Effect of a backplate on SH-wave generation in EMATs

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1. Introduction

An electromagnetic acoustic transducer (EMAT) can generate or detect ultrasonic wave in electrically conductive or magnetic materials by means of Lorentz force and/or magnetostriction effects. EMATs are non-contact transducers that allow fast moving inspection under hot and a hostile environment. Especially, horizontal polarized Shear-waves (SH-waves) are useful for NDE of dissimilar or anisotropic austenitic inspection due to absence of mode conversion as compared to SV- and L-waves.

The efficiency of the EMAT ultrasonic generation and detection is dependent on the whole system including a coil, a magnet, current pulse generator and samples. Also, it is well known that a lift-off between a metal sample and the exciting coil has an influence on eddy current generation between the coil and the metal sample, the equivalent coil inductance[1-3].

If there is no electrically conducting backplate between permanent magnet and EMAT exciting coil, ultrasonic wave may occur within the electrically conducting magnet as well as a metal sample by means of Lorentz force from the interaction between an eddy current with the static magnetic field and/or magnetostriction due to the dynamic field by EMAT exciting coil. Then, the ultrasonic generation in the magnet can cause the unwanted signal from a metal sample[1,2].

The purpose of this research is to investigate the influence of the metal backplate on SH-wave generation by EMATs. Also, we investigate the response of the EMAT system to some changes in a design parameter such as an air gap between EMAT exciting coil and magnet

2. Theoretical background

2.1 EMAT coupling mechanism

By the definition of coil inductance, the electric potential in the coil is given by

$$V = -L_{eq}\frac{\partial i}{\partial t} \tag{1}$$

The equivalent coil inductance depends on three factors, this can be described by

$$L_{eq} = \frac{\Phi(t)}{i(t)} = L - L_m + L_\chi \tag{2}$$

Where L , L_m and L_χ are self inductance, eddy current related inductance and magnetization related inductance, respectively.

The equivalent inductance of coil depends on the electrical conductivity and magnetic susceptibility of the conductive material and the geometry of the coil and lift off etc. arising from the coupling mechanism [2,3].

2.2 Experimental setup

Fig. 1 shows a wave generation mechanism and physical model of typical EMAT consisted of a magnet, a coil, and an electrically backplate positioned between the coil and the magnet. The backplates are used to shield from an eddy current generation in the magnet by EMAT exciting coil. Where the air gap is defined as the distance between the coil and the backplate, and the liftoff is defined as the distance between the coil and the sample.

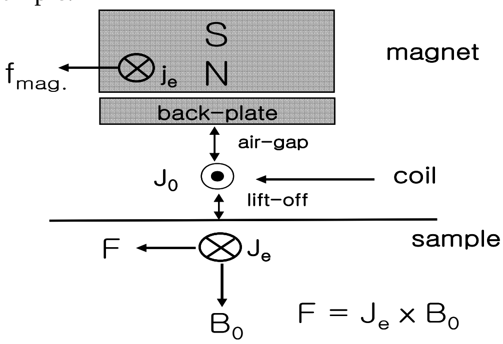

Fig. 1. Mechanism of ultrasound generation by EMAT and physical model of a typical EMAT.

Inspection sample is aluminium(Al), which is 4.9 mm of thickness. Backplates are aluminium(Al), copper(Cu) and steel(Fe) and thickness of all metal backplate is 0.1 mm. The lift-off between coil and sample is fixed at 0.1 mm.

A scene of the experimental setup is shown in Fig. 2. The EMAT is connected to High power pulser/Receiver (Ritec, RPR-4000) with 2.7 MHz of an exiciting pulse and 64.8 dB of receiver gain. A NdFeB permanent and a rectangular elongated coil are used.

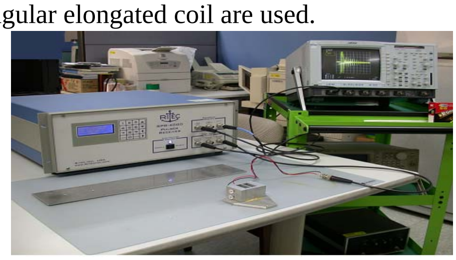

Fig. 2. Photography of the experimental setup.

