ASSUMPTIONS OF THE PROJECT "DEVELOPMENT OF NON-DESTRUCTIVE DIAGNOSIS OF GAS PIPELINES BASED ON A MAGNETIC NON-CONTACT MAGNETOMETRIC DIAGNOSTIC AND SENSORS INTEGRATED WITH THE USE OF MACHINE LEARNING ALGORITHMS" IMPLEMENTED AS PART OF THE INGA PROJECT

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Keywords: NCMD inspection; NDT; buried pipelines

Abstract:
The presentation presents the assumptions of the project "Development of non-destructive diagnosis of gas pipelines based on a magnetic non-contact magnetometric diagnostic and sensors integrated with the use of machine learning algorithms" implemented as part of the INGA project. The Warsaw University of Technology will be the scientific partner. The project will be implemented in 2019 - 2021. The aim of the project is to carry out R & D works as a result of which a technology will be developed for non-destructive diagnosis of gas pipelines based on non-contact magnetic method and sensors integrated with the use of machine learning algorithms. The employees of the Consortium Leader together with the Consortium Partner based on their experience and ongoing work in the field of technical diagnostics with non-destructive methods (NDT) and material research developed conceptual assumptions regarding the innovative service of non-destructive diagnosis of gas pipelines.

The scope of research and development works includes:
- determining the applicability of the MPM method depending on the test conditions and the development of specialized intelligent algorithms,
- material tests - identification of defects and damage to the structure and their impact on the measurement signal,
- development of construction monitoring technologies using the MPM-BDM method as well as integrated sensor networks and signal fusion
- development of specialized algorithms based on intelligent machine learning technologies and supporting research execution and monitoring of the transmission network
- long-term research with verification by NDT methods as well as microstructure and construction monitoring
- testing of selected sections of pipelines together with conducting analyzes and monitoring of critical zones
- determination of methods allowing testing pipelines running in casing pipes.

The target group of the project are primarily gas network operators, distributors and natural gas suppliers.
Assumptions of the project "Development of non-destructive technology of gas pipelines diagnosing based on the magnetic non-contact method as well as integrated sensors with the use of machine learning algorithms " implemented as part of the INGA project

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## Activity profile

### Advanced NDT

- Metallographic examinations
- Testing using the WIT method
- Magnetic Metal Memory (MPM)
- Non-contact Magnetic Diagnostics (BMD)
- Eddy current testing - testing of exchanger tubes (including ET Array)
- Eddy current testing of ET Array welds
- IRIS method tests - measurements of UT pipes from the inside
- Ultrasonic testing (PA, TOFD)

### Conventional nondestructive testing

- Magnetic Metal Memory (MPM)
- Visual testing (VT)
- Penetration testing (PT)
- Magnetic particle testing (MT)
- Ultrasonic testing (UT)
- Ultrasonic testing (UTT, 2-8mm, etc.)
- Measurements of oxides (inside pipes),
- Ferrite measurements

**Corrosion mapping - ultrasonic measurements UT Mapping**

### Assessment of technical condition of devices - evaluation of the possibility of further safe operation

### Support for maintenance services through the development of research methodologies and procedures - also in the scope of RBI
The issue of the assessment of the condition of the natural gas transmission network in Poland is extremely important from the point of view of the energy security of the country. Some sections of the transmission network are more than 30 years old. The risk of infrastructure failure increases with the aging of the transmission network. Extensive network failure creates the danger of a long-term interruption of supplies to individual and industrial customers of natural gas. Therefore, it is crucial to provide technical solutions allowing for a low-cost and reliable assessment of the transmission network status and its monitoring. This will significantly reduce the risk of breakdown and avoid high costs of exchanging segments of the transmission network.

Technically, the assessment of the state of unpiggable gas pipelines is a very difficult task. At present, one of the few methods present in the world that allows a qualitative assessment of the condition of the gas pipeline is the method of Magnetic Metal Memory. This method does not require expensive, preparatory earthworks and does not require the gas pipeline to be shut down.
MPM-BMD technology

MPM-BMD – Magnetic Metal Memory – Non Contact Magnetic Diagnostic

EXAMINATIONS OF BURIED PIPELINES using the MPM-BMD method allow to assess the technical condition of underground pipelines without digging them out.

The MPM BMD method as the only one at the moment allows in a relatively quick and non-invasive way to determine the condition of the buried pipeline and indicate places of stress concentration as well as micro and macro defects in the material of the pipeline.

The method is based on the study and analysis of distortions of the magnetic field of the Earth (Hx, y, z), caused by a change in the state of magnetization of the ferromagnetic material from which the pipeline is made. These changes occur in stress concentration zones (SKN) and in zones of developing corrosion-stress defects.

In addition, the pipeline working in variable conditions, i.e. change in temperature, humidity, soil movement, etc. and under the influence of technological and assembly stresses, work loads, self-compensations, etc., undergoes deformations, which affect the nature of the Earth's magnetic field (frequency of changes Hx, y, z, amplitudes Hx, y, z).
1. Detection of anomaly:

Non-invasive testing along the entire length of the pipeline along with determining its exact location. High-sensitivity transducer magnetometers are used for the tests. The result of the examination is the indication of magnetic anomalies.

2. Categorization of anomalies:

Analiza zebranych danych pozwala wskazać 3 kategorie anomalii magnetycznych. Od takich, które zaleca się monitorować, do takich w których należy przeprowadzić prace odkrywkowe.
3. Outcast works:

In the indicated places, earthworks are carried out to determine the sources of magnetic anomalies.

