

Next Step to Advanced Data Analysis with Pulsed Eddy Currents

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ABSTRACT

Pulsed Eddy Current (PEC) is a proven inspection method used for the detection and assessment of Corrosion Under Insulation (CUI), Corrosion Under Fireproofing (CUF), and material loss under various types of coatings or materials that prevent direct access to the surface. In recent years, PEC inspections have become increasingly common, enabled by more sensitive sensors and innovations that increased productivity such as dynamic scanning and Pulsed Eddy Current Array (PECA) sensors. The technology remains cross sensitive to wall loss and changes in electromagnetic properties or the presence of interfering components. This limitation renders analysis difficult on more complex geometries. The objective of this paper is to introduce an innovative data analysis tool for PEC technology. The new signal representation correlates localized changes in wall thickness measurement with signal amplitude changes to discriminate real wall loss from material property changes or interfering components. The tool provides a simple and easy to interpret vector with orientations illustrating the real or false nature of an indication. The various signatures are presented and explained based on a variety of field data and manufactured samples that demonstrate the capabilities and limitations of this new graphical representation. This innovation, used alongside existing tools, contributes to increased confidence of analysts when facing challenging applications.

Key words: Pulsed Eddy Current, Pulsed Eddy Current Array, Corrosion Under Insulation, Corrosion Under Fireproofing, Flow Accelerated Corrosion, Corrosion under coatings, Non Destructive Testing, Advanced Data Analysis, Material property changes, Interfering components, False positive indication

INTRODUCTION

Pulsed Eddy Current (PEC) technology is a widely accepted inspection method now covered by several industry standards such as ISO⁽¹⁾ 20669, API⁽²⁾ RP 583, and the new ASME⁽³⁾ Section V (BPVC for Boiler and Pressure Vessel Code), article 21.^{1,2,3} PEC is a versatile inspection technology which provides an average remaining wall thickness through insulation and coatings. The technique can also be used to safely assess the minimum remaining ligament under corrosion scabs or blisters without surface preparation. PEC is resilient to liftoff variations and provides volumetric measurements of remaining material. It is capable of both detecting and assessing general corrosion on the outer surface of the pipes such as scabs and blisters, and detecting erosion or Flow Accelerated Corrosion (FAC) on the inner surface. The technology remains however cross sensitive to wall loss and changes in electromagnetic properties or the presence of interfering components. This limitation renders analysis difficult on more complex geometries and can lead to false positives.

The actual algorithms used to size wall thicknesses assume that variations in the eddy current decay are only a function of wall thickness and that other material properties are constant. It is also assumed that eddy currents come from only the inspected component. Consequently, when there are property variations or an interfering component is present, they will affect the sizing of the region of interest. It may turn out that no corrosion is present, or it has been overestimated, which is called a false positive. While the rate of false positives is not prohibitively high, the goal remains to eliminate or minimize them to increase inspection accuracy. False positives can have one of several causes, including but not limited to: localized material property variations, interfering conductive components near the probe, temperature gradients, and others.

As schematized in Figure 1, PEC analysts need to consider three major factors to make accurate calls and identify false positives: 1) the C-scan to find areas of interest while taking into account the varying baseline and noise level, 2) the signals (A-scan, Tau-scan and the new indication discriminating tool) from data points in the areas of interest, and 3) the context to evaluate its influence on the C-scan and signals in order to make an informed call.⁴ It is thus recommended to gather all the information available on the component including, but not limited to, as-built drawings, corrosion mechanisms, and morphology.

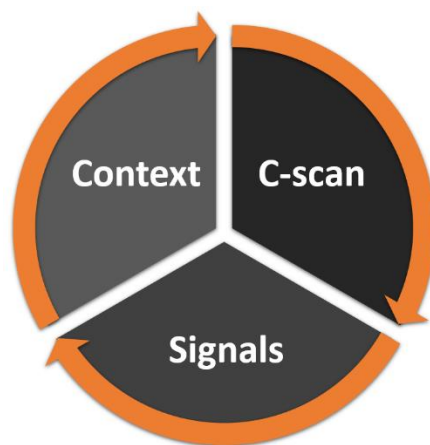


Figure 1 Requirements for post-processing analysis

Differentiating true wall loss from a false positive indication (Figure 2) requires a few key elements. The first one is the quality of the C-scan image which is aided by the ability to perform high-resolution scans.

