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Mechanical Damage Inspection Using MFL Technology
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The project to design, fabricate, and test a new magnetic flux leakage (MFL) inspection tool that performs an inline inspection to detect and characterize both metal loss and mechanical damage defects has been completed. This inspection tool couples mechanical damage assessment as part of a routine corrosion inspection with minimal additional inspection complexity. This tool is expected to have considerably better prospects for application in the pipeline industry.

The design is based on prior research that showed detecting and assessing mechanical damage can be accomplished by applying a low magnetic field level in addition to the high magnetic field employed by most inspection tools. A lower field than is commonly applied for detecting metal loss is appropriate for detecting mechanical damage, such as the metallurgical changes caused by impacts from excavation equipment. The lower field is needed to counter the saturation effect of the high magnetic field, which masks and diminishes important components of the signal associated with mechanical damage. The high field is still needed for corrosion sizing and mechanical damage signal interpretation.

This new tool, shown in Figure 1, was designed to produce both high and low magnetic fields in a single inspection. Finite element modeling was used in the design effort and the results have shown that a single magnetizer with three poles is the most effective design. Furthermore, the three pole system performs best when the high magnetization pole is in the center. The three pole design also has mechanical advantages including a magnetic null in the backing bar, which enables installation of a pivot point for articulation of the tool through bends and restrictions.

Figure 1. Dual-field MFL tool for mechanical damage inspection

This design was prototyped and tested at Battelle's Pipeline Simulation Facility with signals nearly identical to prior results acquired with a single magnetizer reconfigured between tests to attain the appropriate high and low field levels. Hundreds of mechanical damage anomalies made with Battelle's dent and gouge machine and a large track hoe excavator were examined. The dual magnetization tool could be easily configured to apply the appropriate high and low magnetic field levels to detect and characterize mechanical damage in pipes up to a half inch thick. Inspection variables including velocity and pressure were tested.

The results showed that the decoupling process, used to combine the high and low signals, exposes anomalies hidden by the natural magnetic variation of some materials. With respect to characterization, the processing exposes areas of cold working and residual stresses that are missed when examining high magnetization data alone. The information contained in the decoupled signal can help in the assessment and prioritization of these anomalies. Inspection variables, including velocity and pressure, were also tested. The tool performs well at typical inspection speeds with only slight signal degradation at 5 mph. Additionally, tests performed at 60 percent of operating pressure did not reveal any significant changes in flux leakage signals.

Many newer commercial MFL tools incorporate deformation sensors to assist with mechanical damage identification, such as dents with metal loss. The dual field approach augments this robust MFL technology to provide additional information on pipeline anomalies. The dual field method exposes areas of stress, re-rounding and cold work. In particular, the decoupled signal can expose a region of cold work where the ductility of the steel has been exhausted and the re-rounding of the dent applies a tensile load to the anomaly. As data storage cost and processing times decrease, this added inspection capability could be available for only a modest increase in cost.

The dual magnetization technology could be immediately applied today using two separate MFL magnetizers, sets of sensors and data recorders. However, the new tools with combined magnetizers could be easily built to overcome inspection constraints, such as pipeline bends, restrictions and shorter launch and receive facilities. The dual magnetization technology is generic; in fact, two drastically different tool configurations give nearly identical inspection results, indicating that this inspection technology is applicable for a wide range of tool configurations, pipelines, and inspection variables.

Ultimately, this research shows that there is added value in using dual magnetization techniques to inspect for mechanical damage and metal loss anomalies in pipelines. In addition, this research demonstrates that a single inspection tool can be developed that records signals from both high and low magnetic fields with only a moderate increase in inspection tool costs. The next step for this technology is pigging vendor implementation and assessment on operating pipelines.

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