

Recent Advances in Depth Assessment of Stress Corrosion Cracking Using Tangential Eddy Current Array on Carbon Steel Pipelines

Michael Sirois
Eddyfi Technologies
3425 rue Pierre-Ardouin
Quebec City, G1P 0B3
Canada

Mathieu Bouchard
Eddyfi Technologies
3425 rue Pierre-Ardouin
Quebec City, G1P 0B3
Canada

ABSTRACT

Despite being a method of choice for the detection of stress corrosion cracking (SCC) on carbon steel surfaces, eddy current array (ECA) technologies are still rarely being used for measuring the depth of these cracks. Phased array ultrasonic testing (PAUT) remains the technique of choice. While offering a high level of accuracy on crack depth, PAUT is still relatively slow and dependent of the operator carrying out the inspection. There is currently a strong need in the pipeline industry for a technology that would ally the speed and ease of use of ECA with the depth sizing capabilities of PAUT. This paper presents the most recent advances of eddy current array technologies for the depth sizing of SCC in carbon steel pipelines. Several field trials have been conducted to validate the performance and accuracy of tangential eddy current array (TECA) through comparisons with controlled grinding of the SCC indications. These results show that the main advantages of ECA over PAUT reside in the short amount of time required to locate and size the deepest crack within a colony of SCC, in addition to being more user-friendly and less operator dependent. Ultimately, the field results presented in this paper show how TECA could transform the work of technicians in the digs, and above all, ensure a more reliable management of SCC related threats in pipelines.

Key words: Cracking, Stress corrosion cracking, Hydrogen induced cracking, Intergranular stress corrosion cracking.

INTRODUCTION

Stress corrosion cracking (SCC) is a failure mechanism that occurs in susceptible materials exposed to a corrosive environment and submitted to tensile stress above a certain threshold. In the presence of these combined factors, SCC can occur and potentially lead to the failure of an asset. This failure mechanism has been widely reported in several susceptible alloys of carbon steel, making SCC a considerable threat for pipelines in contact with corrosive soil. The cracking initially takes the form of localized clusters of fine and shallow cracks on the external surface of the pipe, with most of the surface left unaffected (Figure 1). These colonies of cracks are typically oriented with the axis of the pipe, perpendicular to the hoop stress. However, transverse SCC can also occur from transverse stresses caused by construction misalignment or various geotechnical factors such as dents or ground movement^{1,2}. If not identified and repaired quickly, these cracks can expand and interlink with each other, eventually forming long and deep cracks that will force operators to lower the operating pressure of the pipeline. This will lead inevitably to a lower productivity of the asset and higher environmental risk.

The damage induced by SCC is difficult to predict: a disastrous failure can happen unexpectedly, with minimal material lost to corrosion [3]. This lack of wall loss makes SCC difficult to detect by in-line magnetic flux leakage (MFL). Similarly, hydrostatic testing is unable to detect SCC at its very early stage of shallow crack colonies since the maximum sustainable hoop stress is only affected superficially. This leaves ultrasound-based technologies such as shear wave or electromagnetic acoustic transducer (EMAT) smart pigs which have their own resolution limitations when it comes to detecting fine and shallow SCC. Moreover, the detection and characterization of circumferential cracks requires modifications of the smart pigs and is not carried systematically during every in-line inspection of axial SCC.

For all these reasons, direct assessment remains a necessity for the detection and characterization of SCC, and magnetic particles inspection (MPI) remains the standard non-destructive technique for this purpose. Despite the wide availability of certified technicians, MPI faces its share of well-known limitations. First, it is strongly dependent on the operator: the yoke manipulation, eye fatigue, lighting, environmental temperature and conditions, time pressure and psychological factors are all at risk of deteriorating the probability of detection (PoD) of cracks [4]. The sandblasting of the pipe, the concentration of the magnetic particle liquid, condensation on the pipe and the overall contrast of the indications will also strongly affect the PoD, especially at the bottom of the pipe (Figure 1).

