Needles in a haystack

Mike Niosi, Onstream Pipeline Inspection, Canada, discusses the management of pinhole corrosion with high-resolution magnetic flux leakage and neural networks.

Pipeline corrosion comes in all shapes and sizes, and can cause significant issues for owners and operators. Cases of pinpoint corrosion create a difficult situation, made tougher by the fact that the size of this anomaly is not typically visible by the naked eye, and can cause issues on the external shell of valuable pipeline assets. The result is time-consuming, costly damage that threatens to increase safety hazards and cause an expensive shutdown.

Onstream Pipeline Inspection – a member of MISTRAS Group, a global company that provides asset protection solutions – has developed an answer to this critical problem. Advanced magnetic flux leakage (MFL) pipeline tools and software technology enable pinhole corrosion to be accurately detected and characterised.

MFL inspection data is a product of a two-component, interdependent system: data acquisition tools, married with data processing software and algorithms.[1] After the original MFL tools were designated as simple 'thing finders', technology has evolved over the last 40 years, enabling MFL to detect and size smaller and smaller features like pinholes or illegal taps. This article will detail how advancements made in MFL technology have enhanced the detection and sizing of these challengingly small defects.

Pinpointing pinhole corrosion

Pinhole corrosion defects are a challenge to pipeline integrity, as they can be difficult to detect and size for inline inspection (ILI) techniques, as well as for non-destructive examination (NDE). By definition, a pinhole metal loss defect is a metal loss feature that is less than 10 mm (0.39 in.) in length and width, or less than one multiple of wall thickness in length and width if the pipe wall thickness is greater than 10 mm. Pinhole corrosion can occur somewhat randomly on the exterior of pipelines where coatings have failed. They can occur in isolation, as well as part of more complex corrosion morphologies. Pinholes are often found originating from the inner pipe wall, caused by caustic environments or microbiologically-induced corrosion (MIC). MIC pinholes can be extremely small in diameter, even submillimeter in some cases.

Ultrasonic inspection techniques, either inline or in-ditch NDE, often struggle to reliably detect or accurately characterise pinholes. Accurate in-ditch assessment of pinholes is often not possible with ultrasonic testing, particularly when the defects are internal. Eddy current assessment methods only detect features on the same side as the sensor, therefore internally-applied eddy current methods will not detect external pinholes. Reliable assessment often requires removing the pipe, splitting it open, and measuring the defects with either a 1 mm resolution laser or with mechanical methods such as pit gauges.

When it comes to an ILI, high-resolution MFL techniques detect all sorts of pinholes, even those that are very small. The typical challenge for the technology is not in the detection, but rather in the reliable identification and sizing of pinholes. MFL is an indirect measurement technique, whereby the MFL signal response is dependent on the defect geometry and volume.

Reliable prediction of the defect geometry and volume using the MFL signal response requires not only a high-resolution sensor, but also sophisticated mathematical models which can help differentiate the geometry of a pinhole feature. Advances in computer science, artificial intelligence, and neural networking software algorithms can leverage a vast training library of dig results to make more reliable determinations about defect geometry and, consequentially, also provide improvements to sizing.

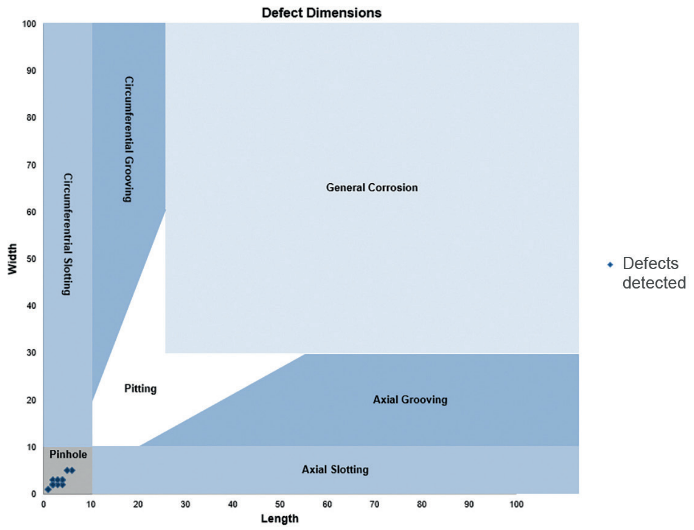

Figure 1. On a 6 in. pipeline inspection, there were 19 pinhole features found across three joints of pipe that were cut out and verified by destructive testing. All the defects verified were classified as pinhole defects.

