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CORROSION INSPECTION UNDER REPAIR BY EDDY CURRENT WITH EXTERNAL MAGNETIC FIELD

Vitor Manoel A. Silva[1], Cesar G. Camerini, Lucas B. Campos, Gabriela R. Pereira
Federal University of Rio de Janeiro
Rio de Janeiro, Brazil

Ana Lúcia F. S. d'Almeida
Petrobras Research Center
Rio de Janeiro, Brazil

ABSTRACT

The oil and gas industry is an economic branch highly dependent on metallic equipment, especially those produced with carbon steel. Often, such materials suffer from corrosion and repair with composite materials is one way of stopping this type of degradation. However, to meet manufacturing and operating codes and specifications, the metal substrate needs to be inspected routinely over its lifetime. The aim of this work is evaluate the ability of eddy current technique with external magnetic field to inspect the corrosion under composite repair. For comparison purposes, the conventional test, without using the field, was also performed. The latter, in turn, was not able to detect defects even on the thinner sheet. With the application of the external magnetic field, the wall loss equivalent to 50% was effective for substrates up to 12.7 mm thick and 5 mm repair layer.

Keywords: Eddy current, carbon steel, corrosion.

NOMENCLATURE

EC	Eddy current
SEC	Eddy current with external magnetic field
R	Resistance
X_L	Inductive reactance

1. INTRODUCTION

The production of the oil, that involves the extraction, the transport and the refining, is an industry branch highly dependent on structures and metallic materials, specially those made by steel. Some examples are oil platform, semi-submersible and FPSO types, pipelines, storage tanks, pressure vessels and boilers (PETROBRAS, 2018).

During the lifetime of a metallic equipment, there are several degradation mechanisms, especially corrosion, which can lead to rupture due to the reduction of metallic thickness (ECHTERMEYER et al., 2014). Even stainless steels are subject to this problem since chloride and sulfide ions, common in the oil extraction process, are capable of breaking the passivation film and triggering the corrosive process. To solve this problem, welding is the most traditionally used option as a form of repair. However, by involving electric arc opening and flame formation near equipment, that carries flammable liquids, alternative methods have large space for application (ECHTERMEYER et al., 2014).

As an alternative, repairs with composite materials, which are used mainly in aircraft, now is being applied in oil and gas field. The repair with these materials stands out by the ability to restore the lost metallic thickness without the need for heat or flame opening. Another feature is the possibility of adaptation to complex geometries and the application with the equipment in operation or only with reduction of the pressure, as in the case of pipelines.

Due to the increasing experience of using composite repairs for the petroleum and petrochemical industry, standards and technical specifications have emerged with the aim of consolidate methodologies for the design, manufacture, operation and inspection of repairs. The main ones are ASME PCC-2 and ISO/TS 24817: 2006. These documents provide the necessary methodology from the design of the repair to its final use period, including its decommissioning.

Although repairs perform well in general applications, their improvement to employment as long-term repairs and more relevant structures (transportation of oil, gases, and other hydrocarbons) run into the limitation of ensuring repair integrity and condition defects repaired as determined by ISO / TS 24817: 2006. According to this document, composite repairs can be designed for a life of up to 20 years if they are inspected frequently over time. The same applies to repairs designated as Class 3 (indicated for any fluid and pressures according to qualification) (SOARES et al., 2018).

In this scenario, the work has the objective of using electromagnetic technique in order to be as an alternative for corrosion inspection of the metallic substrate. The proposed

[1] Contact author: vmsilva@poli.ufrj.br

technique is based on the test of eddy current with the application of an external magnetic field.

2. MATERIALS AND METHODS

2.1 Material

The experimental tests were performed on carbon steel plates with different thickness as denoted on Table 1.

TABLE 1. Dimensional features of plates.

