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WYKORZYSTANIE POŁĄCZONYCH METOD DCVG/CIPS/MTM DO OCENY STANU GAZOCIĄGU I JEGO POWŁOKI

USING COMBINED DCVG/CIPS/MTM SURVEY TO ASSESS CONDITION OF PIPELINE AND IT'S INSULTION

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Streszczenie

Ocena stanu rurociągów, na których nie jest możliwe zastosowanie inteligentnych tłoków do dziś pozostaje wyzwaniem dla operatorów rurociągów. Szeroko stosowane techniki badań DCVG i CIPS zorientowane są na kontrole stanu powłoki izolacyjnej i nie dostarczają informacji o stanie ścianek rurociągu. Metody te nie pozwalają także na wykrycie odspojenia katodowego izolacji. W ciągu ostatnich lat w przemyśle metoda tomografii magnetycznej zyskała legitymizację. Oparta na zjawisku odwróconej magnetostrykcji technika MTM określa naprężenia odcinków rurociągu poprzez pomiar zmian pola magnetycznego. Jako efektywną metodę kompleksowej oceny stanu rurociągów nienadających się do badań inteligentnym tłokiem, autorzy proponują przeprowadzenie połączonych badań DCVG/CIPS/MTM.

Summary

Integrity management of non-piggable pipelines up to now remains as an essential challenge for all Operators. Widely applicable aboveground survey techniques such as DCVG and CIPS alone, targeted at evaluation of pipeline coating integrity and CP effectiveness, do not entirely determine the integrity of non-piggable pipelines. Furthermore, these methods have limitation – they are not intrinsically sensitive to coating disbondment. In the meantime, over the last years Magnetic Tomography Method went through extensive industrial validation. Based on the converse magnetostrictive effect, MTM defines stress characteristics of pipe sections by registering changes in the magnetic field of the pipeline. As an effective instrument for comprehensive integrity assessment of non-piggable pipelines, authors propose to perform combined DCVG/CIPS/MTM survey.

1. DCVG/CIPS Survey

Nowadays multiple options exist for aboveground surveys to identify areas of disbonded coating on pipelines using AC or DC principles. These coating assessment techniques tend to fall into two main categories:

- voltage gradient techniques based on the principle of impressing an alternating (Pearson and ACVG) or direct (DCVG) current between the pipe and the earth, and then detecting high potential drop in the neighborhood of a coating holiday;
- AC current attenuation techniques based on the principle of an electrical current attenuation which is applied to a coated buried pipeline. Its magnitude decreases gradually as it travels away from the injection point. When a discontinuity is found in the coating of a buried pipeline the current attenuation changes abruptly because the dielectric constant of the coating has changed.

Results of the comprehensive evaluation and validation of existing aboveground techniques for coating condition assessment, carried out by various institutions (among others DNV GL) and presented in reports [for instance, 1, 2], pointed that DCVG was the most accurate survey technique, better able to resolve individual indications than the other surveys, enable to pinpoint a coating defect epicentre in the range of ±75 mm [3].

In DCVG, when a DC current is impressed onto a pipeline, there will be an associated voltage gradient surrounding the pipe. Well coated sections of line have a high pipeline to ground resistance. Hence, little or no current will flow to these sections and there will effectively no measurable voltage gradient in the surrounding soil. However, at sections which are bare or have defective coatings, the pipe-to-soil resistance is reduced. Consequently, there is a marked increase in current flowing to these sections of line resulting in voltage gradients around the bare or defective area. The larger the defect the lower the resistance and therefore the higher the voltage gradient for a given soil resistivity. Thus coating defects can be detected by measuring the potential between an over-the-line electrode and one laterally offset.

As a defect is approached it will be seen on the DCVG measuring tool as a changing potential which is in phase with the applied signal. The magnitude of the swing is the potential difference between probes as a result of applied signal. Operator then locates the epicentre of the defect which is identified by a zero deflection on the meter. This occurs when the probes straddle the epicentre of the defect i.e. lie on the equipotential line of the potential field of the defect. The operator then measures the potential from over the line to remote earth as well as the soil resistivity of adjacent earth.