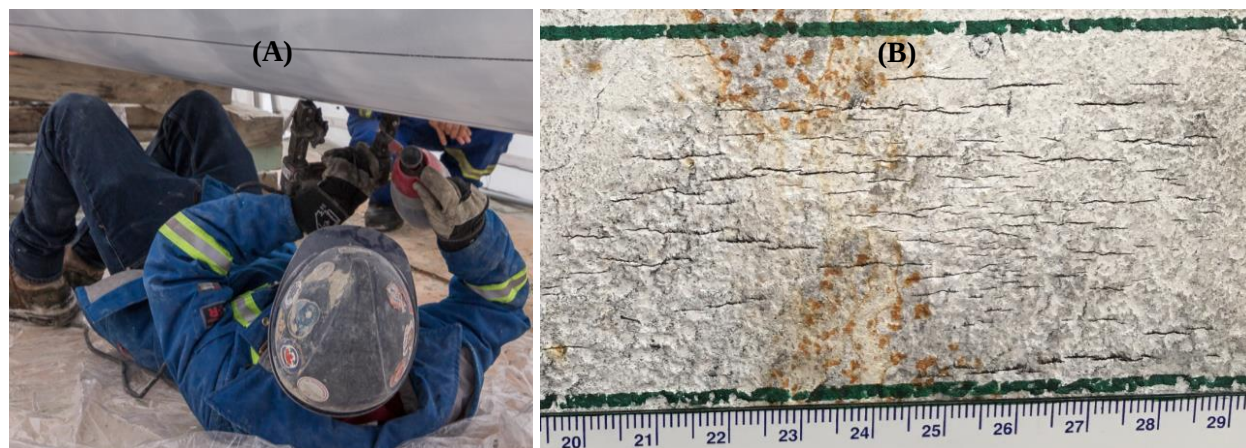


Figure 1. (A) MPI technician inspecting for SCC under a 30" pipeline. Even in optimal environmental conditions (dry ground, good lighting), fatigue and poor contrast at this position often lead to major indications being missed. (B) Colony of external stress corrosion cracking in a liquid pipeline.

MPI cannot provide any precise depth characterization of the cracks: once the SCC colonies have been located, phased array ultrasonic testing (PAUT) remains the method of choice for depth assessment. With the adequate experience and level of training, a PAUT operator can achieve a precise and accurate depth profiling of a crack. On the other hand, it is a slow process that can require hours for a single colony of cracks, and the accuracy of the depth sizing is strongly dependent on the operator [5]. This shows a clear need in the industry for a faster, less training- and operator-dependent, and more versatile tool for the accurate depth sizing of SCC.

In this paper, a novel technology based on eddy currents array (ECA) is presented: the Sharck-HR™, a high-resolution TECA probe designed for the depth sizing of cracks during the direct assessment phase [6]. The presented results show the unique advantages of this technique compared to PAUT in terms of low user dependency, inspection speed and depth accuracy. Its operating principles are first detailed, followed by several in-the-ditch trial cases that highlight the performance of the TECA technology.

EXPERIMENTAL PROCEDURE

Essential TECA parameters and requirements

Providing a high accuracy of depth sizing, maintaining a low user dependency, and increasing the overall user's productivity were the main priorities driving the development of the new TECA technology. The essential eddy current parameters have been specifically chosen for SCC assessment on carbon steel pipelines. These parameters include:

- Coil topology (how the eddy current coils are used to create a channel)
- Operating frequency
- Coil size, array resolution and coverage
- Array spatial resolution

The inspection requirements are the following:

- Pipeline alloys B and X42 up to X65
- Depth sizing up to 3 mm
- Capable of assessing high-density SCC
- Accuracy: $\pm 15\%$
- Surface condition: accurate depth sizing at lift-off up to 1 mm
- High scan and analysis speed

Topology

The selection of an eddy current topology must consider all the essential parameters listed above [7]. The eddy currents induced by each TECA element of the array are tangential to the surface of the pipe and perpendicular to the scan direction. To provide an accurate depth sizing, the TECA probe must move in the same orientation as the axis of the cracks. The key advantage of TECA over more conventional ECA topologies for depth sizing of SCC resides in its unique signal signature. First, it provides an optimal orthogonality between cracks and lift-off signals, which allows monitoring each parameter independently. Secondly, for a given lift-off, when the crack depth varies, its signal phase remains constant and only its amplitude changes.

Frequency

Frequency selection was based on optimum signal signature, i.e., best phase separation between cracks and lift-off signals, and signal-to-noise ratio. For TECA, the optimal frequency was found to be 100 kHz.