Sample	Thickness (mm)
#1	6.3
#2	6.7
#3	10.0
#4	12.7
#5	20.0
#6	25.5
#7	31.6

On each plate was machined, in the central region, a defect similar to a loss of thickness by corrosion. For each specimen, the defects had the following relationship: depth equal to 50% of the thickness and diameter equivalent to twice the thickness of the sheet. Figure 1 shows the discontinuity in one sample. Additionally, in order to simulate the repair layer, a 5 mm thick rubber blanket was used throughout the sheet surface.

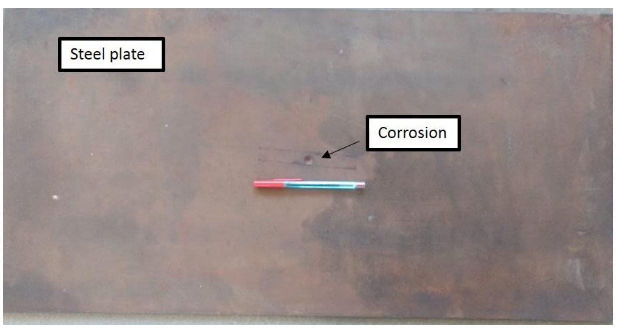

FIGURE 1: SAMPLE WITH CENTRAL DEFECT SIMULATING LOCAL CORROSION.

The main methodology used to inspect the test specimens described above was the use of the eddy current with external magnetization (SEC). This technique uses the same equipment used in the conventional test of eddy current (EC) with the additional use of an external source of constant magnetic field, which is applied to the material inspected in the same region that the probe is located. In this work, for use of the SEC, a probe with two windings, differentially connected, with 500 turns in each (AWG wire 40) operating at a frequency of 10 kHz was used. In addition, a commercial eddy current equipment and an oscilloscope were used. The latter equipment was applied with the objective of extracting the data of resistance (R) and inductive reactance (X_L) for later reconstruction of the data and visualization of the graphs with the aid of Matlab® software. The external magnetization was provided by an electromagnet capable of imposing a constant magnetic field around 1000G. It is important to highlight that inspections with the conventional technique, EC, was also carried out in order to compare the results among the techniques. In addition, the inspections were performed on the opposite side to the insertion of the defect, with the blanket of rubber between the inspection probe and the steel plate.

3. RESULTS AND DISCUSSION

Figure 2 shows the results, presented in the form of the impedance plane, for four specimens: #1, #3, #4 and #5 with thickness of 6.3 mm, 10 mm, 12.7 mm and 20 mm respectively. The results presented in this figure are relative to SEC inspection.

Figure 2 (a), regarding #1, shows the formation of a Lisajouss figure in the impedance plane. According to Henriques et al. (1990), the signal representing the detection of a defect when inspected by differential probes, as used in this work, is exactly the signal detected in the impedance plane, which demonstrates the identification of the discontinuity in this case. A similar result is observed for #3 and #4, as shown in parts (b) and (c) of the same figure. In contrast, the inspection for #5 did not demonstrate the formation of the pattern for differential probe, which allows to say that the detection of the discontinuity in this sample, with 20 mm of thickness, was not possible.

In the sequence, in Figure 3, the results are shown for the inspections performed by the EC method, that is, without application of the external magnetic field. It is observed in part (a), regarding the inspection of #1, with 6.3 mm of thickness, that there was no formation of the Lisajouss figure, indicating that the defect was not detected. In addition, the signals of the two components of the impedance plane, resistance (R) and inductive (X_L) appear erratic, with amplitudes close to zero. Similarly, the same result is obtained for the #3, 10 mm thick, with noisy signals of small amplitude and without the expected standard for defect detection with differential probes.

According to Eddyfi (2018), the high magnetic permeability of ferrous alloys, such as carbon steel, reduces the penetration of eddy current, given the inverse relationship between these quantities. Consistent with these statements, EC inspection on thicker specimens than those shown in Figure 4 did not demonstrate any signal that could be classified as detection, and, as a result, were suppressed.

