Enhanced Acoustic Emission Technology Induced by Electromagnetic Stimulation with External Magnetic Field

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Abstract — This paper introduces a new electromagnetically induced acoustic emission technology (EMAE) enhanced by an external magnetic field. The external magnetic field generated by Nd-Fe-B magnet can improve the ability of detecting the defects, due to the even bigger deformation generated by the enhanced Lorentz Force. In this paper, the finite element model of EMAE including an external magnetic field has been implemented in accordance with the practical experiment models. The sample's deformation has been analyzed when the exciting coil locates at different positions. The experiment of EMAE is built according to the FEA results. Experiments' outcomes indicate that the defect itself can generate modulated acoustic emission signals, which could be used to boost the detection ability of small cracks in the thin-walled metallic structures.

I. INTRODUCTION

The tradition Acoustic Emission Testing Technology evaluates the defect by monitoring the components in work or loading the whole structure. Acoustic Emission (AE) sensors will receive AE signals from the whole component. The received signals contain a lot of noise. That makes the processing of AE signal very complicated and reduces the reliability of AE Testing Technique and positioning accuracy. The signal processing only needs to deal with the AE signal from the tested areas by using electromagnetic coil as the local exciting source [1]. So, the influences of AE signals and noises can be reduced from the undetected region.

Based on [2], the paper discusses a method to produce the elastic wave by means of transient electromagnetic stimulation induced by a coil. The current and deformation at the cracks are analyzed by the finite element method when the coil is at different positions. The experimental results show the electromagnetic exciting can stimulate the defect itself to produce the elastic wave and the deformation can cause the temporal modulation of AE signals at the crack. This technology can be used to increase the ability of detecting cracks in metal sheet and strengthen the capability of the Acoustic Emission Technology to detect the defect.

II. MECHANISM OF LOCAL ELECTROMAGNETIC STIMULATION OF ACOUSTIC EMISSION

Fig. 1 shows the experimental setup of electromagnetic induced Acoustic Emission. A hole with a triangular crack is the typical defect in thin-walled metallic structures. A coil is used to introduce the dynamic electromagnetic exciting (eddy currents). Two AE sensors are used to receive the ultrasonic signal. An external magnetic field B generated by Nd-Fe-B magnet is normal to the defect plane for enhancing the electromagnetic forces.

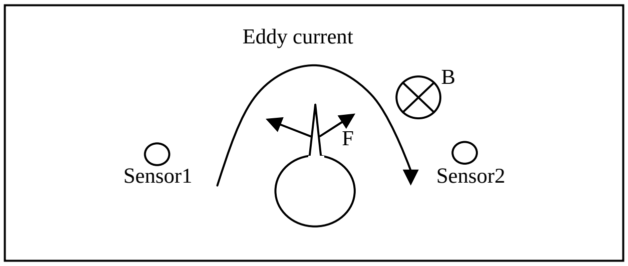

Fig. 1. Experimental setup of electromagnetically induced acoustic emission

The EMAE uses the electromagnetic exciting to generate the Acoustic Emission signals, which is an electromagnetic-stress coupling process. The acoustic wave equation of the isotropic elastic medium is below:

$$\frac{E}{2(1+\mu)}(\nabla^2 u+\frac{2\mu}{1-2\mu}\nabla(\nabla\cdot u))+F=m\frac{\partial^2 u}{\partial t^2} \qquad (1)$$

III. SIMULATION ANALYSIS AND DISCUSSION

The model is a piece of rectangular aluminum sheet with a radial crack and a hole in its center. Differences of the deformation will be reflected in the intensity of Acoustic Emission signals because Acoustic Emission signal is due to the expansion or vibration of cracks caused by the deformation. So, we can calculate the deformation to get the law about the AE and the coil position.

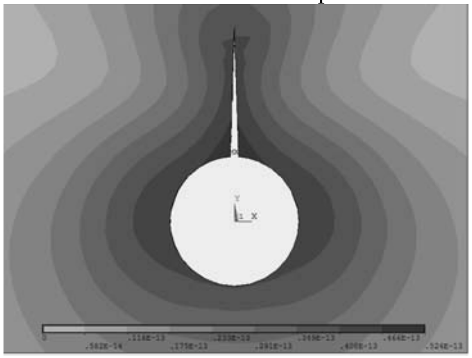

Fig. 2. Deformation contours without an external magnetic field

When the centers of the hole and coil overlap, the sample deformation contours without an external magnetic field are shown in Fig. 2. The deformation analysis shows that the deformation close to the defect has relatively large gradient along its normal direction.

