



# Detection of Defects Using GMR and Inductive Probes

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**Abstract.** Eddy current testing (ECT) is one of the most extensively used non-destructive techniques for inspecting electrically conductive materials at very high speeds that does not require any contact between the test piece and the sensor. However, the characterization of a crack is not easy to obtain, and for this purpose, other eddy current evaluation methods are still under investigation.

This work introduce a new eddy current testing technique for surface on near surface defect detection in nonmagnetic metals using giant magnetoresistive (GMR) sensors. It is shown that GMR-based eddy-current probes are more sensitive than the Inductive probes to determinate the cracks dimensions that were machined on aluminum plates.

**Keywords:** Giantmagneto-resistorsensor · Eddy current testing (ECT) · Non-destructive testing · Crack detection

## 1 Introduction

ECT is widely used to inspect the presence of cracks in metallic structures [1]. Those materials are important to monitor how some previously known cracks and characterize theme, also localize the very small defects less than 100  $\mu\text{m}$  and inside maximum in those materials. The delicate measurement of crack's location is quite difficult and has been the field of study of several researchers [2]. To develop the performance of the inspection of metallic structures using ECT [4], the probe with best properties [3, 4] excitation signals methods [5] and signal processing techniques [6] are still under investigation. ECT is generally used with high-frequency magnetic fields, above kilohertz order, or search coils [7]. High-frequency magnetic fields are suitable for identifying surface defects. In order to apply ECT to examining defects in depths, it is necessary to use a low-frequency magnetic field. However, it is difficult to sense a weak signal due to a defect by using a low-frequency magnetic field because the sensitivity

of the search coil is not very high [4]. For this reason, other sensitive sensors for weak magnetic fields are desired. Recently, in our system we testing defects in samples by using a low-frequency magnetic field, an MR and inductive sensor, and a lock-in amplifier [8, 10]. This system has sensitivity of sub-nanotesla order in a non-shielded environment. In this study, we measured the length of cracks machined in plate of aluminum; we use two types of sensors inductive and GMR probes in the same condition of experience (frequency 20 kHz) and we use the (same coil) for the excitation with the GMR.

## 2 The Experimental Setups

The experimental setup is depicted in Fig. 1, including a pancake coil with Ferrite pot (external radius: 9 mm, internal radius: 4.7 mm, number of turns: 175 and height: 2.2 mm) manufactured by SCIENSORIA, an MR sensor (Giant magneto-resistor).type AAH004 00 manufactured by NVE is inserted along the coil axis, with the sensing direction perpendicular to the plate. With an active area about 100 by 200 mm in the middle of the layout [10]. Their characteristics of coil and MR are presented in Tables 1 and 2.

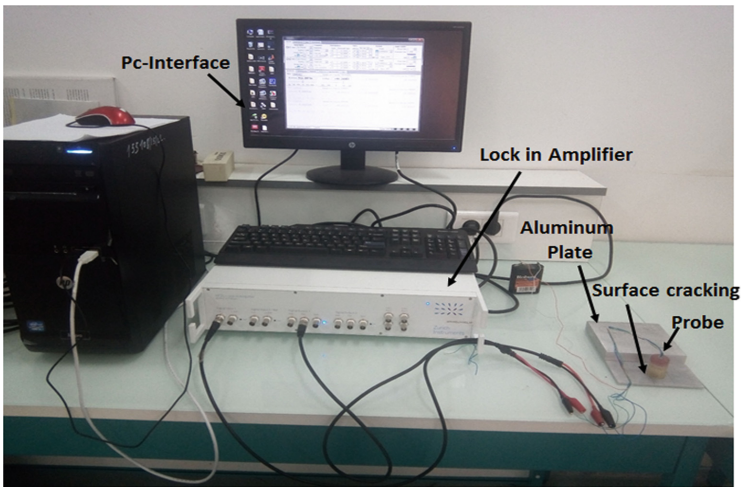


Fig. 1. Measuring system.

