DETECTION OF CORROSION UNDER INSULATION (CUI)

USING

ADVANCED PIPE INSPECTION TECHNOLOGY

Ankit Vajpayee and David Russell

Russell NDE Systems Inc. 490975, Ave Edmonton, AB, Canada T6B 2S3
avajpayee@russelltech.com
Phone 780-468-6800
Fax 780-462-9378

Abstract

Corrosion under Insulation (CUI) is one of the most expensive issues our industry is facing today. For a reliability specialist in a hydrocarbon processing environment, this issue has the potential to be catastrophic. For example: refinery’s steel piping is subject to temperature fluctuations. Thermal insulation applied to the pipe or vessel mitigates the effects, but the presence of seams, gaps or other discontinuities in the insulation layer makes them susceptible to infiltration by outside moisture or from the process environment. The result of infiltration is moisture held in contact with the pipe – resulting in CUI. Its occurrence can be unpredictable and undetectable based on visual examination. Traditional methods of addressing this issue involve selective removal of insulation for visual inspection, radiography or spot thickness measurements with PEC (Pulsed Eddy Current). This paper discusses the development and deployment of an Advanced Rapid Inspection Technique for detection of CUI without the need to remove the insulation.

Key words: Corrosion under Insulation (CUI), Rapid, Piping, Hydrocarbon, Electromagnetic, Insulation.

Introduction

Although varieties of conventional and standard NDE techniques are available, there are always demands for new inspection techniques that meet the unique needs of asset owners. Many NDE techniques are applicable only when the pipe line is shut down or when pipe has no insulation layer. However, in some applications, the pipes need to be inspected while still in service and with thick external insulation layer in place. These requirements basically rule out many available internal and external NDE techniques and require special NDE solutions.

Recently RNSI developed new NDT Technique based on Electromagnetic Through Transmission (TT) phenomenon and the probe is called Bracelet probe (BP). A second-generation BP is shown in figure 1. BP is intended to inspect a live pipe with thick insulation layer. The TT technique requires neither system shutdown nor insulation removal.
The probe is an external inspection tool and can inspect pipes with the diameter range of “150 mm” to “4 m” and sometimes more due to its flexibility. The pipe materials that can be inspected by the BP include cast iron, ductile iron and steel pipes. The probe can detect both internal and external wall loss, including pits, local and general wall loss. It can also detect Stress Concentrated Zones.

Each scan covers a circumferential swath of “0.250 m” when the probe is scanned axially along a pipe. The scan speed is determined by pipe material type and wall thickness.

In order to facilitate BP Inspection of buried pipelines, the segment of a pipeline is excavated to provide inspection access to the pipe. The pipe surface does not face to be smooth or super clean for the probe. Loose surface clay and mud should be removed; however, any coatings can be left in place without interfering with the inspection. Internal liner and transported product are usually non-ferromagnetic and therefore do not affect the operation of the Bracelet Probe. The full circumferences of the pipe can be inspected with multiple axial scans along and around the pipe.

Field technicians’ marks up the datum (“0 mm”, reference mark) and the axial scan paths on the pipe exterior surface. The BP scan starts from the datum and finishes at the target distance. The BP data can be analyzed outside immediately and any indications of internal and external defects can be verified by visual confirmation for the external indications and by UT (Ultrasonic Testing) for internal indications.
One advantage of the BP technique is that the inspector can pinpoint problem areas quickly and efficiently in comparison with other available NDT scanning techniques. The other advantages include minimal surface preparation, no interruption to pipeline operation, speed of inspection and cost.

This paper presents results of experimental study of the TT technique and its feasibility as an effective NDE technique for pipes with and without insulation layer.

Experiments

A BP is connected to a Ferroscope 308 instrument (as shown in figure 2) while the latter is connected to a computer for instrument control and data acquisition. Instrument settings can be optimized so that highest possible sensitivity to defects is achieved for the probe at given pipe wall thickness. The probe can be designed so that a part of the pipe circumference is inspected per scan.

Figure 2: Ferroscope 308 instrument.
Results and Discussion

Finite element simulation was done to show magnetic field pattern in a TT probe. Electromagnetic field propagation in a TT probe allows both ID and OD defects to be detected. Signal phase separation is expected from both ID and OD defects due to the nature of TT phenomenon.

TT signal from machined defects in a “150 mm” carbon steel pipe is shown in Figure 5 in the form of both strip chart and colour map. The probe can detect all ID and OD “ф12.5 mm” defects, including 30% ID RBH. Signal phase spread among these defects is noticeable and can be used as a measure of defect depth. Signal magnitude may be used as an indication of volumetric material loss when proper calibration is available.
More machined defects in another “150 mm” carbon steel pipe is shown in Figure 6. At “25 mm” detector liftoff, the probe can detect small through holes (THs – “ϕ12.5 mm” and “ϕ6.25 mm”) and shallow FBHs (20% deep) in addition to large and deep defects. The pipe clearly shows magnetic permeability variation due to residual stress. The pipe also shows general wall thickness variation along the pipe length probably from manufacturing tolerance. The TT probe demonstrates its high sensitivity to local and general wall thickness variations, including manufacturing tolerance.

Figure 5: TT signal for machined defects in “150 mm” CS pipe. Probe liftoff is “0 mm”.

Figure 6: TT signal for machined defects in “150 mm” CS pipe: Probe liftoff is “25 mm”.
Figure 7a) shows TT signal of four “ϕ25 mm” OD FBHs in an “200 mm” CS pipe at “50 mm” probe liftoff. The 30% FBH can be detected at “50 mm” probe liftoff. Figure 7b) shows that defect signal peak-to-peak voltage, Vpp, decreases exponentially with probe liftoff. Figure 8a) shows signal of four “ϕ25 mm” OD FBHs from same pipe with “50 mm” insulation covered by aluminum sheeting. Insulation material is not expected to affect defect signal. However, outside aluminum sheeting slightly reduced probe sensitivity on these defects. TT signal for OD defects with simulated “60 mm” insulation and “0.4 mm” thick stainless-steel sheeting is shown in Figure 8b). All defects can be detected with high sensitivity. A comparison of Figure 8a) and 8b) indicates that stainless steel sheeting causes less signal attenuation than the aluminum sheeting.
Figure 8a: “50 mm” insulation covered by “0.4 mm” thick aluminum sheeting.

Figure 8b: “60 mm” insulation covered by “0.4 mm” thick stainless-steel sheeting.

Figure 8: TT signal for machined defects in an “200 mm” CS pipe: a) “50 mm” insulation covered by “0.4 mm” thick aluminum sheeting; b) “60 mm” insulation covered by “0.4 mm” thick stainless-steel sheeting.
Figure 9 below shows defect signals from the “2 m” diameter pipe. The following defects can be detected at zero probe liftoff: “φ6.25 mm” TH, “φ6.25 mm” RBH, “φ12.5 mm” TH, “φ19 mm” TH and “φ25mm” TH. Spiral pattern from manufacturing was visible from both strip chart and colour map display.

Conclusion

Application of TT technique has been demonstrated to be feasible for assessing pipe conditions. The technique shows high sensitivity to local wall loss and general wall thickness variations including those from manufacturing tolerance. The advantages of the TT probe include flexibility of one probe for many pipe sizes, pipe condition assessment with or without insulation, and true in-service NDE technique.

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