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Detection of defects in steels using eddy currents

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Abstract: Despite the advent of new materials, carbon steel remains of paramount importance to the industrial world. Materials are the source of numerous defects during their processing, as well as during their use under the action of fatigue, corrosion, and accidents. Non-destructive testing is used to detect, in a part, without damaging it and while respecting its integrity, any particularity of its structure that could influence its behavior in service. Visual inspection is the simplest of all non-destructive testing techniques. External defects can be indicated by penetrating or magnetic methods. Internal defects are highlighted by ultrasound or radiography. The purpose of this work is to study the method of non-destructive testing by eddy currents, in order to evaluate its performance in the industry.

Key words: magnetism, eddy currents, welding, sensor, defects.

1. Introduction

Manufacturers are closely monitoring developments in the field of material assessment, subject to stresses that may arise during growth, manufacturing, or use. During operation [1, 4, 6, and 7], materials undergo damage that is detrimental to performance and performance. To anticipate material degradation throughout the lifecycle of various equipment and prevent the occurrence of defects in service, samples are characterised using the non-destructive eddy current method.

2. Principles of Eddy Current Control

The passage of a variable current through a coil generates a magnetic field; the propagation of this field in a conductive piece induces eddy currents, which in turn create a magnetic field that opposes the excitation field.

The interaction between the two fields causes a variation in the coil's impedance, and the measurement of this impedance is the basis of eddy current non-destructive testing [2, 3, and 5] (Fig.1).

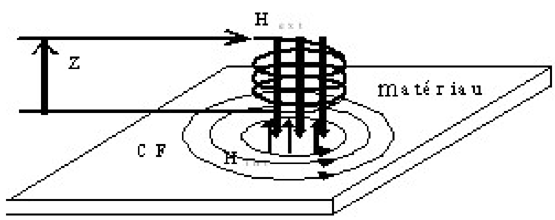

Fig. 1 principle of eddy currents

3. Realization of defects

Welding is an operation consisting of assembling two or more parts of a system, in order to ensure continuity. Electric arc welding is the most widely used industrial process for assembling steels. It is carried out using an electric arc, created and maintained between the metallic core of the electrode and the workpiece to be welded. An electric generator supplies the current; its

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intensity depends on several parameters, such as the diameter of the electrode, the nature of the coating, the welding position, the type of assembly, the size and grade of the parts to be assembled (Fig.2).

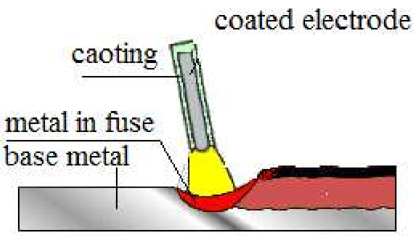

Fig. 2 Arc welding

Defects will be intentionally created by a qualified welder on samples. An X-ray radiographic inspection will be performed on all the parts (see Fig.3 and Table 1).

Table 1 Defects produces

Landmark	Interpretation
1	Ideal sample
2	Tungsten inclusion
3	Vermicular Blowers
4	Slag inclusion
5	Elongated blow
6	porosities
7	Incomplete fusion

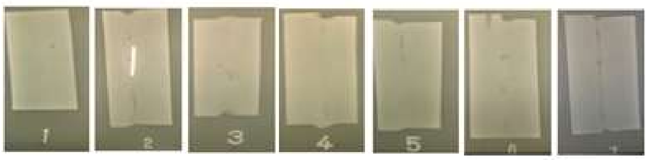

Fig. 3. radiogram of the samples

4. Sensor developments

We have developed a program that allows for the characterisation of the probes performed and, simultaneously, the acquisition of data during the control; while ensuring the automated management of the various devices used (see Table 2, with the first colon is diameter in mm, second colon is wire diameter in mm, and third is probe length in cm).

Table 2 Sensors

Diam	wire diam	Probe length	L(mH)	R(Ω)
3.4	0.123	4.4	1.354	39.278
3.4	0.123	3.9	1.222	34.276
2.6	0.123	2.8	0.053	21.765
1.8	0.123	1.9	1.258	28.688
1.1	0.123	1.3	2.076	24.613
1.5	0.23	1.5	6	13

The diameter of the winding wire was chosen in such a way as to increase the self-inductance of the sensors (increasing the number of turns), and to reduce the resistance value (heating due to the Joule effect). The use of ferrite as the core (support) of the sensors allowed.

