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# Non-destructive Crack detection using GMI sensor

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In this study, the variation of the magnetic flux distribution in a magnetised ferromagnetic material which has inhomogeneity as a crack is studied using giant magnetoimpedance, GMI, sensor. The sensor was moved by a specially designed moving system. The amorphous $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ wire was used as a GMI sensor and 1 MHz with 5 mA ac current applied to the GMI sensor. A large decrease in the output voltage of the sensor 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.



## 1 Introduction

Non-destructive evaluation systems have been widely utilized for inspection of many materials used in safety-critical applications. Magnetic non-destructive testing methods such as eddy current testing and the residual magnetic field technique are useful methods for the prevention of accidents due to break of mechanical parts in the machines, and also useful for the prolongation of the service life-time of a structure [1, 2].

The microstructural changes induced in a thermal or stressed environment and cracked region of industrial applications and moving machine parts are often degradation of the mechanical properties of steel. The giant magnetoimpedance sensor can be used either to detect magnetic fields created by current passing through conductors or to detect localised magnetic fields non-destructive testing applications [3]. The occurred discontinuity resulting from a crack also produces disturbance in the magnetic field in the material, and the magnitude of the disturbance is determined by the size and shape of the crack. The giant magnetoimpedance property of the amorphous wire can be to capture cracked regions in the materials [4].

## 2 Experimental details, results and discussion

$Fe_{71}Cr_7Si_9B_{13}$ Giant magnetoimpedance effect in amorphous wires is now widely exploited in the design of new magnetic field sensors. In this study, the amorphous $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ wire was used as a GMI sensor and 1 MHz with 5mA ac current applied to the GMI sensor. Generally, wires with 2–3 mm length were used as a magnetic field sensor to detect magnetic field variation in small scale. But, the wire with a smaller length show smaller GMI effect and consequently less sensitive magnetic field sensor due to the increase in the shape anisotropy. In this study, 10 cm length FeCoSiB wire was used as a GMI sensor and the wire was bended to U-shape as shown in Figs. 1 and 2b. Two ends of wire were connected to a signal generator and a digital voltmeter. The tip of U-shaped wire was nearly touched the

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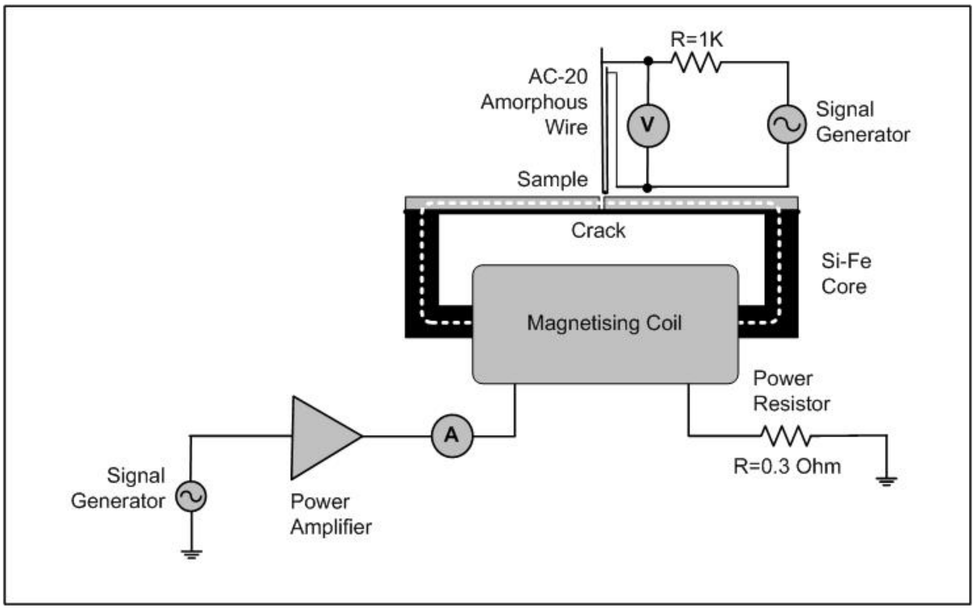


**Fig. 1** Schematic diagram of the crack detection system.

ferromagnetic sample with a crack. The main advantage of this arrangement is that the output of the wire sensor is sensitive to the applied magnetic field from any direction [5].

An experimental setup has been used to capture cracks in a material as shown in Fig. 1. C-core was used to magnetize the system along the length of the sample. Cross sectional faces of both limbs were touched to the sample surface to transfer magnetic flux lines from limb to the sample. C-core was made from 3% Si-Fe laminations with 110 mm limb length with 1200 $mm^2$ cross-sectional area of limbs and 220 mm distance between the limbs. $N_1$=110 turn magnetisation coil was made on the C-core to get magnetisation in the core. Number of crystalline 3% Si-Fe lamination sheets have been used to simulate cracks in the material. Lamination sheets with 0.35 mm thickness, 30 mm width and 150 mm length have been stacked on each other to simulate full and half cracks.

1.6 mm wide crack has been made in the middle of the sample and the crack was located along the sample of the cross section as a full crack. 2 mm wide and 1.6 mm deep crack is also prepared in the middle of the sample and called as a half crack as shown in Fig. 2(b).