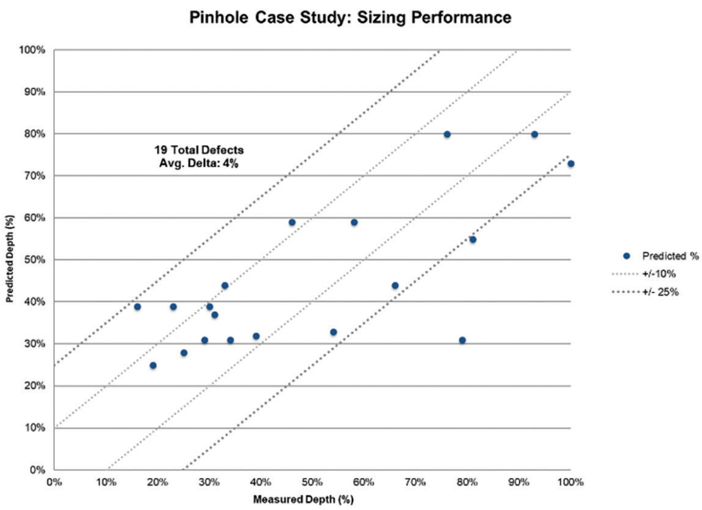

Figure 2. Pinhole defects were detected by MFL technology and verified through destructive testing inspection methods. These defects were predicted to be within ± 25% of their actual depths.

Pinhole corrosion analysis

Onstream has inspected many pipelines that have shown susceptibility to MIC utilising high-resolution MFL technology, and many more that have been deemed potentially prone to external pinhole defects. This determination has been identified through the combination of MFL data, with data obtained through high-quality laser scans, destructive testing data, and specialised pit gauging pinhole defects.

This has created a database of nearly 6000 verified, natural pinhole defects; manufactured pinholes; and finite element modelled (FEM) defects. A database like this can be used to train and test a specialised algorithm that can deliver substantially improved analysis performance on anomalies like pinholes. Utilising high-resolution MFL inspection equipment, next-generation analysis models, and an extensive library of real data, significant advancements have been made towards managing this challenging type of defect.

The analysis models, like the MFL tools themselves, have progressed over the last 40 years from simple linear amplitude-based models, to neural networks involving multiple inputs, to the current state-of-the-art convolutional neural networks. To put this increase in intelligence into perspective, instead of using one calculation when calculating depths of the defect, more than 62 million calculations are now completed.

Case study: sub-specification pinholes

Internal pinhole corrosion was detected and reported on a dig from a 6 in. inspection of a carbon steel pipeline. The inspection detected some extremely small pinholes, well below the published detection specification of any MFL tool in the industry. The smallest verified pinholes detected were 1 mm × 1 mm (0.039 in. × 0.039 in.), and 19% in depth (Figure 1).

Although many of the defects reported were below the minimum pinhole size detection specification of 5 mm × 5 mm (0.2 in. × 0.2 in.), sizing performance was still significant, with an average sizing delta of 4% and with 16 of the 19 pinholes sized within ±25% of wall thickness.

As shown in Figure 2, many of the defects were predicted to be within ±25% of their actual depths, which were measured using destructive testing. One of the defects detected and reported was verified to be a through-wall pinhole. The most significant outlier was a defect which was predicted to be 31% deep by the MFL tool, and found to be 79% deep by destructive testing. This defect was somewhat unique in comparison to the other defects, as several very small pinholes almost coalesced into a singular defect at this location. All other pinholes verified had at least 1 mm - 2 mm of spacing between them.

The results of this inspection are significant, considering the extremely small size of the pinholes. The results, along with the verification data, will be added to the neural network training library to improve the analysis algorithms.

Conclusion

Magnetic flux leakage technology, combined with neural network data analysis techniques, can be a reliable way to manage pinhole corrosion defects in pipelines. The ability to identify and characterise such small areas of corrosion using inline inspection technology is an important advancement for the pipeline integrity industry. The accurate sizing and characterisation of challenging defects like pinhole corrosion can enhance pipeline safety, and save operators time and money.

References

1. 'Next-generation MFL technology', *World Pipelines*, May 2019.