of the stress concentration zones. In the case of zones of highest stress concentration index the ultrasonic tests (UT) are performed.

3. ANALYSIS OF DETECTED FAILURES

GAZ-SYSTEM S.A. has diagnosed pipelines with the MMM method for a few years. The first measurements with this method were performed in 2011 on a pipeline section DN 400 PN 6.3 MPa Oświęcim-Komorowice. In 2014 a 10 km pipeline section DN 400 PN 5.4 MPa, DN 500 PN 5.4 MPa Odolanów-Adamów, and a 12 km pipeline DN 100 PN 6.3 Tomkowice-Bolków were diagnosed.

As a result of the NCMD measurements there were selected SCZ sites for recommended earth works. The welded connections in the open parts of the pipeline were evaluated on the basis of “STO Gazprom 2-2.4-083-2006 Guidelines for non-invasive methods of assessing the condition of welded connections while performing and refurbishing gas pipelines”.

Failures in the butt welded connections were localized within this diagnosis.

a) b)

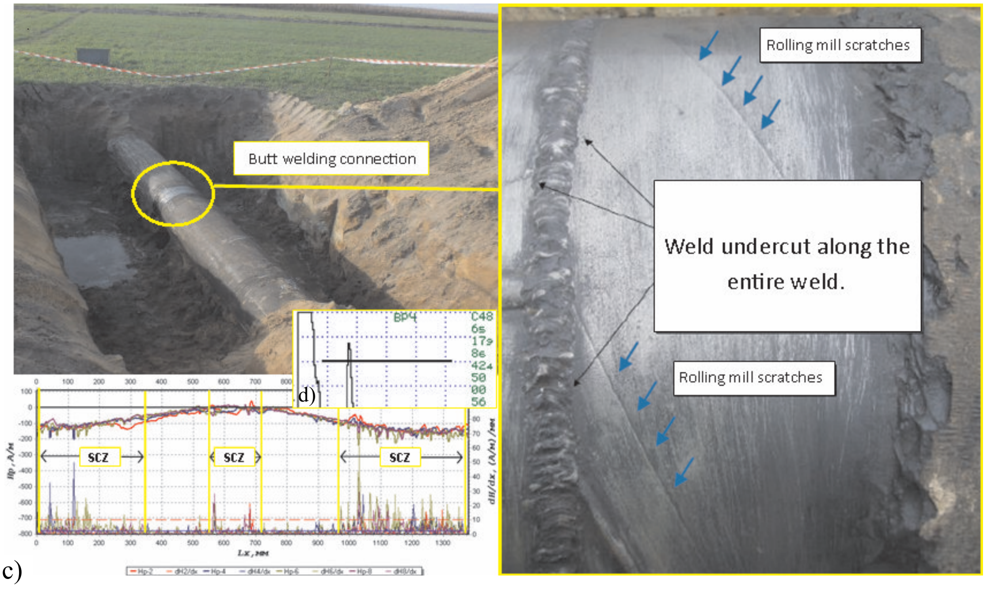
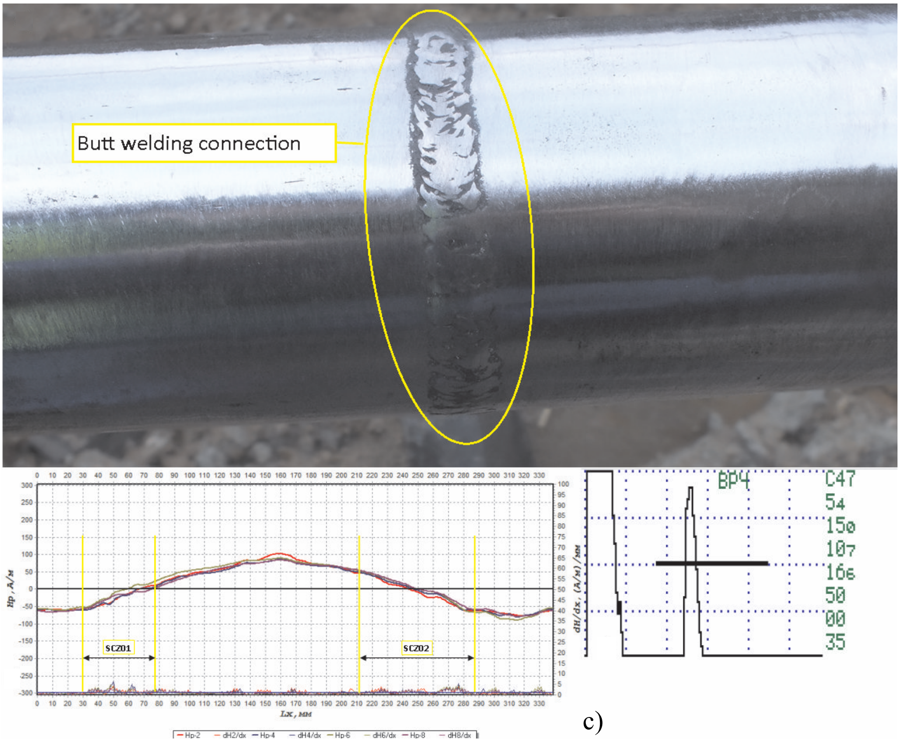