According to [3] the DCVG signal strength should be adequate to enable the surveyor to detect small indications distant from the CP current source. Typical DCVG signal magnitudes measured to remote earth range between 100 and 1,500 mV in soil environments. In DCVG, CP interrupting cycle is set in accordance with manufacturer’s or operator’s procedures and typically is 0,7 sec ON and 0,3 sec OFF.

Indication pipe to remote earth DCVG signal magnitudes (P/RE) are calculated using equation (1):

$$P/RE = S_1 + \frac{d_x \cdot (S_1 - S_2)}{d_2 - d_1} \qquad (1)$$

where:

P/RE – pipe to remote earth DCVG signal magnitude (mV),

S_1 – DCVG signal amplitude to remote earth at Test Station 1 (mV),

S_2 – DCVG signal amplitude to remote earth at Test Station 2 (mV),

d_1 – distance measurement of Test Station 1 (This is zero at the beginning of a survey.) (m),

d_2 – distance measurement of Test Station 2 (m),

d_x – distance measurement of indication from Test Station 1 (m).

Once an indication is located, its severity index (%IR) is estimated by measuring the potential difference from the indication epicenter to remote earth (OL/RE). This potential difference is then expressed as a percentage of the total calculated potential shift on the pipeline at the indication location (P/RE), as shown in equation (2):

$$\%IR = \frac{OL/RE \cdot 100}{P/RE} \tag{2}$$

The following classification of the defects by the severity index was adopted:

- Category 1 – the defects with %IR above 35% needed to be repaired;
- Category 2 – the defects with %IR in range between 16 and 35% should be taken into consideration as possibly deserving repair;
- Category 3 – the defects with %IR under 15% are small and they do not need to be repaired.

To add value to the data collected during DCVG survey, attempts have been made to combine coating-fault location with CP pipe-to-soil potential measurements in DCVG/CIPS hybrid technique. The close interval potential survey (CIPS) alone is not classified as a coating assessment tool and rather is a cathodic protection system assessment tool, but data from CIPS is used in coating condition assessments. Modern digital data loggers allows to run DCVG and CIPS survey simultaneously during one pass along the pipeline route, as well as to detect defects/holidays in the pipeline coating and, most importantly, to measure the "ON" and "OFF" potentials along pipeline with step approximately 1 m, and at all defects epicentres. Thus, in addition hybrid DCVG/CIPS survey allows to determine whether the exposed pipeline wall is effectively protected by CP system.

In response to hybrid DCVG/CIPS survey, the CP criteria was adopted as a crucial factor for qualifying the defect as needed to be repaired. According to potential criteria included in the European Standard EN 12954 [4], the OFF potential near the defect epicentre more negative than:

- -0,85V for soil with resistivity less than 100 Ωm;
- -0,75V for soil by resistivity in the 100÷1000 Ωm range;
- -0,65V for soil resistivity higher than 1000 Ωm;

proves the effectiveness of applied cathodic protection system and coating defect despite high %IR (for instance, cat. 1) values does not need to be repaired.

DCVG and DCVG/CIPS hybrid techniques have number of limitations among which low sensitivity to coating disbondment, which is considered as one of the significant threats to integrity of pipelines. For instance, in Gazprom gas pipelines with tape coating make 70–80% of total length and 95% of large diameter pipelines. Lifetime of such coating lasts only 8–12 years and most of operating pipelines exceed this age.

2. MTM Survey

Magnetic Tomography Method (MTM) was developed in early 2000s and is patented in Russia, Malaysia, USA, and Canada. MTM is based on the inverse magnetostrictive effect (Villari effect) – the change of the magnetic susceptibility of a material when subjected to a mechanical stress. Method uses "natural" magnetization of the ferrous pipes by magnetic field of the Earth.