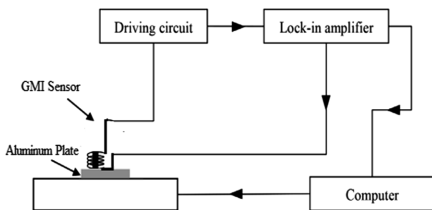
**Table 1.** Geometric parameters of the coils and their pot

	Dimension coil
Inside radius	4.7 mm
Outside radius	9 mm
Length of coil	2.2 mm
Number of turns	175
Number of layers	14
Diameter of wire	0.14 mm
	Ferrite pot size
Material	T6
Core diameter	4.6 mm
Internal ring diameter	9.1 mm
Internal height	2.5 mm
Permeability	$\mu_r = 4000 \pm 25\%$

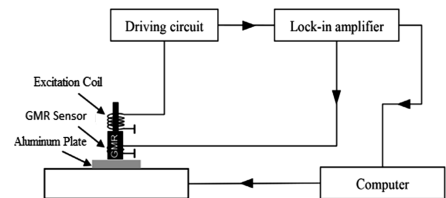
**Table 2.** Geometric parameters of the GMR sensor

	Dimension GMR NVE AAH004 00
Saturation	1.5 mT = 15 Oe
Sensitivity	32–48 V/T/V
Linear range	0.15 and 0.75 mT
Resistance	2 K $\pm$ 20% (ohms)
Power supply	9 V
Package	MSOP8

A lock-in amplifier is also source of alternating current (AC source) [9], arranged as shown in Fig. 1. The applying coil are for applying an alternating magnetic field to the sample. The coil is connected to the lock-in amplifier. The lock-in amplifier is connected with the MR sensor. The signal detected from the sample, which includes amplitude, is referred to that of the alternating current source. In this experiment, the general procedure consists in scanning the area including cracks to determinate the Length. Firstly, we scanning with GMR probe depicted in Fig. 2. The same measurement was done with a Inductive probe, the scanning with the same excitation coil, which depicted in Fig. 3. In this way. Depicting the variations of the tension recorded as measured on the scanned area. This variations useful information about the crack’s characterization.

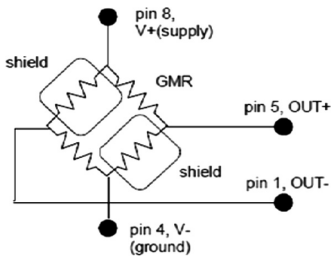


**Fig. 2.** Schematic of the experimental setup for the ECT system with Inductive Probe.

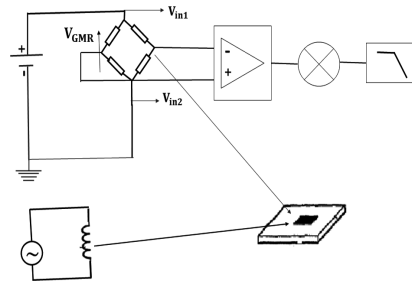


**Fig. 3.** Schematic of the experimental setup for the ECT system With GMR Probe.

Figure 4 depicts the internal configuration of the giant Magneto-resistor sensor AAH004-00 produced by non-volatile electronics. Four giant magneto-resistors are connected in a bridge configuration, with two of them magnetically shielded. Figure 5 depicts Schematization of the measurement system explained the Block diagram of the experimental setup.



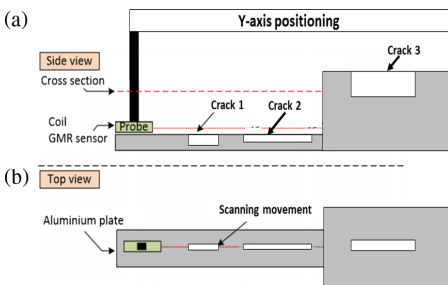
**Fig. 4.** Giant magneto-resistor bridge sensor.



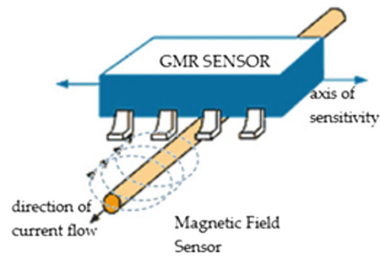
**Fig. 5.** Schematization of the measurement system.