C-core was magnetised by applying an ac current to the 100 turn magnetisation windings. Therefore, an ac magnetisation was occurred in the core because of the reorientation of the magnetic domains along the flux lines. During this progress variation of flux density ($(dB/dt)\neq 0$) in time becomes greater than zero. Magnetic flux lines follow closed magnetic circuit, than jump to the sample from the C-core limbs and flux flows in the core up to meet a crack. The normal component of the flux gets bigger around the cracked region. An amorphous wire has been used to capture normal component of magnetic flux lines. The wire connected to a high frequency signal generator over a 1kΩ resistor. A digital voltmeter and oscilloscope were also connected to both ends of the wire to measure variation of signal due to GMI effect as shown in Figure 2b. The amplitude of the measured signal was changed when amorphous wire captured the normal component of the magnetic flux on the surface of the magnetised sample and that means a crack or scratch is located around the wire. When a crack or a scratch somehow occurs on the material, a discontinuity suddenly appears and normal component of magnetic flux becomes greater than zero instead of a signal becoming big enough to occur a giant magneto impedance effect in the amorphous wire. Therefore, a signal variation could be read from the digital voltmeter and oscilloscope.

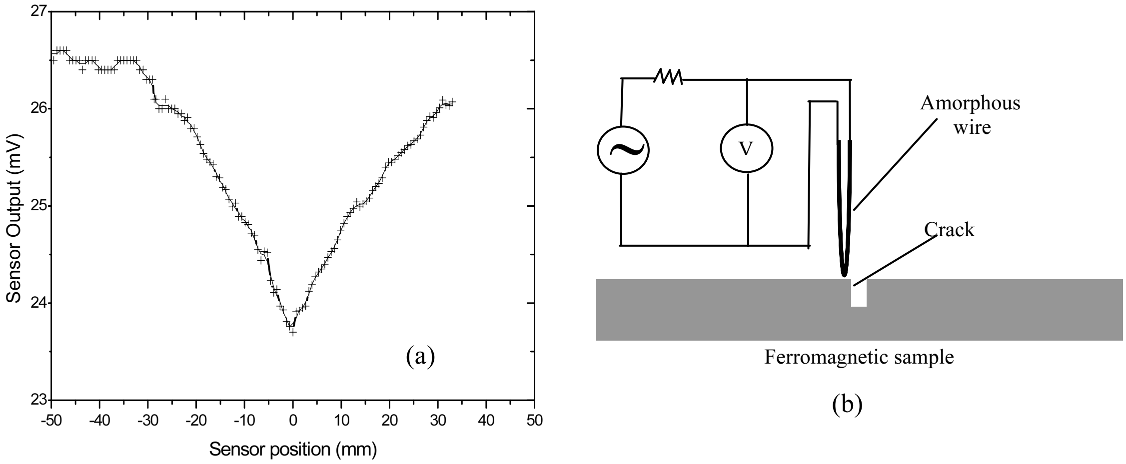


**Fig. 2** a) GMI sensor output as a function of the position of the FeCoSiB wire sensor at 1 MHz driving current frequency b) Circuit diagram of the amorphous wire as GMI sensor and simulation of half crack.

A large decrease in the output voltage of the sensor 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. Figs. 2 and 3 show variation of the GMI sensor output as a function of the position of the wire sensor. The measurements were performed at various ac current frequencies. The largest change in the sensor output was observed at 5 MHz driving current frequency. If the magnetised materials have not got any crack, no significant variation in the sensor output was measured (Fig. 3). Because all magnetic flux lines pass through the material due to its higher permeability.

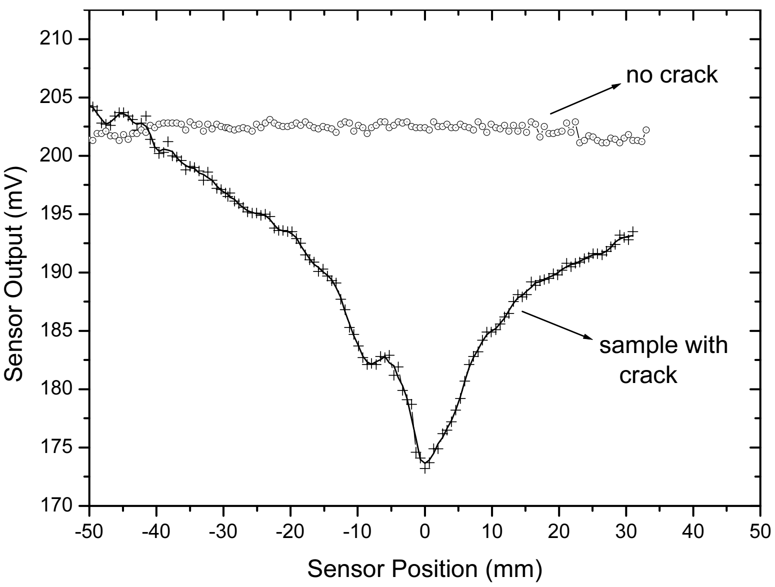


**Fig. 3** GMI sensor output as a function of the position of the FeCoSiB wire sensor at 5 MHz driving current frequency for samples with crack and without crack.

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