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⁽³⁾ The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990, USA

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The second key element that makes for an accurate call is the ability to look at the signal shape of data points in areas of interest to determine whether they correspond to true wall loss or a false positive.

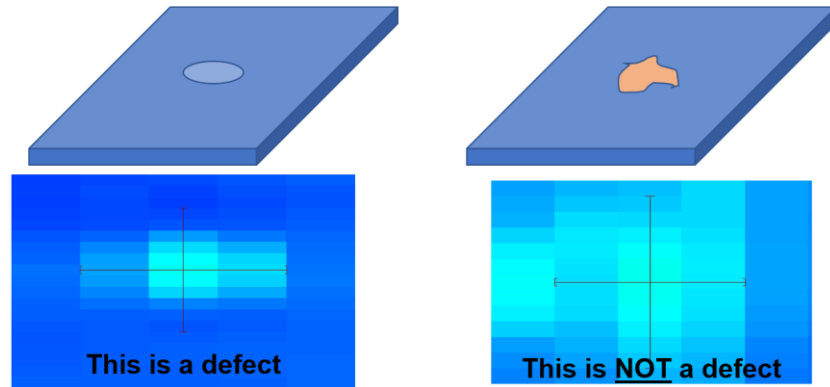


Figure 2: True wall loss and false positive C-scans

On the signal side, the A-scan provides information regarding the amplitude variation as a function of time. It also contains two important parameters: the initial signal amplitude, and the eddy current decay rate. On one hand, for a true wall loss indication, the signal amplitude is fairly constant in the area of interest and a faster decay correlates with a thinner thickness. On the other hand, a false positive is typically associated with an indication with a lower wall thickness measurement combined with a stronger signal amplitude and a steeper slope early in time. In this situation, the A-scan goes above the calibration in the beginning and drops significantly at the end as shown in Figure 3. This is also characterized by an A-scan crossing the calibration line.

