Customized eddy current probes for pipe inspection at high temperatures

Miguel A. Machado[1], Fernando S. Crivellaro[1], Ana Peixoto[1], Pedro H.G. Riscado[1], José P. Sousa[2], António Custódio[3], Rosa M. Miranda[1], J. Pamies Teixeira[1], Telmo G. Santos[1]

[1] UNIDEMI, Mechanical and Industrial Engineering Department, School of Science and Technology, NOVA University of Lisbon, 2829-516 Caparica, Portugal.

[2] ISQ - Taguspark, Porto Salvo, Oeiras, Portugal

[3] ISPT - Taguspark, Porto Salvo, Oeiras, Portugal

Abstract

This paper presents the development and experimental validation of a customized eddy current NDT system for the inspection of pipes at high temperature (300º C). To overcome this difficulty a customized solution was designed, produced and tested consisting on eddy currents probes dedicated to piping material and geometry, with a cooling system integrated to reduce the thermal effects optimized with numerical simulation tools. The experimental results allow the detection of artificial standard defects with rectangular and circular geometries even with high probe lift-offs.

Introduction

Several components, like steam transportation pipelines must stand for high temperatures, above 300º C, requiring adapted inline inspection methods to assess its condition. There are several solutions for pipe inspection [1] but few exist for high temperature conditions, so a customized equipment is needed for this specific application [2-5].

Existing systems for high temperature NDT include permanent inspection of hot wire [2] and i*n situ* monitoring using eddy currents [6]. However, these developments envisage very specific applications and are unable to inspect other types of surfaces as in pipes.

Other Non-destructive Testing (NDT) methods, as ultrasonic or liquid penetrant, have fundamental components that are sensitive to material temperature. Otherwise, if the electromechanical properties of the inspection material do not vary with temperature, the challenge of the eddy current method is translated into the temperature probe isolation and its consequent lift-off.

Developments and results

Two customized NDT probe prototypes were produced and tested. The first probe developed consisted of two coils connected in a differential bridge mode. A water cooling system was developed in order to reduce thermal effects on the probe. Numerical simulations were performed to understand and characterize electrical and magnetic phenomena involved in the probes operation, including the probe's core material and dimensions, the number of windings, and testing parameters. A very low frequency was used (10 kHz) to increase the depth of penetration due to such high lift off. Fig. 1 depicts the simulation and experimental results from an inspection of an artificial defect engraved, with 0.5 mm depth, 1 mm wide and 15 mm length, on a 16Mo3 Steel pipe with 550 mm diameter (Fig. 1a). The two-coil bridge differential probe allowed a good signal to noise ratio. A laboratorial prototype was developed to perform the inspection in specimens with standard defects to assess the behaviour of the produced probes on the material at high temperature (Fig. 1c). This prototype heats up the tube specimens with a 7.5 kW resistance coil (by Joule effect) placed the inside the tubes and provides the heat control to maintain the temperature. The tube rotation and probe movement were also provided by the equipment and controlled by computer in a LabVIEW environment.

* - Corresponding author. Phone: +351 21 2948567, E-mail address: p111094@campus.fct.unl.pt

A second probe was developed in a planar PCB substrate where the two coils operate in differential mode as well. This solution allowed a higher temperature of the probe which makes possible the use of cold air refrigeration. Fig. 2a presents the signal obtained with the inspection material at room temperature and at 300º C in the same specimen. The signal to noise ratio is very superior to the first probe and the high temperature did have a small impact in the signal amplitude. Fig. 2b shows a thermographic image of the test.

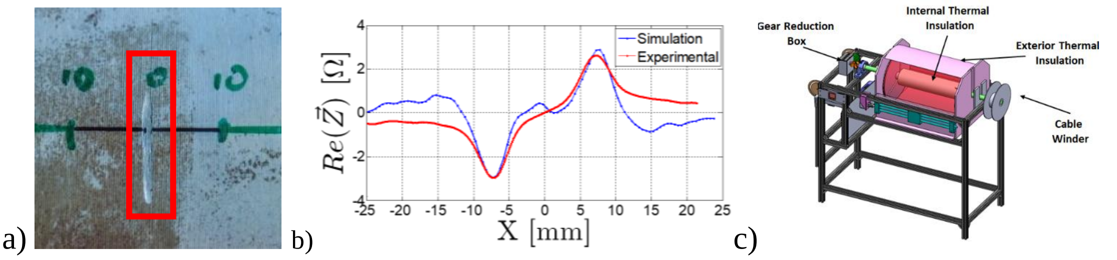

Figure 1 – a) Artificial defect with 0.5 mm depth, 1 mm wide and 15 mm length, b) Output signal of the eddy current probe when the defect is scanned at 10 kHz compared with the simulation result with the same parameters, c) Laboratorial prototype for high temperature tube inspection.

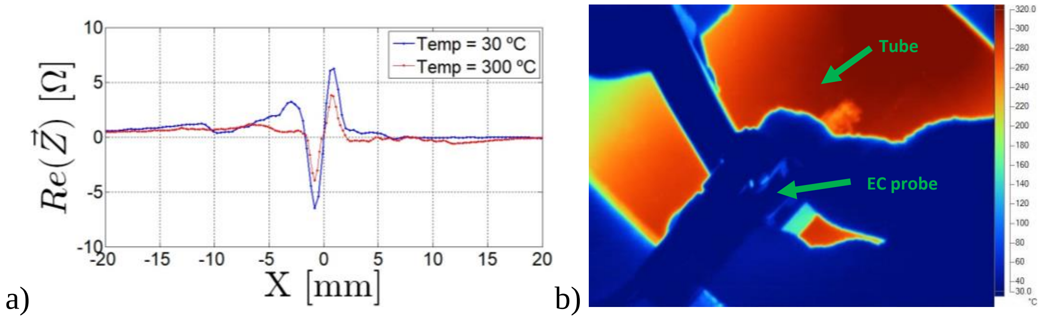

Figure 2 – a) Output signal of the eddy current probe when the defect is scanned at 12 MHz at room temperature and at 300º C, b) Thermographic image of the test.

Conclusions

Despite the high lift-off required for high temperature EC testing, very good results were obtained with both differential probes. The PCB probe showed improved results with higher signal to noise ratio and the test at high temperature originated a small amplitude drop. Experimental validation of the prototype showed very promising results. The numerical simulation proved to be an important tool to achieve the expected solution.

Acknowledgements

The authors would like to acknowledge Fundação para a Ciência e Tecnologia (FCT, MCTES) for its financial support via the PhD scholarship FCT-SFRH/BD/108168/2015, project PEst-OE/EME/UI0667/2014 and Project Hi2TRUST, (Refª 3335), supported by Fundo Europeu de Desenvolvimento Regional (FEDER), Programa Operacional Regional de Lisboa (Lisb@2020 and Portugal2020).

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