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MAGNETIC CHARACTERIZATION OF HEAT-RESISTANT AUSTENITIC STEELS BY USING AN OWN EDDY CURRENT SYSTEM

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ABSTRACT

In this study, different microstructural conditions of an HP centrifugally cast austenitic stainless steel were determined based on the alteration of its electromagnetic properties. The eddy current testing (ECT) method, based on a Hall sensor as a detector, has been developed to detect changes in the electromagnetic properties of an austenitic steel samples. Results suggest that the proposed method is a potential non-destructive method for the characterization of heat-resistant austenitic steels with different microstructural condition.

Keywords: heat-resistant steel, non-destructive inspection, eddy current testing.

INTRODUCTION

Heat-resistant austenitic HP steel tubes are commonly used in steam reformer furnaces. As they are exposed to harsh environmental conditions, their microstructure changes as a function of the service temperature [1]. According to the operational temperature, the as-cast steel undergoes several microstructural changes that contribute to decrease the tubes remaining life, being important to evaluate the properties of the steam reformer tubes in order to avoid unwanted failures and huge economic losses. Microstructural variations also carries electromagnetic properties changes [2], which suggests that electromagnetic non-destructive testing methods can be applied to correlate the microstructural condition with the magnetic response of the steam reformer tubes. For this purpose, an eddy current testing (ECT) system has been developed to test three specimens extracted from the same reformer tube that was in service during 90,000 hours. The samples were taken from three different regions of the furnace operating at temperatures close to 600 °C, 700 °C and 1,000 °C, respectively. The experimental results show a clear change in the amplitude and a phase-shift in the magnetic field values measured according to each microstructural condition. This study suggests that ECT can be a reliable method to correlate the changes of electromagnetic properties with the microstructural condition of the reformer tubes.

RESULTS AND CONCLUSIONS

Figure 1 shows the block diagram of the eddy current system that was developed and used to characterize the test samples. The system consists of a current generator to drive the probe, an amplifier to amplify the Hall-sensor output voltage and a data acquisition system to acquire the data with a sampling rate of 1.2 MS/s. The probe consists of a pancake excitation coil and a Hall sensor placed at bottom axial center of the excitation coil in order to detect the magnetic field, which is perpendicular to the surface of the test specimen. The probe has a sinusoidal excitation current with 100 mA of amplitude at 2 kHz.

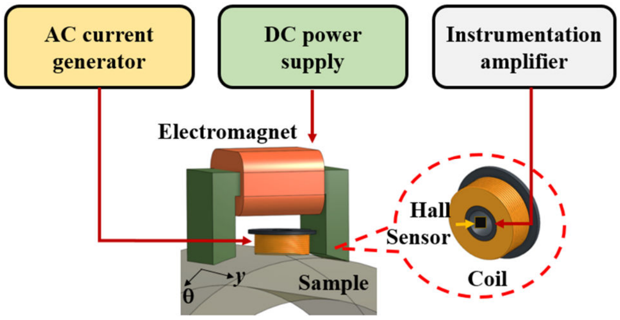

Fig. 1 - Schematic diagram of the eddy current system.

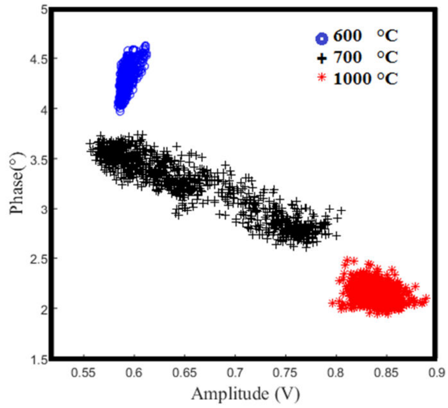

Fig. 2 - Amplitude vs. phase-shift in samples exposed to different temperatures.

Two features, i.e., the amplitude and phase-shift (between excitation field and sensed magnetic field) were obtained to interpret the experimental results and used to determine the magnetic response of each sample. A current sampling resistor of 10 Ω is connected in series with the coil. The voltage drop across this resistor is used to calculate the phase difference between the coil current and total magnetic field (Hall-sensor voltage). The amplitude and phase-shift values of the magnetic field correspond to 1000 evenly distributed points taken over the tubes surface. Data was obtained by scanning the perimeter and length in each of the three tubes exposed to temperatures of 600°C, 800°C and 1000°C, as shown in Figure 2. From the graph, it is observed that three different samples are clearly distinguishable. According to these results, one can conclude that the change in the electromagnetic properties of the samples can be related with microestrutural variations caused by the service temperature.

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