Magnetic tomography charts the attributes and characteristics of pipe sections by registering and analyzing changes in the magnetic field of the pipeline (Fig. 1). These changes are related to stress which in turn are related to defects in the metal. Magnetic measurements data is collected from the ground surface and anomalies detected are a function of stress, mechanical loading and structural changes in the metal.

MTM does not measure the dimensions of geometric defects alone but instead it measures the stress caused by these defects and identifies their character, location and orientation in accordance with the location and orientation of the stress concentration area. Linear and angular coordinates of flaws in the metal and coating are defined within a tolerance of +/-0,25m.

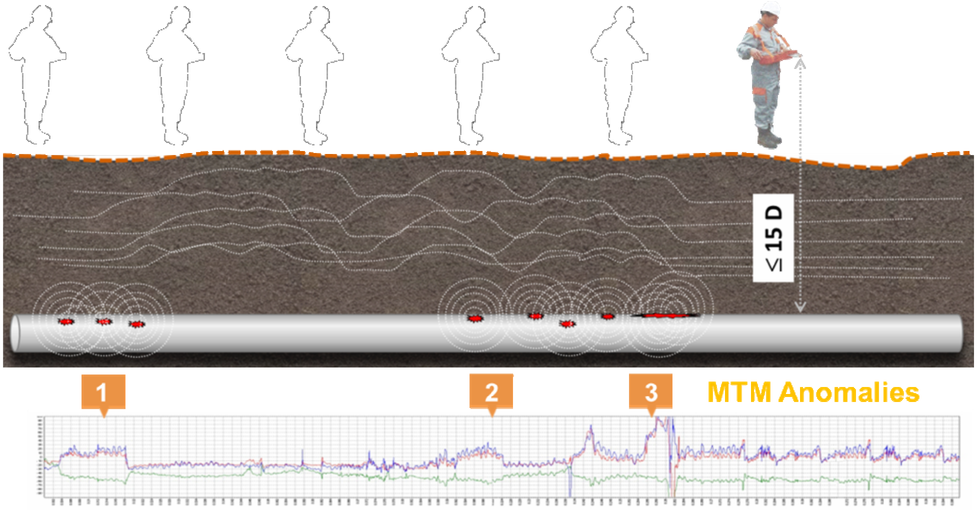

Fig. 1. MTM scanning process

MTM Identifies and analyzes magnetic field anomalies in areas with stress concentrators due to:

- Defects or changes in structural conditions (such as metal loss, cracks, dents, lamination and inclusions);
- Excessive mechanical stress caused by erosion, seismic activity, or third party damage;
- Combination of the above.

The significant advantage of the method is that MTM does not require any preparation of the pipeline for inspection such as cleaning, opening the pipe, or interrupting pipeline operation. Magnetic field measurements are performed while pipeline operating as usual.

Evolution of this method in Russia is mostly connected with introduction of RD 102-008-2002 [5] practical guidance, developed by VNIIST (Transneft research center) in early 2000s. The practical guidance describes remote megnetometric survey procedures, requirements for equipment and survey outcomes.

According to [5] magnetic anomalies assessment is performed based on integrity index F, corresponding to extension of magnetic anomaly S, m; amplitude and distribution structure of magnetic field vector. Integrated index F reflects exceedance of registered values over baseline; density of peak values and their distribution pattern. The index is derived from the following equation (3):

$$F=(F+1)e^{-ka}/S \quad (3)$$

where:

A – number of stress concentration lines in magnetic anomaly zone;

S – the length of magnetic anomaly, defined by number of measurement points of magnetic field (number of MTM scan intervals) m;

К – stress concentration ratio in magnetic anomaly zone;

a – coefficient , accounting for no-failure life, calculated based on following formula (4):

$$\alpha=\ln(P_{op}/P_d)/(T_s-T_c) \quad (4)$$

where:
Pop – operating pressure by the survey time;
Po – design pressure;
Ts – date of survey;
Tc – date of commissioning.

