WHITE PAPER

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Non-Contact Magnetometric (NCM) Inspection as an Alternative to In-line Inspection (ILI) for Steel Pipelines

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Abstract

The technology of complex non-contact magnetometric(NCM) inspection of pipelines offers an affordable and effective solution for evaluating the technical state of pipelines where in-line inspection is challenging or impossible.

This method is successfully applied on underground and underwater pipelines, allowing for carrying out an integrity assessment promptly, inexpensively and safely, without any additional costs from the customer, and without changing the operating mode.

Background

Ensuring accident-free operation of oil and gas pipelines is crucial for the energy sector. Failures in pipeline operation can have catastrophic consequences for human health, the environment, and the economy. With the increasing length of new pipelines and the aging of existing ones, monitoring their technical condition becomes increasingly vital.

There is a wide variety of existing inspection methods for pipelines, and as technologies keep improving, more advancements are expected in this area. Nevertheless, today there is no single inspection method that is suitable for pipelines of all types, classes and categories. Each approach has its advantages and limitations of its application.

As of December 2022, there were about 3200 km of operating gas pipelines and 2535 km of operating oil pipelines in Nigeria to transport crude oil and gas. The total length of the operating pipelines in Nigeria is over 12700 km. The total length of associated (oil-gathering, injection water, returning) and inter-field pipelines is several times greater. The most frequently used inspection method is in-line inspection (ILI) where a flaw-detecting tool (“smart pig”) is placed inside a pipeline. The method has gained a very good reputation over decades of use; however, a significant number of pipelines (up to 40%) are not suitable for ILI.

From a safety perspective, even when pipelines are equipped for in-line inspection, such diagnostics are not always safe. ILI is especially risky for old pipelines, especially when the documentation for such pipelines is incomplete or absent. In such cases, there is a high risk of the smart-pig clashing with obsolete parts of shut-off valves not designated in the documents, the smart-pig getting stuck in sections with a variable (telescopic) diameter, or breakage of the smart-pig due to non-standard repair structures. It is also very risky to carry out ILI on pipeline sections where unauthorized taps might be because craft-produced joint structures can protrude into the pipe and, with their sharp edges, damage or even destroy the in-line flaw detector.

The undesirability of ILI can also be due to the reluctance of pipeline owners and operators to change the operating mode of facilities, carry out internal cleaning of pipes, or incur additional economic costs associated with loss of product and/or shutdown of pipelines caused by preparation for the ILI process. In the case of a demand to inspect several unconnected pipelines, the labor intensity of their preparation increases the cost of diagnostics to the point of unprofitability.

The traditional alternative to ILI is a method of regular linear excavation, meaning at least 2 excavations per 1 km of a tested pipeline. Such a method is considerably time and labour-intensive. Moreover, it does not guarantee that an excavation would be done exactly at the points of the worst technical state of a pipeline, i.e. has a large element of randomness, which exponentially increases the amount of work to overcome.

NCM as an Effective Alternative to In-line Pipeline Inspection

Non-contact magnetometric (NCM) inspection provides a modern alternative to random excavation, enabling the prompt, cost-effective, and safe evaluation of buried onshore and offshore steel pipelines. NCM is based on the physical effect where defects or stresses in metal disturb the pipeline's magnetic field. It can be used in combination with other methods for a comprehensive examination of pipelines that are not suitable for in-line inspection.

Based on the modern requirements for non-contact inspection, the specialists of Engineering Center “Diagnostics” developed the “GeoMag2” system. It allows detection of magnetic field distortions (magnetic anomalies) from a distance of up to 10 diameters of the pipe being inspected. The diagnostic process consists of an operator moving with the magnetometers along the pipeline axis. There is no need to change the pipeline’s operating mode, to magnetize the metal, or introduce any other interference in the operation of the facility. The device is completely passive and has no impact on the pipeline, the environment or the operators. The scanning speed is limited only by the speed with which the operator can move along the route of the target pipeline. In the case of subsea pipelines, an ROV acts as the carrier of the tool.

The GeoMag2 system uses the newest primary transducers of the magnetic field, providing high sensitivity and selectivity of measurements.

The main feature of the GeoMag2 is the use of three-component AMR-transducers, assembled into a measuring system according to the gradiometer scheme. Simultaneous measurement of three field components at different distances from the pipeline makes it possible to construct two full vectors of magnetic induction.

The transition from measuring and analyzing single components to full vectors makes it possible to eliminate measurement errors associated with a change in the location and orientation of the magnetometer relative to the axis of the pipeline, as well as with a change in the orientation of the pipeline relative to the external magnetizing field. The frequency of magnetoresistive sensors sampling in GeoMag2 can be changed within a wide range from 30 to 150 Hz when carrying out the inspection using vehicles such as snowmobiles, ATVs, etc. At an increased speed of movement (20 km/h), the sampling frequency is set to 150 Hz, which allows measurements to be made without losing data quality.

Figure 1: NCM Field Work

Comparing NCM with ILI

The NCM method can be applied on pipelines that are equipped for in-line inspection, and if the main target of the inspection is not a detailed description of each minor defect and its precision sizing, then NCM can offer several advantages over ILI.