Fig.4 highlights the plots of the normalized impedance diagrams of the chosen probe on all the specimens produced; we observe that the maximum energy exchange occurs in the middle of the curve, where the ratio of the reactive parts tends towards unity, which is equivalent to a frequency of 1kHz.

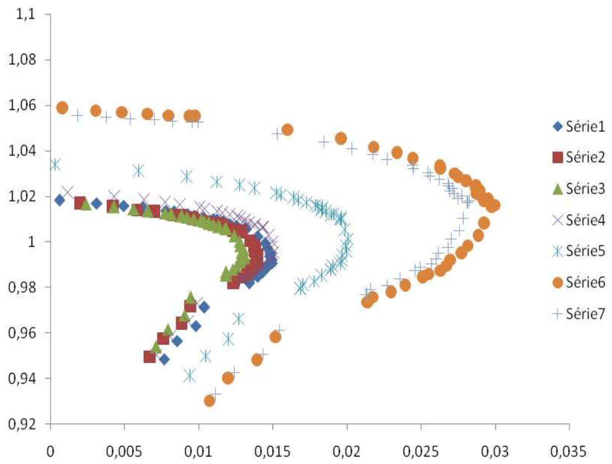

Fig. 4 Normalized Impedance Diagram

5. Result and discussion

The two-dimensional representation of the results of the eddy current inspection was done using a program written in MATLAB, allowing the presentation of the x and y coordinates of the parts to be inspected based on the values of the resistive or inductive components of the sensor's impedance collected during the inspection operation (Fig. 6, 7, 8, 9, 10 and 11; designation: default; see Table 1).

It is observed that defects such as porosities and blowholes, regardless of their nature, tend towards the same color (Fig. 7, 9, and 10), whereas a tungsten inclusion, which is a ferromagnetic metal, stands out from all the other samples (Fig. 5).

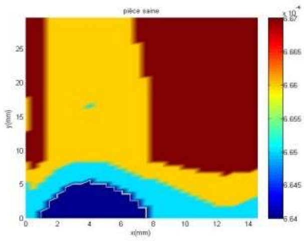

Fig. 5 Flawless

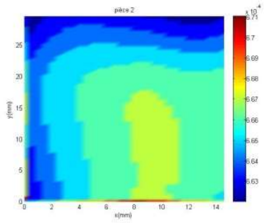

Fig. 6 Tungsten

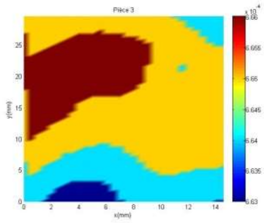

Fig. 7 Vermicular blowhole

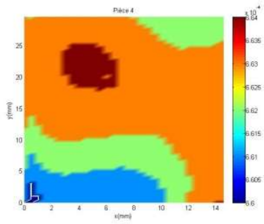

Fig. 8 Slag inclusion

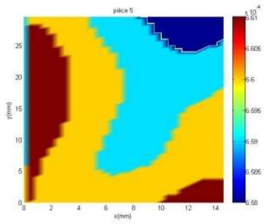

Fig .9 Elongated blowhole

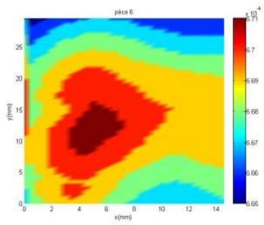

Fig. 10. Porosity

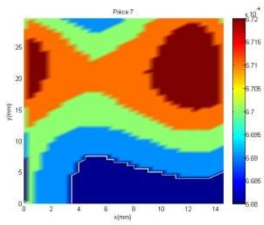

Fig. 11 Unmelted surfaces

6. Conclusion

The sensitivity to defects and other inspection parameters can be modified by the probe design. All that is required is to establish the direction of eddy current flow, adjust the magnetic field intensity and select the appropriate coil size for the geometry of the part to be tested.

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