According to [5] MTM anomalies can be classified by three ranks depending on index F calculations as it is demonstrated in Tabl. 1.

Table 1. Magnetic anomalies classification according to index F

Index F	Anomaly Rank	Assessment
$0,75 \le F \le 1,0$	3	APPROPRIATE
$0,45 \le F < 0,75$	2	ALLOWABLE
$F < 0,45$	1	UNACCEPTABLE

Over the last years MTM survey technique went through extensive industrial validation on more than 17 000 km of Gazprom, Transneft, TNK-BP and Lukoil pipelines. Most remarkable were the results of branch pipeline "Kolomna-II" survey in 2014 [6]. This pipeline is operated by "Gazprom transgaz Moscow". On 2.3 km pipeline section 563 magnetic anomalies (stress concentration areas) were detected: 11 – 1st rank, 56 – 2nd rank, 496 – 3rd rank. Based on the MTM survey results operator has done 120 excavations and replaced 670 m of pipeline due to extensive corrosion damages (more than 50% of wall thickness).

Data obtained during the verification on "Kolomna-II" branch pipeline enabled to calculate statistical performance parameters listed in Table 2.

Table 2: Statistical MTM performance parameters on “Kolomna-II” branch pipeline (calculated through 120 excavations)

Performance parameter	1st rank anomaly	2nd rank anomaly
Probability of Detection POD	87%	85%
Probability of Identification POI	77%	75%
Probability of False Call POFC	9%	10.7%

Like any other technique, MTM has several limitations:

- Deviation if magnetometer when it far from pipeline (>15D);
- Deviation associated with residual over magnetization of pipeline due to production effects or ILI;
- Need 1-2 pits for calibration;
- Deviation generated by magnetic masses, located close to pipeline (<1D).

The most significant limitation is that MTM results in low accuracy for detecting pipe features with stress level less than 5% of the SMYS (e.g., pitting corrosion). The same pattern is observed when actual mechanical stress is more than SMYS. In addition it should be noted, that the method to the date remains as indicative, not allowing to evaluate absolute values of stresses in pipe wall in defect area, type of a defect and its dimensions, as well as significantly depend on proficiency of data interpreter.

3. Combined DCVG/CIPS/MTM Survey

Given above investigation of aboveground techniques and their inherent limitations bring AMT to present on market the combined survey technique – DCVG/CIPS/MTM – as an effective instrument for comprehensive integrity assessment of non-piggable pipelines. Combined DCVG/CIPS/MTM corrosion survey allows:

- To compensate limitations of each method (DCVG/CIPS and MTM);
- To evaluate coating and pipe integrity in one-pass;
- To conduct survey with same conditions (soil moisture, temperature, weather, etc.);
- To align data easily since all records are assigned to only linear reference system;
- To increase the confidence level of MTM data interpretation.

Corrosion survey process using combined DCVG/CIPS/MTM technique engages five main steps: design, operation and survey data gathering; DCVG/CIPS/MTM survey; direct assessment (excavations); FFP analysis; development of rehabilitation plan. Figure 2 illustrates a typical DCVG/CIPS/MTM survey process scheme, where five surveyors are involved.