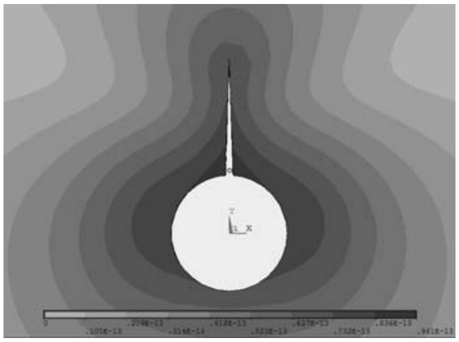

Fig. 3. Deformation contours with an external magnetic field

The sample deformation contours are shown in Fig. 3 when the centers of the hole and coil overlap. It is known that the deformation contours with an external magnetic field (about 0.1 Wb/m2) is very similar to the one without an external magnetic field by comparing Fig. 2 and Fig. 3. But the increase of the deformation amplitude is obvious.

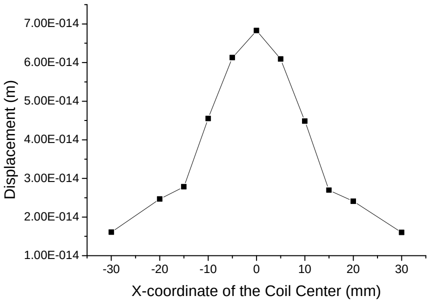

Fig. 4. Tip Displacement of the crack as the coil moves along the X-axis.

Fig. 4 shows the crack tip displacement of the calculating results when the coil center moves along the X-axis. Because the outer radius of the coil is 15 mm and the tip of the crack is at (0, 0.015), the maximum of displacement appears when the coil center is at the original point and the deformation amplitudes decreases when the coil is away from the crack. The size and gradient of the deformation are significantly better than other conditions when centers of the coil and hole overlap. Thus EMAE using coil exciting has an excellent performance in identifying the position of the defect.

IV. EXPERIMENT RESULTS

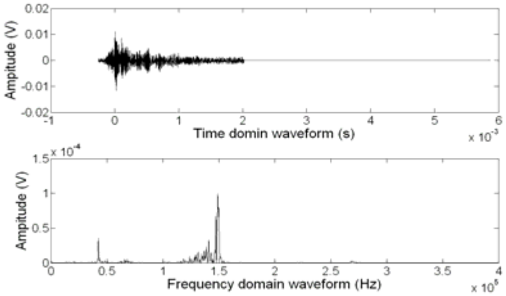

Fig. 5. Acoustic emission signals from the defect with an external magnetic field

When the coil is on the crack, the signals received by AE sensors are shown in Fig. 5. The low frequency signals (＜50 KHz) are decided by the shape of the coil and the exciting current frequency. The high frequency signals (about 150 KHz, the typical AE signal of the metal) are generated by the cracks vibration. So, signal's differences in the spectrum can be used to distinguish the AE signal from noise signals. Thus, this characteristic of signals can be used to detect the defects and enhance the capability to defect small cracks.

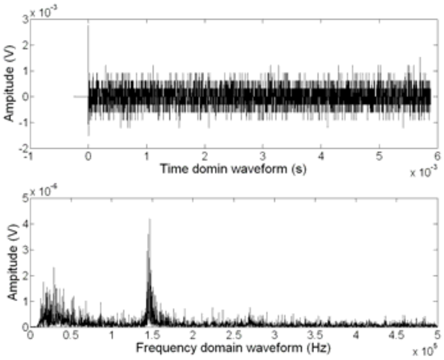

Fig. 6. Acoustic emission signals from the defect without an external magnetic field

When the coil center is at the origin point, the typical acoustic emission signal is shown Fig. 6. The AE signals also contain two frequency bands generated from the loaded crack. Comparing Fig. 5 and Fig. 6, it is known that the external magnetic field obviously strengthens the amplitude of AE signals.

V. CONCLUSION

The advantage of EMAE is that a transient external electromagnetic stimulation can excite the vibration of the defect itself and further generate elastic waves. The electromagnetic coils can generate AE signals by introducing the electromagnetic stimulation as well as the electrodes. It is more convenient to utilize the coil than only using the electrodes. Experiment results demonstrate that the EMAE have this ability of detecting the micro crack in the thin walled conducting structures. The external magnetic field can obviously increase the amplitude of AE signals. This feature can be used to reduce the size of the coil and demands for the power source. Electromagnetic Acoustic Transducer (EMAT) can be used for a rapid detection, and EMAE can be used to do a reinspection when some areas can not be qualitative. That will increase the ability of the micro-crack detection. EMAE can use equipments of EMAT except the power and exciting coil, so this composite detection method does not increase significant cost.

VI. REFERENCES

[1] P. Finkel and V. Godinez, "Numerical simulations of an electromagnetic of the ultrasonic signal for nondestructive detection of ferromagnetic inclusions and flaws [J]," *IEEE Trans. Magnetics*, vol. 40, no. 4, pp. 2179–2181, 2004.

[2] Liang Jin, Qingxin Yang, Suzhen Liu, "Electromagnetic Stimulation of the Acoustic Emission for Fatigue Crack Detection of the Sheet Metal," *IEEE Transactions on Applied Superconductivity*, vol.20, no.3, pp.1848-1854, 2010.