### 3 Results and Discussion

ECT exploits the phenomenon of electromagnetic induction. A time varying current passing through an excitation coil will produce electromagnetic field. If an electrically conductive material is in the proximity of this electromagnetic field, an eddy current will be induced in the material. If a flaw exists in the testing sample, the amplitude and the distribution of the eddy current will be changed. Figure 6 depicts the scan tests that were performed to evaluate the conditions of the material. Three surface cracks were machined in the aluminum plate crack 1, 2 in plate 1 (thickness = 4 mm) crack 3 in plate 2 (thickness = 20 mm), and their dimensions are presented in Table 3. The scanning tests were performed along of the cracks in a direction of the sensitivity of GMR sensor with depicts in Fig. 7 because it is the region where the maximum perturbation of the x component of the magnetic field ( $B_x$ ) occurs.



**Fig. 6.** Representation of the performed scan: (a) Side view; (b) Top view.



**Fig. 7.** Representation of the sensitivity direction of GMR Sensor

**Table 3.** Dimension of the cracks in plate

	Width	Length	Depth
Crack 1	0.5 mm	10 mm	2.75 mm
Crack 2	0.5 mm	15 mm	1.5 mm
Crack 3	1 mm	14 mm	5 mm

A large increase in the output voltage of the GMR and inductive sensors circuit was observed when the sensor was moved on the top of the crack, after the further movement of the sensor the output voltage came back to the nearly previous value. Figures 8, 9, and 10 show variation of the sensors output as a function of the position of the sensor. The largest change in the sensor output was observed with GMR sensor then the inductive sensor. If the materials do not have any crack, no significant variation in the sensor output was measured. Because all magnetic flux lines pass through the material due to its higher permeability.

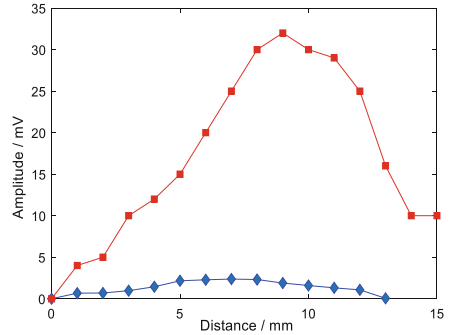
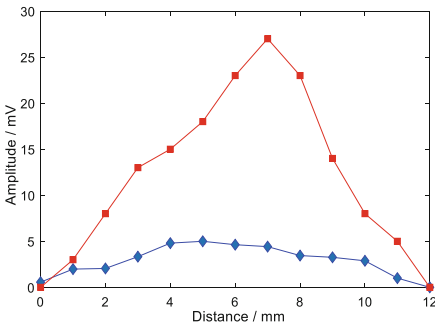


Fig. 8. GMR Inductive output voltage (crack 1). Fig. 9. GMR Inductive output voltage (crack 2).

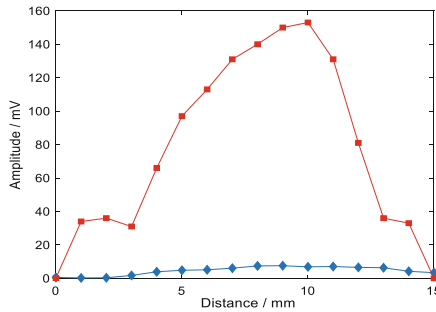


Fig. 10. GMR Inductive output voltage (crack 3).

### 4 Conclusion

Experimental tests were performed to evaluate surface cracks in aluminum plates, using mono-frequency excitation signal to compare both Inductive and GMR sensors were used for the detection. The analyses of the results were presented in the tension. For a 4 mm of aluminum plate thickness allowed the detection of surface and cracks with different depth (1.5 mm, 2.7 mm) and the second aluminum plate with 20 mm including crack of (5 mm). The results obtained confirmed that the GMR sensor-based eddy-current probes are more sensitive than the Inductive probes to determinate the

cracks dimensions. Therefore, it is easy to obtain information about characterization of cracks (Depth, Length, Width, position...). So the GMR sensor give good results with the ferrite coil and we observed them in other works before. As future work, we are going to extend this technique to characterize very small defects less than 100  $\mu\text{m}$  inside in non-ferromagnetic metallic structures.

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