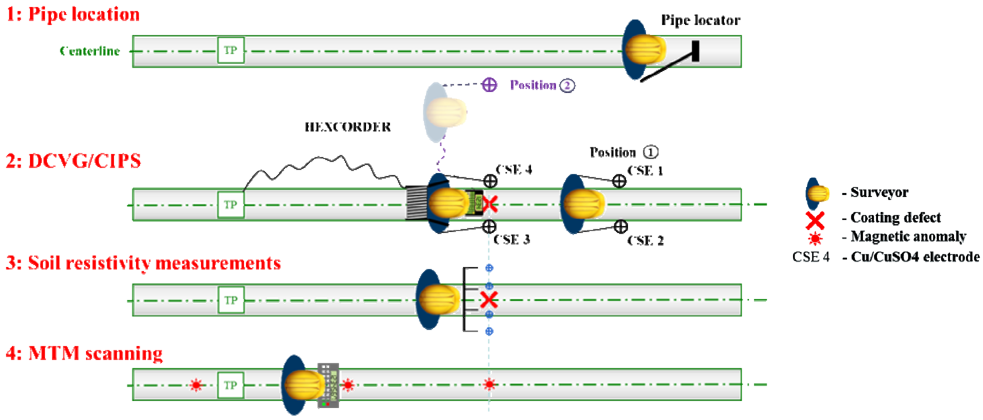

Fig. 2. Typical DCVG/CIPS/MTM survey process scheme

Excavation program for pipeline direct assessment is developed based on DCVG/CIPS/MTM measurements considering integral parameter K□, which is calculated by formula (5):

$$K_{\Sigma} = \sum G_i(l_i) \cdot \xi_i \tag{5}$$

where:

K_{Σ} – integral parameter – the sum of pipeline integrity factors;

$G_i(l_i)$ – value of i-factor;

ξ_i – weight coefficient of i-factor.

Integrity factors include coating condition, ground-water level, cyclic soils wetting, stress condition, type of soil, soil resistivity, CP effectiveness.

With confidence in the accuracy of the data generated by direct assessment procedure, an operator can go forward by utilising FFP methods (RSTRENG, DNV, ANSI/ASME B31g, STO Gazprom 2-2.3-112-2007, etc.) and make decisions relating to the current and future integrity of a pipeline, remaining life assessment.

Detailed consideration of DCVG/CIPS/MTM survey data enables to identify “hot-spots”, where appropriate preventative maintenance and inspection activities should be held (as it shown on Fig. 3).

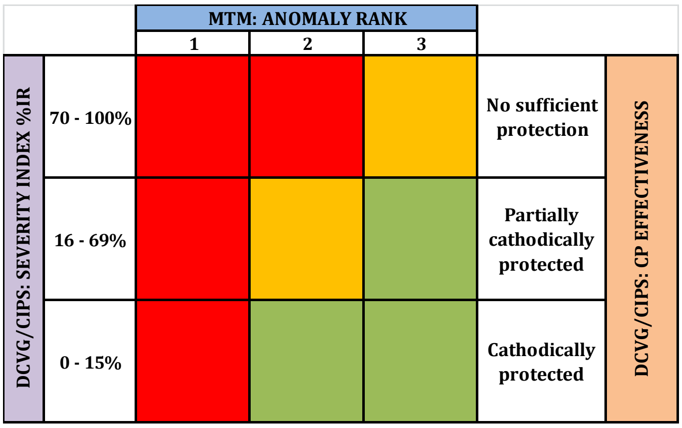

Fig. 3. Decision matrix for developing an effective pipeline rehabilitation plan

4. Conclusions

The preceding sections summarize experience of implementation DCVG/CIPS and MTM survey techniques in Russia, where multiline gas pipeline transmission systems with extensive CP system are operated. Over the last years these two survey techniques went through extensive industrial validation resulted in proved efficiency. However, inherent limitations disable implementation of DCVG/CIPS and MTM alone to determine entirely the integrity of non-piggable pipelines.

It became the result that AMT has presented on market the combined survey technique – DCVG/CIPS/MTM – as an effective instrument for comprehensive integrity assessment of non-piggable pipelines. The results that can be achieved from this combined technique are to:

- Compensate limitations of each method;
- Provide a qualified statement on the current condition and integrity;
- Identify active degradation mechanisms and assess probable causes of corrosion;
- Recommend appropriate corrosion mitigation and control strategies;
- Calculate remaining safe working life;
- Define effective integrity management plan (pipeline and/or coating).

For the moment, together with Gazprom the DCVG/CIPS/MTM method has been actively developed. By 2017, AMT expects that combined survey technique, as an effective instrument to maintain safety and reliability of assets, will be a part of integrity management plans of many Operators in Russia.

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