First of all, the cost of diagnostics with NCM is several times lower than that of ILI. Another advantageous feature of NCM is the reliable detection of the stress-deformed states of pipelines by detecting changes in magnetization, which are proportional to the stresses that arise in the metal. This very important advantage allows for the detection of areas with deviations in the position of the pipeline relative to the design, due to environmental influences, for example, in zones of soil displacement that occur as a result of landslides, screes, local faults, or heavily watered areas (swamps, underwater crossings).

As for subsea and underwater pipelines, it is known that diagnostics of underwater crossings using ILI is associated with a significant risk of the projectile getting stuck, so the capabilities of the NCM method for diagnosing underwater are a great advantage.

A more detailed comparison of the NCM and ILI methods is summarized in the table below:

Table 1: Comparison of NCM and Pigging (ILI)

Factor	NCM	Pigging (ILI)
Pipeline preparation	Not Required	Required
Necessity of additional equipment	Not Required	Required
Manpower required	Just 2 (maximum 3)	Many
Pipe function / Shutdown of pipeline?	Not Required	Required
Pipe magnetization	Not Required	Required
Excavations (number of pits)	Required at 2-3 points for data verification	Required at the launching and receiving point and the locations of intolerable flaws
The speed of diagnostics (on a prepared pipe)	Up to 10-15 km/day (1 shift)	Up to 100 km/day
Limitations	Requires an operator to pass the entire length of the pipeline	Pigging is applicable only at specially equipped pipelines
Characteristics of the survey	Continuous	Continuous
Informative value	Screening Technology	Direct contact measuring
Duration of preparation works	Not Required	1 – 3 weeks per 100 km + logistics time expenses (at least 1 month)
Transported product limitations	No Limits	limited
Time required for a report issue	from 1 week	Up to 9 months
Total cost	Low (no “hidden” expenses) E.g.: A 100 km inspection costs less than 2000 USD/km	High (lots of “hidden” expenses) E.g.: A 100 km inspection costs over 5000 USD/km (considering the preparation and logistics) + product lost expenses
Stress state detection	Direct detection	Calculation
Metal loss detection error	± 10% - 20% from initial w.th.	± 10% - 20% from initial w.th. depending on the type of a flaw
GPS coordinates binding	Real-time stream with a frequency of over 30 Hz	Coordinates are calculated using markers and distance readings from welds

Considering all of the above, it should be understood that the NCM method is an indirect non-contact method, therefore its ability to detect single spots of corrosion or pitting is lower than that of the in-line inspection method.

NCM Data Analysis

Data processing of the magnetometric inspection is carried out using patented software developed by the Engineering Center “Diagnostics” specialists to implement all the capabilities of this diagnostic system.

The software has 2 main functions:

1) The control of equipment modes, synchronization of data on both measurement channels, high-precision (±0.3 m) binding of data to geographic coordinates using GNSS "Trimble", real-time data visualization, and data storage in non-volatile memory.
2) The primary data processing is used for prompt identification of the most significant anomalies in the magnetic field of the pipeline. If necessary, such an express-analysis of a section up to 10 km long can be carried out directly “in-situ”. The main goal of on-site operational data analysis is the selection of points for reconnaissance excavation.
3) Detailed mathematical data processing using wavelet transformations. An example of transforming the original signal is shown in Figure 2.

The software has State Registration Certificates (Certificate #2021612750, dated 17.02.2021 “The software for real-time magnetometric inspection data receiving, storing and visualizing “MagDriver”), and the hardware part is protected by the Certificates of State Registration of Software No.2021612750 dated 24.02.2021 and No.2021616560 dated 22.04.2021.

An Example of a Magnetogram Processing:

