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# ANALYSIS OF HIGH TEMPERATURE PIPE INTEGRITY USING CUSTOMIZED EDDY-CURRENT SYSTEM

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## ABSTRACT

This work presents the development and experimental validation of eddy current probes for high temperature (300 ºC ~ 500 ºC) pipe inspections. The modules (probes and chassis) were customized to operate as part of an automated scanner system and to be adapted to steel pipes geometries and to operation temperature levels. The project includes a refrigeration system and uses thermal isolation materials to stablish an adequate operation environment to the temperature sensible probe components. The experimental results have shown the detection of artificial standard defects with rectangular and circular geometries even through high probe lift-offs, as seen in probe numerical simulation comparison. The module operation in the high temperature range (340 ºC) also was validated.

***Keywords:*** high temperature, eddy currents, pipes.

## INTRODUCTION

The temperature of steel pipes in superheated steam transport arises above 300 ºC. These pipes need operation monitoring to evaluate its integrity and reduce the costs involved in industrial maintenance stops. There are already developed eddy currents solutions for pipe inspections (Machado, 2017), but there are few for high temperature operation conditions. Therefore, a module development for this specific application is necessary (Kawalla, 2010; Ricken, 2008; Rahman, 2006; Hartmann, 2006).

Other Nondestructive Testing (NDT) methods, such as ultrasonic or liquid penetrant are very sensible to the temperature of the inspection material. Otherwise, assuming the electromechanical properties of the inspection material do not significantly vary within this range of temperature, the main challenge of the eddy current method is translated into a specific probe architecture development capable to precisely excite and sense the inspection material through the insulation material and its consequent high lift-off.

## SYSTEM DEVELOPMENT

In order to analyse the pipes integrity under this temperature harsh environment, the developed system uses the eddy current inspection method. The system is constituted by a pipe support which allows the pipe rotation and probe movement along the pipe face. Besides this, there is an electrical resistance heating (Figure 1) inside the pipe to simulate its operation temperature. Lastly, it was developed two probes: a cylindric helicoidal with ferrite core (Figure 2) and a planar Printed Circuit Board (PCB) with rectangular coils (Figure 3), both in bridge configuration. The probes are located inside specific developed cups with Teflon™ as thermal insulation material. The chassis of the cylindric helicoidal probe was produced with polylactic acid (PLA) through Additive Manufacturing (AM). The PCB probe uses an aluminium cover and a PLA support to position the PCB at the bottom of the cup. The probes refrigeration is made with water through connectors positioned at the top of the probes, which maintain the internal side of the cup always at a temperature close to the input water. The full mounted system with the PCB probe is presented in Figure 4.

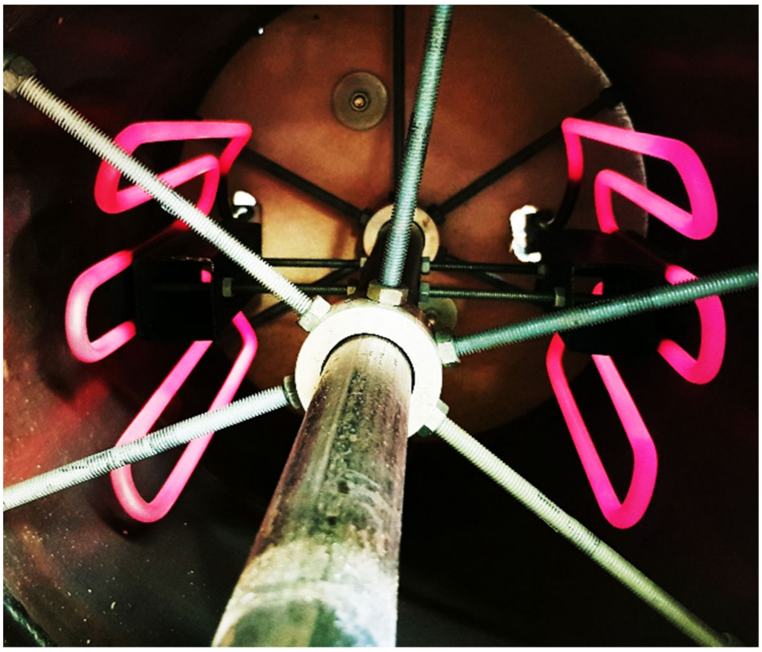

Fig. 1 - Interior of the pipe with electrical resistance heating.

