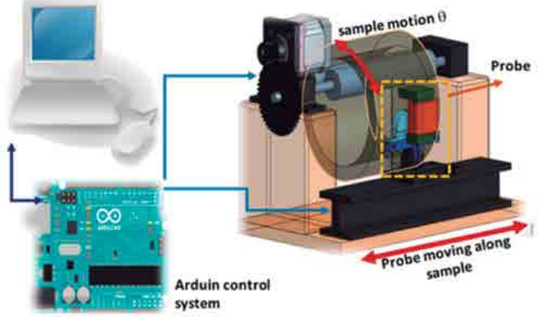
EVALTUBES

Remaining Life Evaluation of Catalytic Furnace Tubes

In this work non-destructive testing techniques (NDT) based on eddy currents are used to inspect pipes made of austenitic steel, subject to conditions (temperature and pressure) very demanding and originating material degradation. These methods enable detection with high sensitivity of defects not only fatigue but also the initial appearance of intermetallic phases, which when correlated with the microstructural changes occurring during the service time, enable to assess the state of the material and predict its remaining life.



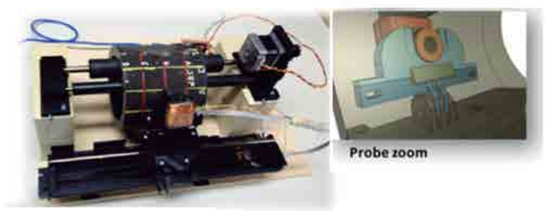


Photo of the implemented system

Main Project Team

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Indicators

Funding	46k €
Journal papers	5
Conference papers	7
Concluded PhD	1

Two Main Publications

C. S Angani, H. Ramos, A. L. Ribeiro, T. Rocha, Transient eddy current oscillations method for the inspection of thickness change in stainless steel, "Sensors and Actuators A-Physical," Vol. 233, No. 9, pp. 217 - 223, September 2015.

D. Pasadas, A. L. Ribeiro, T. Rocha, H. Ramos, Remote field eddy current tube inspection using giant magneto-resistance sensors, "International Journal of Industrial Electronics and Drives", Vol. 1, No. 3, pp. 167 - 173, July 2014.

PROJECT WEBPAGE URL

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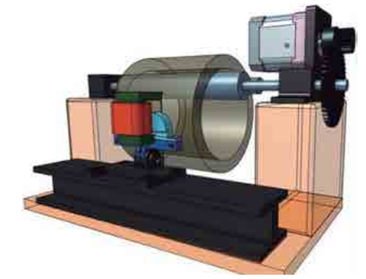

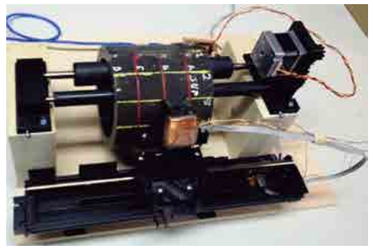

Fig. 1 Eddy currents based system to characterize HP Steel.

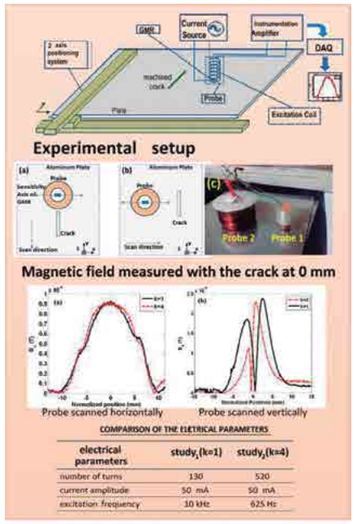

Fig. 2 Detection of cracks by eddy current testing based on dilation invariance principle.

GENERAL MOTIVATION AND OBJECTIVES

The objective of this project is to evaluate from the output surface the damage of the catalytic tubes of the columns of the reformer furnaces in order to predict its remaining life. Catalytic tubes are the most critical components in reformer furnaces. Reformer furnaces are widely used in the petrochemical industry to produce hydrogen from hydrocarbons. It is in the radiant tubes containing a catalyst that the hydrogen production takes place, as a result of endothermic reactions between hydrocarbons (mostly methane) and water vapor. These reactions proceed at a temperature range between 800 and 900ºC and the working pressure in a reformer furnace is between 2 and 5 MPa. These are severe working conditions that cause structural damage in the tubes. It is necessary to develop methods for the inspection of tube degradation and for a realistic prediction of its residual life.

This project assesses the conditions of the material of the tubes using eddy current testing (ECT). The proposed method is based on the application of magnetic fields that vary in time to diffuse into the interior of the material to give rise to a secondary field, which is accurately measured on the outer surface of the conductor. The singularities of this secondary field are related to the properties of the material and with its geometric shape. Indeed, ECT is the most appropriate method due to its high sensitivity and also because, as it depends on the material properties, it is potentially able to detect the changes that precede the appearance of defects within the tubes material.

CHALLENGE

The in-service inspection from the outer surface of the tubes of the columns of the reformer furnaces is a difficult problem to be solved that leads to cutting edge research. Two limit conditions exist:

1) Thickness of the tube, which can vary from 10 to 20 mm, that surpasses the limit capacity of detection of currently existing ECT commercial equipment;

2) Detection of the microstructural changes that initiate within the tube wall some two thirds of the way through from the outer surface;

3) Accurate correlation between the results obtained with the non-destructive tests based on "eddy currents" and the micro-structural characteristics.

The work carried out by the IT team complements the work of colleagues from the Laboratório de Ensaios Não Destrutivos, Corrosão e Soldadura of the Universidade Federal do Rio de Janeiro on the failure analysis and remaining life assessment of the tubes based on the microstructural observations.

WORK DESCRIPTION AND ACHIEVEMENTS

The methodology adopted to execute the project involved modeling, experimental and theoretical issues.

A theoretical study based on electromagnetic field theory was developed to scale the quantities and the geometrical parameters involved in the laboratory setup. Results obtained at this stage provided valuable data for the design and implementation of the full scale measurement system.

Commercial software to simulate physical models based on electromagnetism (as OPERA 3D and FLUX Modelling) was used to model the electromagnetic behavior when different probes were used. The design of the probes and the test specimens was developed accordingly.

A prototype able to scan the outer surface of a piece of furnace tube, taken from a furnace tube after several years of use, was developed and implemented. The experimental work was carried out at the laboratory with this "pilot set".

Two main achievements were attained:

1) A theory able to describe how all the quantities (including the electromagnetic) change when a geometrical transformation (dilatation) occurs was established.

2) A measuring system that by inspection from the outer surface recognizes defects and microstructural changes at an early stages in the tube inner wall.