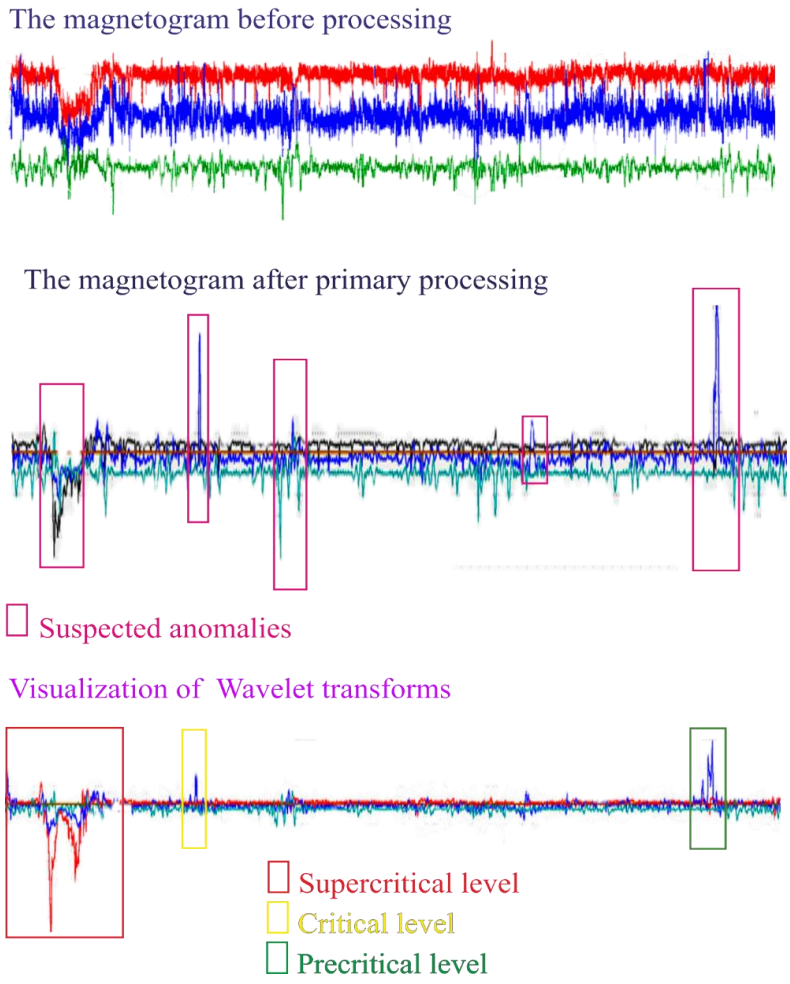

Figure 2: After the initial signal processing, the transformation is performed using wavelet transforms. It is clearly seen how the initially marked zones of magnetic anomalies of the pipeline, presumably associated with defects, are ranked according to the degree of danger, or are excluded from the list as unconfirmed.

In accordance with the main regulatory document GD 102-008-2002 "Instructions for the diagnosing of the technical state of pipelines by the non-contact magnetometric method", the verification of magnetometric data is performed using additional flaw detection (AFDT) in pits, to be excavated at places of the most dangerous magnetic anomalies detected on the pipeline. AFDT is carried out by arbitration NDT methods of contact diagnostics.

Based on the results of a complex inspection of the object, a final report is issued. During the final data processing phase, NCM experts analyze the entire volume of available data on the inspected object, calculate the residual lifetime, and identify the most damaged areas of the object. During the data analysis, both magnetometric data and data obtained during AFDT are taken into account and compared, as well as the initial data of the pipeline taken from the documentation.

A Magnetogram of the Pipeline and Results of an Excavation:

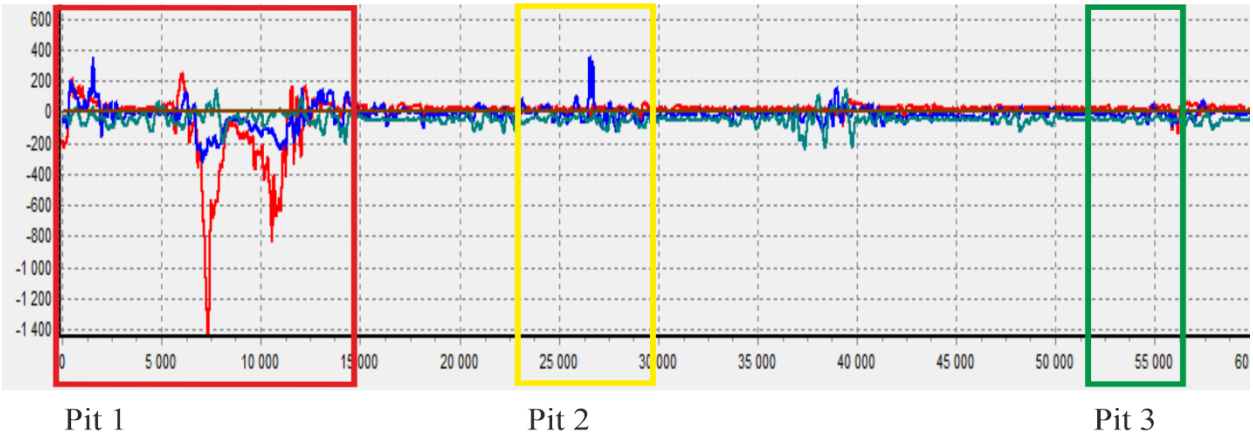

Figure 3: An example of a comparison of magnetometric and contact NDT data

Depending on the general condition of the inspected object, recommendations on the appropriate measures that need to be carried out at this object for its safe operation are issued.

Conclusion

Non-contact magnetometric inspection (NCM) is an indicator method that allows reliable evaluation of the technical condition of pipeline metal without interfering with its operation. It should be noted that NCM today is the only way to distantly identify and assess the danger of stress-deformed states of a pipeline which are responsible for the emergence and development of stress-corrosion processes that occur many times faster than typical corrosion damage. The combination of NCM capabilities provides an excellent tool for assessing the condition of a pipeline and preventing emergencies at minimal cost.

Thus, complex non-contact diagnostics becomes an affordable, reliable and effective tool for evaluating the technical condition of pipelines where ILI is impossible or difficult due to technical reasons.

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