Fig. 7. Uncovered gas pipeline in the anomalous area (a). Weld undercut along the entire weld and deformations of material due to sheets rolling (b). Distribution of magnetic field with indicated areas of SCZ (zones of stress concentration) registered on the butt weld. SCZ are about 300 and 800 mm long. Undercuts are visible on the whole length of the butt weld, disqualifying the weld for further exploitation (c). Confirmed presence of discontinuities in the SCZ with ultrasonic testing (UT) – in both instances of SCZ the discontinuity in the weld on the whole length – confirmed lack of undercuts in the weld (d). Minimum thickness of the mantle measured in areas of removed insulation in the earth works site B2 equaled to 7.9 to 8.0 mm

a)



b) c)

Fig. 8. Butt welding in the earth works area (a). Distribution of magnetic field with indicated SCZ01, SCZ02 (zones of stress concentration) registered on the butt welding. The SCZ01 is about 50 mm long, SCZ02 about 80 mm long (b). Confirmed discontinuity in the area of SCZ01, SCZ02 with ultrasonic testing (UT) method at 1.5 to 2.6 mm depth (c) [6]

Above examples of detected failures presented in photos (Figs. 7, 8) in the form of weld undercuts are a significant part of the detected stress concentration zones. Another group of failures is connected with insulation losses (Fig. 9).

a) b)

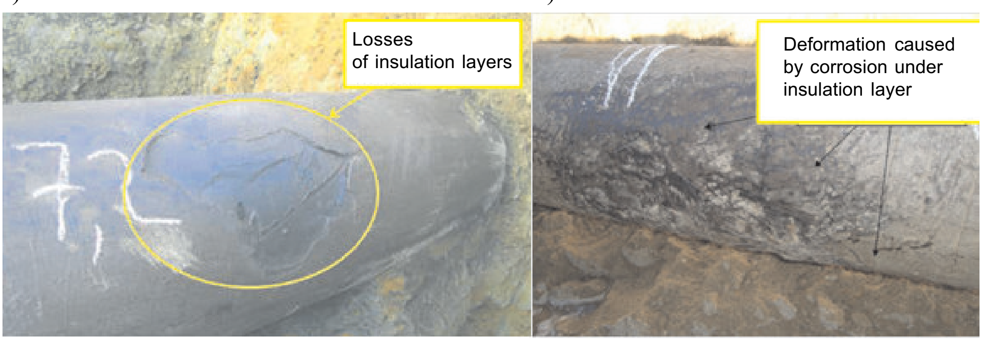


Fig. 9. Exemplary losses and deformations of insulation layers (a, b) [7, 4]

After removing the insulation cover we can see pitting sites presented in Figure 10. The pittings were up to 5 mm of diameter and 0.5 do 2 mm of depth.

a) b)

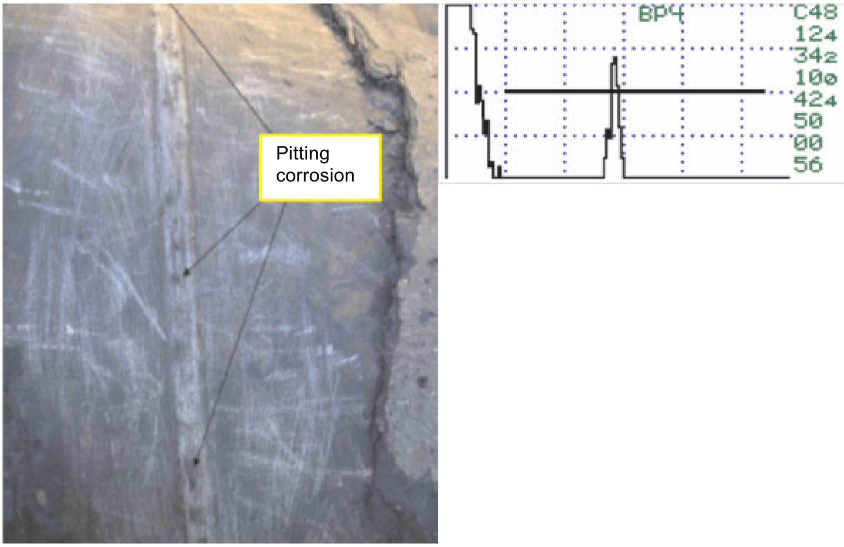


Fig. 10. Uncovered gas pipeline within the anomaly zone. Pittings up to 5 mm of diameter and 0.5 to 2 mm of depth (a). Discontinuity confirmed with ultrasonic testing method – discontinuity in the weld on 300 mm in the SCZ. Minimum thickness of the mantle measured in the zones of removed insulation along the earth works A3 was 7.7 to 7.9 mm (b) [4]

In a majority of cases the measurements confirm the presence of SCZ on the analyzed pipeline. However, sometimes during the earth works the SCZ were also discovered on other objects, e.g. insulator pipes, other pipelines (Fig. 11) or metal objects (Fig. 12). An example of the latter is a metal rod undug at ca. 200 mm depth during earth works on SCZ of pipeline DN100.

Fig. 11. Metal bar detected during the tests [6]

Fig. 12. Crossing pipelines [3]

4. CONCLUDING REMARKS

The use of Metal Magnetic Memory, especially the Non-Contact Magnetometric Diagnosis methods is a very interesting solution as far as the inspection of gas pipelines is concerned. This method is commonly used for diagnosing pipelines (where pigging is not possible) in Europe and worldwide. The magnetometric methods are used by such companies as, e.g. Gazprom, Shell or British Gas.

The performed measurements confirm their efficiency to detect SCZ and failures on the pipelines. Creating a standard of test results assessment (under construction) is another step at normalizing the tests with the MMM method. The measurements are mainly conducted on gas pipelines, where no pigging operations can be performed. Gas industry has seen a growing interest in this type of methods for their efficiency, applicability of NCMD method without performing earth works, and as an alternative for the prediction methods.

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