4. Fault identification:
In places of anomalies, earthworks are carried out to determine the sources of magnetic anomalies. A number of non-destructive testing methods (MPM, UT, ECA, UT Mapping, RT, PT) are used for testing of uncovered parts of the pipeline).
Advantages

- The MPM BMD method as the only one at the moment allows for a relatively quick and non-invasive way to determine the condition of the buried pipeline and indicate places of stress concentration as well as micro and macro defects in the pipeline structure.
- There is a correlation of anomaly categories with severity of defects and their size (the most serious defects are contained in Category I of anomalies).
- In the case of cyclic tests, it is possible to monitor the detected anomalies and determine the rate of their development.
- The method contributes significantly to increasing the safety of the pipeline being operated and to reducing the operating costs of these pipelines. Other research techniques require emptying and shutting down of the pipeline, which is expensive and time-consuming and in many cases impossible. The MPM-BMD tests give the possibility of securing defective sections and planning of repairs.
- In addition, during the tests, the exact route of the pipeline is determined.

The company Energodiagnostyka has over 20 years of experience in the field of MPM methods confirmed by appropriate certificates also in the MPM BMD method. Over 350 km of pipelines in Poland have been tested over the last 10 years.
Limitations

- It is not possible to examine fragments of pipes laid in casing pipes
- Evaluation of testing results requires high qualifications and extensive experience
- Diagnostic errors associated with unstable probe guidance during data acquisition may lead to difficulties in results assessing
- Possible interference from foreign elements, i.e. steel elements located within the pipeline under test, affecting the useful signal
"Development of non-destructive technology of gas pipelines diagnosing based on the magnetic non-contact method as well as integrated sensors with the use of machine learning algorithms"

The gas transmission market is constantly looking for solutions to control gas pipelines and - through technical condition studies - further increase in the security of transmission network operation and continuity of supply. This project is a response to the growing market demand.

The project is financed under Priority Axis IV "Increasing the scientific and research potential", Measure 4.1 "Research and development" Sub-measure 4.1.1 "Strategic research programs for the economy" Joint Undertaking of the Intelligent Development Operational Program for 2014-2020.
Project Objective: Carrying out R & D works, as a result of which the technology of non-destructive diagnosis of gas pipelines based on non-contact magnetic method and sensors integrated with the use of machine learning algorithms will be developed.

Effect of the project implementation: Development of an effective technology for diagnosing and monitoring the gas transmission network.
The necessity of using control methods is dictated by hazards that grow over time and are connected with the occurrence of damage:
- originating from welding or production defects
- stresses related to soil movements and causing the gas pipeline to move.
- increasing corrosion phenomenon (chemical, cavitation, stress, electrochemical, pitting caused by stray currents)

The problem is also the impact of cyclic processes (soil movements, pressure from vehicle traffic) on the development of damage.
The aim of R&D works is to search for solutions that will enable the diagnosis of gas pipelines based on non-contact magnetic method and sensors integrated with the use of machine learning and providing support to operators performing tests through:

1. The use of magnetic metal memory technology for non-contact diagnosis of gas pipelines;
2. Calibration and normalization of indications of the applied measurement technology for different testing conditions;
3. Development and validation during mechanical tests of construction monitoring methods using sensors integrated with the structure.
4. Verification of developed technology components during examinations on the site during long-term validation.
5. Development of the final technology of diagnosing and monitoring the construction of gas pipelines.

The project therefore envisages using the so-called hybrid diagnostic technology using non-destructive testing methods, modern methods of monitoring structures and objects with continuous measurement data registration.

Nobody has the solutions we offer today (signal fusion, sensor monitoring, database that helps to manage test results).
The proposed solution in the form of developed technology for monitoring and diagnosing structures is aimed not only at locating critical and endangered places, as it is the case with currently available methods, but also and continuously monitoring them in the case of critical identification of indications for the applied diagnostic method.
As part of the implemented project, the following innovative solutions will be developed in the field of non-destructive diagnostics:

- a measurement noise control system will be developed related to the stochastic positioning of the measuring sensor

- the maximum depth of the pipeline position will be determined, which may be subject to testing broken down by the diameter of the tested pipelines

- for the so-called open pit testing, the use of automated ultrasound testing with the possibility of depicting test results in the form of a map with very high resolution in the development of the mantle. Ensured repeatability and very high test accuracy through the use of automated multi-sensor head movement with continuous data recording
- the use of eddy currents testing in the open pits with the use of a dedicated multi-element head that allows to dimension localized discontinuities;

- verification and implementation of technology allowing for assessment of the technical condition of the pipeline in places not yet tested: a conduit pipe in the casing pipe on sections of road and railway culverts using surface elastic waves, which requires pipeline discoveries on both sides of the culvert;

- use of data fusion (multicriteria data analysis allowing to claim damage from several data sources). Data collected from various diagnostic methods will be analyzed and evaluated using specialized algorithms for signal analysis and inference by building a learning model.
Determining the possibility of diagnosing pipes in culverts

MPM BMD

Detection of anomalies

Categorization of anomalies

Outcrop

Damage identification

Critical damage monitoring

Statistical analysis, comparison of results, technical condition forecast

Detailed analysis of damage causes

Elimination of signal interference

Determining the maximum pipeline retention depth with a useful signal

Specialized algorithms for analyzing data supporting grouping and classification of indications
Thank you for your attention

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