3. Results and discussions

Fig. 3 shows the measured ultrasonic generation from the permanent magnet with several different backplate by an exciting coil. As shown in Fig. 3(a), we measured an ultrasonic wave generated in permanent magnet without backplate and a metal sample. This noise signal can affect the evaluation of collected signals from a metal sample. For a reduction of the unwanted signal generation in magnet, this noise signal generated in magnet can be reduced by inserting an electrically conducting backplate between the magnet and coil, as shown in Fig.3(b), (c) and (d).

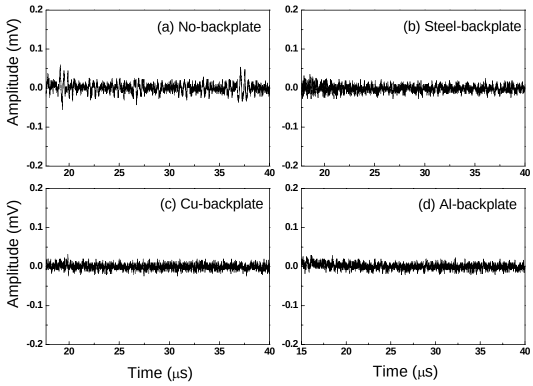

Fig. 3. Measured ultrasonic waves from the permanent magnet with several different backplates of EMAT without an aluminium sample.

Dependence of several air gap on normalized amplitude of ultrasonic wave in Al sample for backplate of Cu is shown in Fig. 4. The ultrasonic amplitude increases by about 41 % as air gap increases up to 0.5 mm. however, in the region above 0.5 mm, ultrasonic amplitude decreases with increasing air gap.

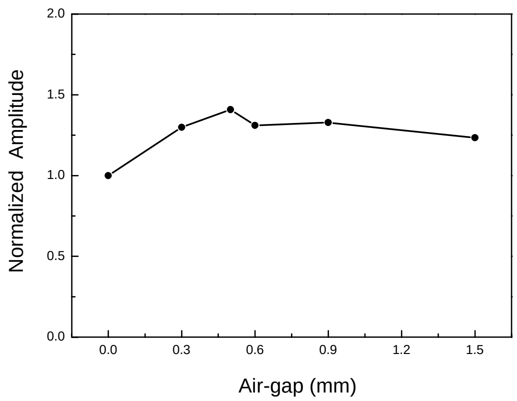

Fig. 4. Dependence of ultrasonic amplitude in aluminium sample for backplate of copper with respect to air gap.

From the result obtained in Fig. 4, the liftoff between the coil and the magnet, and the air gap between the coil and the sample is fixed at 0.1 and 0.5 mm, respectively

Fig. 5 shows the ultrasonic wave in an aluminium sample with different metal backplates. It is found that SH-wave with a Fe backplate and a Cu backplate are increased about 30 and 23 % in amplitude, respectively in comparison with that of no backplate. This result can be considered by reduction of noise signals as shown in Fig. 3(b), (c) and (d).

Furthermore, the enhancement of SH-wave generation with a metal backplate can be explained by decreasing coil impedance depending on material physical properties such as electrical conductivity and magnetic susceptibility.

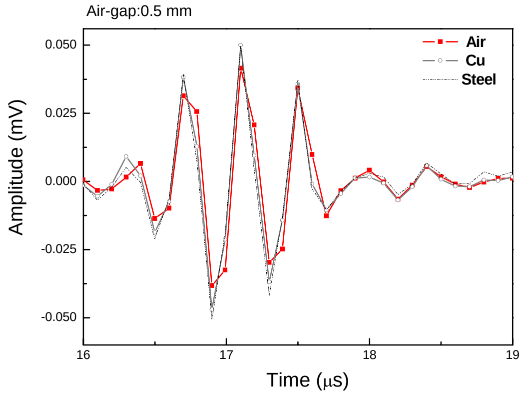

Fig. 5. Measured ultrasonic wave in an aluminium sample at a air gap of 0.5 mm between the coil and the permanent magnet for several different backplates.

4. Conclusion

The air gap in the optimal SH-wave generation efficiency with the metal backplates and 0.1 mm of liftoff is at 0.5 mm. By inserting a metal backplate between the magnet and the coil, the noise signal generation in magnet can be reduced.

It can be concluded that the use of the metal backplate is effective to fabricate the advanced EMAT

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