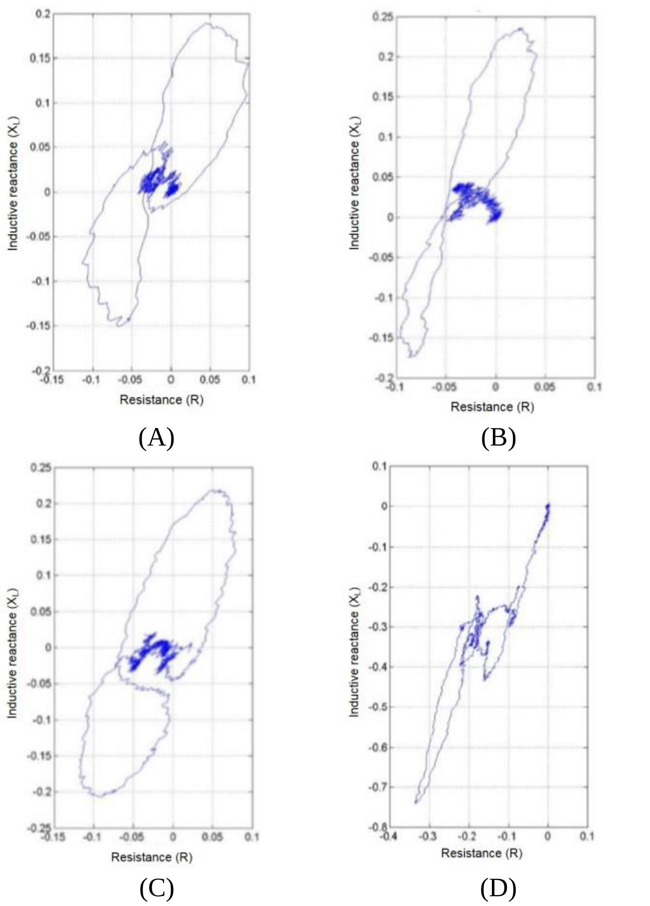

FIGURE 2: IMPEDANCE PLANES RELATED TO INSPECTION OF SAMPLES #1(PART A), #3(B), #4(C) AND #5(D) BY SEC.

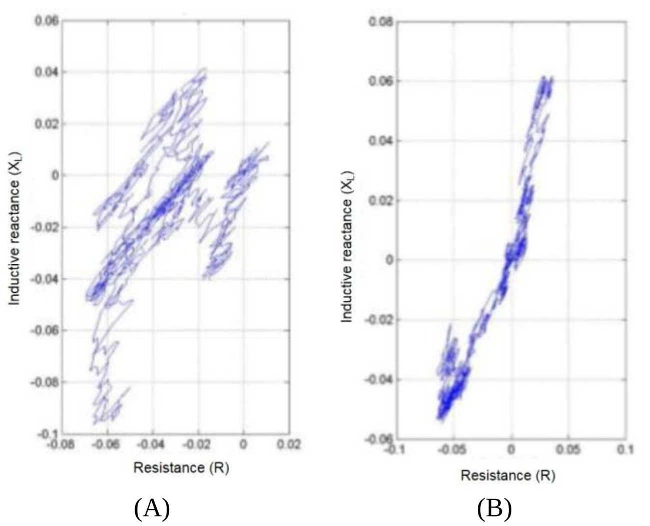

FIGURE 3: IMPEDANCE PLANES RELATED TO INSPECTION OF SAMPLES #1(PART A) AND #3(B) BY SEC.

4. CONCLUSION

As a way of inspection of metal structures with composite repair, the technique of eddy current with external magnetization was used, which allowed inspection of steel plates up to 12.7 mm thick, with a defect depth of 50% of the thickness of the sheet and 5 mm of repair. When comparing with the inspection by conventional eddy current, it is noted that there is benefit in using the external magnetic field since in its absence no discontinuity was detected.

ACKNOWLEDGEMENTS

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