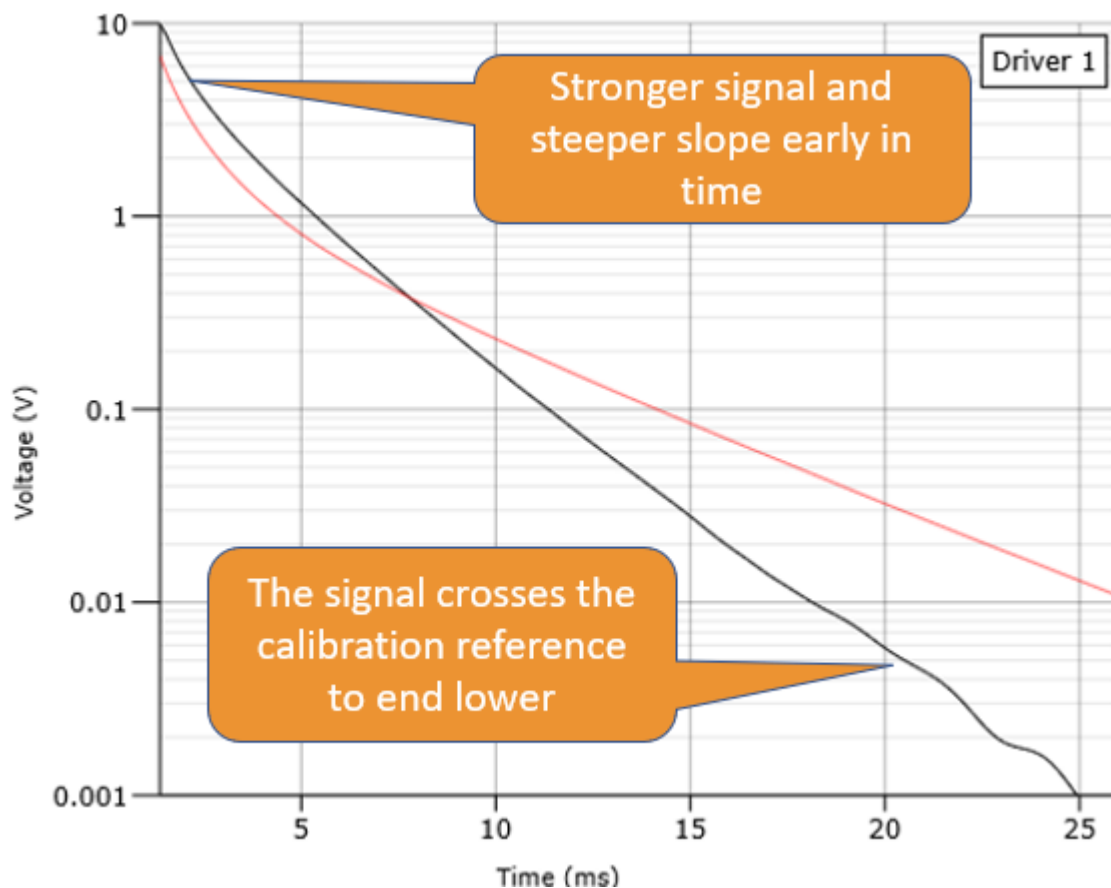


Figure 3: Effects of properties variations on A-scan

Herein we thus present a novel graphic representation of an indication. The new graphical tool expresses the relationship between local wall thickness variation and its corresponding normalized signal amplitude of the selected data points. The typical response of the new tool on several indications observed during PEC inspections will be discussed. The graphical tool will then be used to analyze real-world data coming from the inspection of an in-service pipe.

RESULTS

New post-processing advanced analysis tool

The new post-processing tool was designed to highlight the relationship between local wall thickness variation and its corresponding signal amplitude. As mentioned earlier, the signal amplitude of a true wall loss indication is fairly constant when compared to the local baseline. The signal amplitude of a false positive is different however, being generally higher than the calibration. This leads to the signal crossing the calibration reference line.

Indications cannot be assessed by analyzing independent data points in the areas of interest of a C-scan or their signals. Hence, to best highlight the relationship between wall thickness and signal amplitude variations on an indication, several data points in a single axis (scan or index axis) are required. Based on that relationship, an indication can be classified into one of the four following categories: 1) True wall loss, 2) False positive, 3) Uncertain, and 4) Undefined. Table 1 presents a summary of the main characteristics of the four categories. In addition, the graphical tool uses the local wall thickness variation as a parameter. This means that only data points selected with the tool are used to calculate the thickness variation.

Table 1: New graphical tool indication classification

<i>Indication</i>	<i>Local wall thickness variation</i>	<i>Signal amplitude</i>	<i>A-scan crossing the calibration</i>
<i>True wall loss</i>	< 100 %	Similar or lower than calibration	No
<i>False positive</i>	< 100 %	Higher than calibration	Typical
<i>Uncertain</i>	< 100 %	Similar or higher than calibration	Unclear
<i>Undefined</i>	≥ 100 %	-	-

The main output of the new tool hence consists of two parameters used to discriminate true wall loss from a false positive indication. Therefore, it can be visualized through a 2D plot, as shown in Figure 4, in which the horizontal axis is the normalized signal amplitude in dB and the vertical axis is the local wall loss in percentage. The 2D plot is divided into four areas of interest that correspond to the four categories used to classify indications. An exhaustive campaign of data analysis was used to determine the location and properties of the areas in the 2D plot. First, an indication located in the true wall loss area means that it has a signature typical of true wall loss. This signature is generally defined as a negative local wall thickness variation correlated with a negligible signal amplitude variation. However, other factors, such as liftoff variation, could influence the strength of the signal. These variations will generally decrease or slightly increase the signal amplitude. Hence, the true wall loss area occupies the third quadrant of the graphical tool, more precisely between the relative angles (θ_r) -90° and 25° (see Figure 4). Second, an indication located in the false positive area means that it is most likely a false positive. Its signature is defined as negative local wall thickness variation correlated with an increasing signal amplitude. Therefore, the false positive area is in the second quadrant of the tool, between relative angles (θ_r) 45° and 90° (see Figure 4). Third, indications in the uncertainty area mean that the graphical tool cannot discriminate true wall loss from a false positive. The uncertainty area is in the second quadrant (between a relative angle (θ_r) 25° and 45°) and makes the transition between the true wall loss area and the false