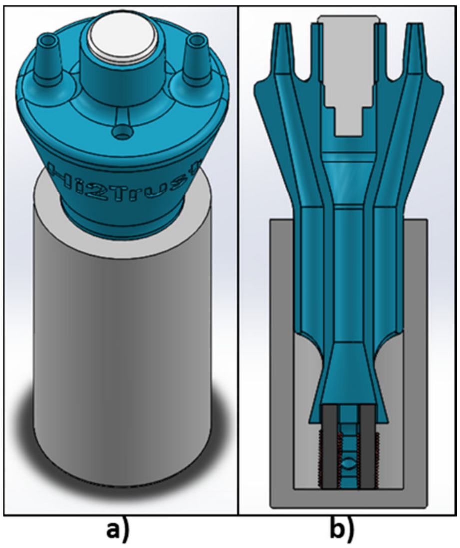


Fig. 2 - Cylindric helicoidal probe external (a) and cut (b) views.

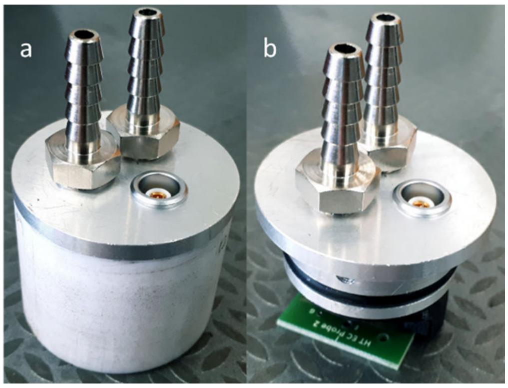


Fig. 3 - PCB Probe in bridge configuration, external (a) and internal (b) views.

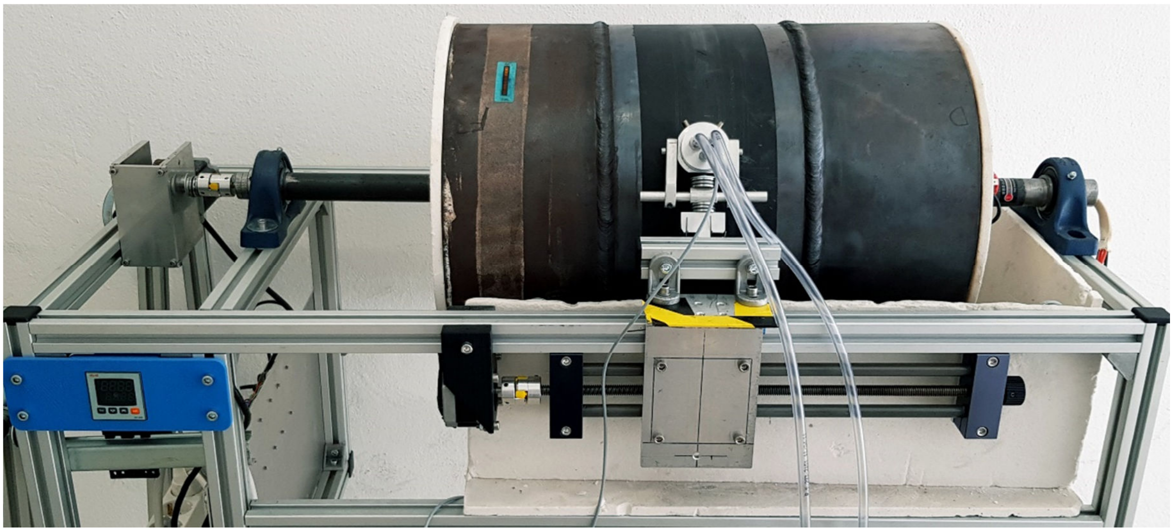

Fig. 4- Full mounted laboratorial system for high temperature pipe inspection.

## RESULTS AND CONCLUSIONS

The helicoidal probe simulation and experimental results from an inspection of an artificial circular standard defect with 1 mm radius and 0,5 mm depth produced on a sample steel pipe with 550 mm diameter are shown in Figure 5. The frequency of the inspections was 100 kHz.

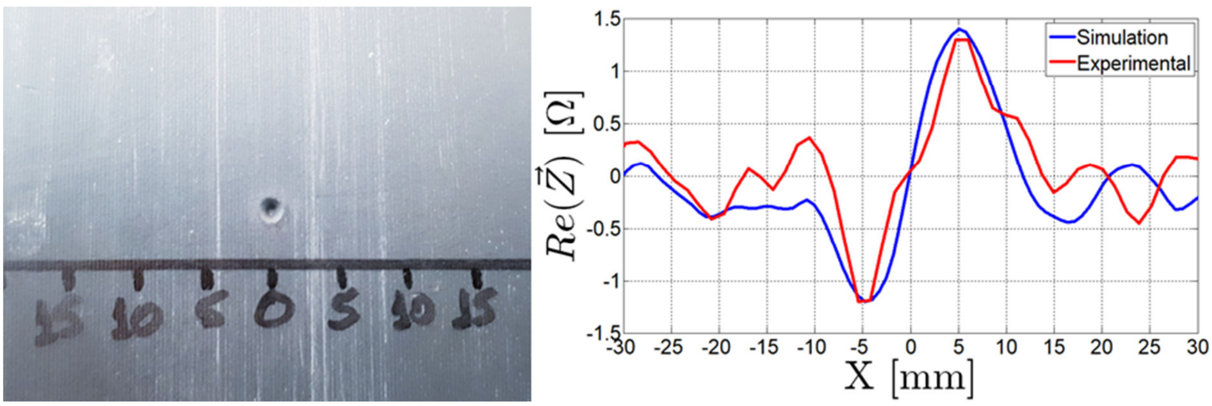


Fig. 5 - Artificial circular standard defect inspection: simulation and experimental comparison.

In Figure 6 the surface scanned from the same sample pipe using the helicoidal probe shows the same artificial circular standard defect detection. A total area of 6300 mm$^2$ was inspected and the defect position precisely identified in the centre of the positive and negative peaks.

The high temperature operation was validated with the PCB probe with a 340 ºC inspection of an artificially produced rectangular defect of 0.5 mm wide, 0.4 mm depth, 10 mm height and with an angle of 45 degrees (Figure 7) that was made in the same sample pipe. In Figure 7, the results obtained for high temperature inspection reproduced the defect characteristics of ones observed at 20 ºC. The small differences between the two temperature curves were attributed to lift-off variations from the inspection system support mechanical gaps, which were also responsible by the use of two different inspection frequencies of 2 MHz for 20 ºC and 500 kHz for 340 ºC.

The pipe temperature monitoring during the high temperature inspection was realized over a silk covered area with a thermographic camera Fluke Ti400 and an emissivity index of 0.95. The Figure 8 shows the inspection area temperature obtained during the trial.

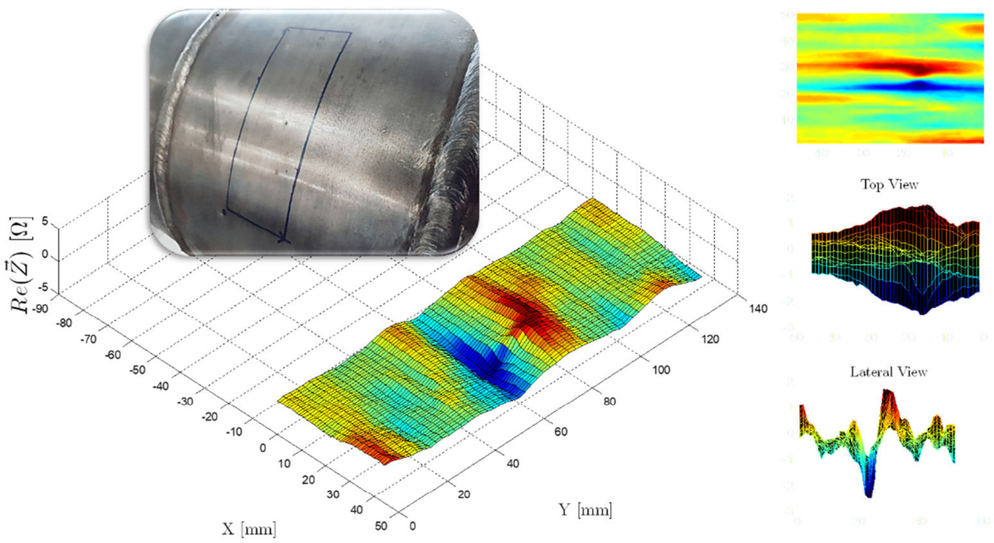


Fig. 6 - Pipe scanned surface with artificial circular standard defect detection

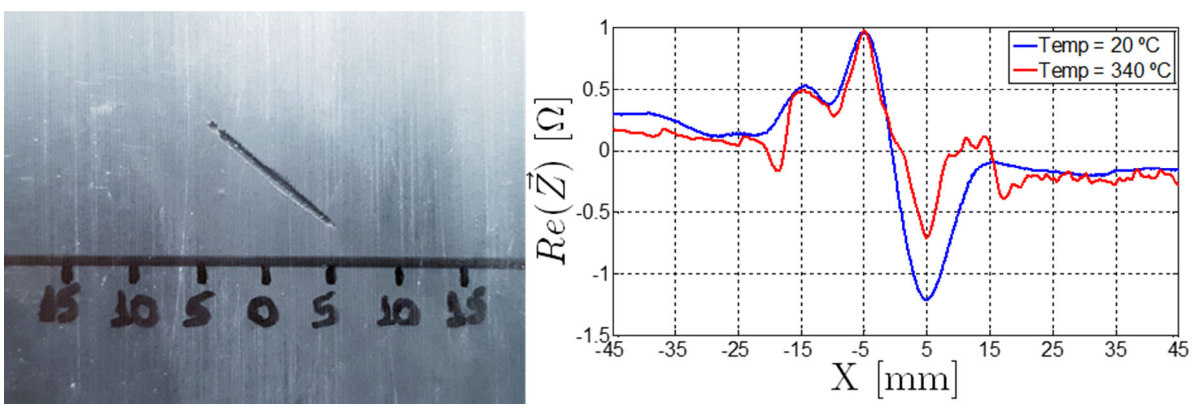


Fig. 7 - Inspection temperature comparison.

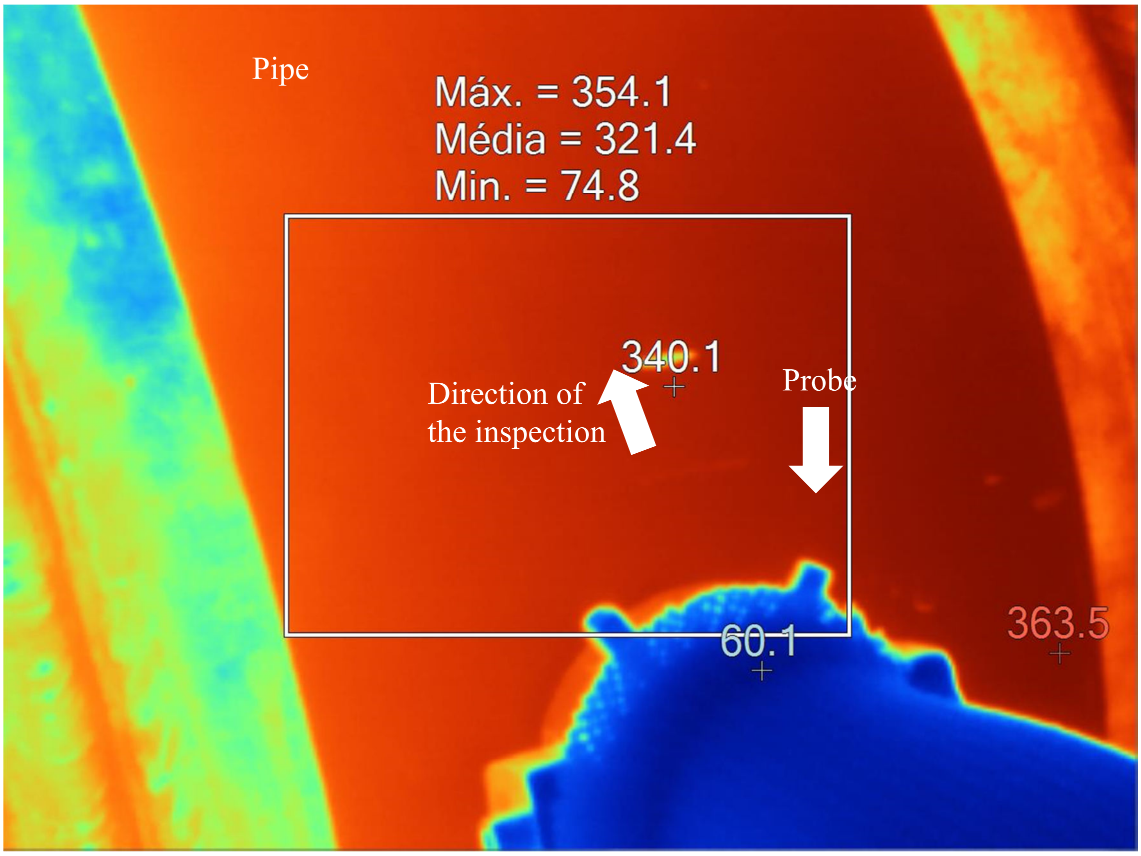


Fig. 8 - Infrared temperature monitoring at 340 ºC.

## ACKNOWLEDGMENTS

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## REFERENCES

[1] Machado M. A., Rosado L., Pedrosa N., Vostner A., Miranda R. M., Piedade M., Santos T. G. Novel eddy current probes for pipes: Application in austenitic round-in-square profiles of ITER. NDT & E International, 87, pp. 111-118, 2017.

[2] Kawalla R., Goldhahn G., Perez C. M., Hartmann K., Llanos M., In-line quality control of hot wire steel, International Conference on Metallurgy and Materials, 18, 2010.

[3] Ricken W., Hartmann K., Becker W. J., Perez C. M., Gonzalo L., Optimised Eddy Current Sensor. Improved Defect Detection on Hot Wire Steel, Technisches Messen, vol. 75, no. 9, pp. 501-507, 2008.

[4] Rahman M., Marklein R., Advanced Techniques for Modelling and Detection of Cracks in Hot Wire Steel, European conference on Non-Destructive Testing, pp. 1-8, 2006.

[5] Hartmann K., Ricken W., Becker W., Improved Eddy Current Sensor for Hot Wire Inspection, European conference on Non-Destructive Testing, pp. 1-9, 2006.