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ELECTROMAGNETIC PULSE-INDUCED ACOUSTIC TESTING FOR METAL/COMPOSITE OR METAL/PLASTICS ADHESIVE JOINTS AND ITS DATA PROCESSING

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ABSTRACT

Composite and plastic materials are used in aircraft, automobiles as metal substitutes to reduce the structural weight. However, it is evident that composite and plastic materials can not wholly replace metals. Therefore, metal and composite or plastic joining is one method that is used to satisfy the above demands. Adhesive bonding is applied commonly to join metal and composite or plastic materials. To ensure the use of safety of the structure, we proposed the electromagnetic pulse-induced acoustic testing (EPAT) method for nondestructive testing in a previous study. In this paper, we first introduce the EPAT method for detecting debonding in adhesive joints. The EPAT system for detecting debonding in FRP/Alumina is used in an experiment.

Meanwhile, a 2D numerical simulation of EPAT method for metal/plastics adhesive joints is established. The experiment and simulation results show that the signal arriving at the AE sensor is delayed when there are debonding parts in a specimen. By processing received signals using FFT method; frequency domain signals also explain the difference between intact (without debonding) and debonding signals. The development of data processing for the EPAT method is required.

Keywords: electromagnetic pulse-induced acoustic testing, debonding detection, data processing

1. INTRODUCTION

Energy and environmental problems are significant for human society and economic development. To realize the sustainable development of society and economy, the development of energy saving and emission reduction technology is necessary. As a way of energy saving and emission reduction, mass reduction is significant for many structural applications. Typically, composite and plastics materials are used in aircraft, automobiles to replace metals to reduce the structural weight [1]. However, it is evident that composite and plastic materials cannot wholly replace metals. Therefore, metal and composite or plastic joining is adopted as one of methods that satisfy the above demands. Adhesive bonding and mechanical fastening are applied commonly to join metal and composite or plastic materials [2]. Mechanical fastener uses rivets and other tools to fix multiple components together. It not only needs more components but also causes deformation in the fastening part. Compared with mechanical fastening, adhesive bonding has advantages, such as not producing distortion in materials or substrates, and reducing the number of components. However, with an increase in usage time, debonding phenomena may occur at the bonding part. To ensure the use of safety of the structure, nondestructive testing for the inspection of metal/composite or metal/plastics adhesive joints is required. Usually, ultrasonic testing is used in adhesive joints [3]. For cases where composite or plastic is located outside of the metal, because of attenuation of ultrasonic waves, it is difficult to obtain an echo signal. Therefore, we proposed the electromagnetic pulse-induced acoustic testing (EPAT) method for nondestructive testing in a previous study [4].

The purpose of this paper is to introduce the EPAT method for debonding detection in metal/composite or metal/plastics adhesive joints and to discuss the data processing for the EPAT method.

2. EPAT METHOD

In the EPAT method, a pulsed magnetic field excites conductive material and generates an acoustic signal, and defects in adhesive joints are inspected by measuring and analyzing the acoustic signal.

Figure 1 shows the EPAT system for debonding detection in FRP/Alumina [4]. A high-power generator drives an exciting coil to produce a peak current of up to 4000 A. The driving current is shown in Figure 2, and the magnetic field generated under the exciting coil is also shown in Figure 2. Therefore, vibration occurs in the alumina specimen due to Lorentz force. This vibration propagates through the whole structure. A debonding affects the propagation of vibration. Acoustic emission (AE)

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sensors were used to receive vertical vibration signals from the upper surface of FRP. Due to the effect of debonding, the time when the first peak signal arrives AE sensor is slightly later than that without debonding.

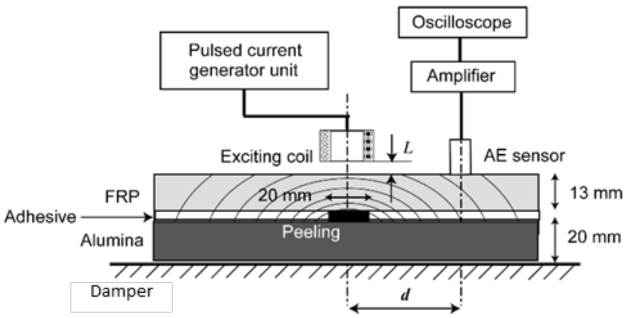

FIGURE 1: EPAT system for debonding detection in FRP/Alumina [4]

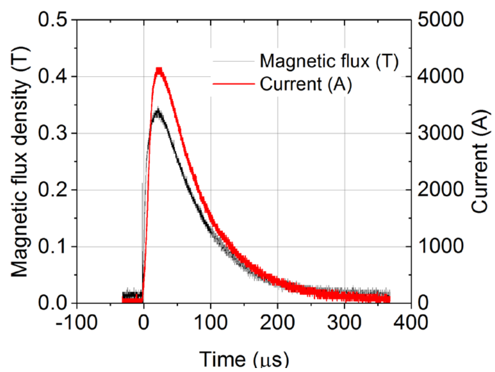

FIGURE 2: Magnetic flux density and exciting current [4]

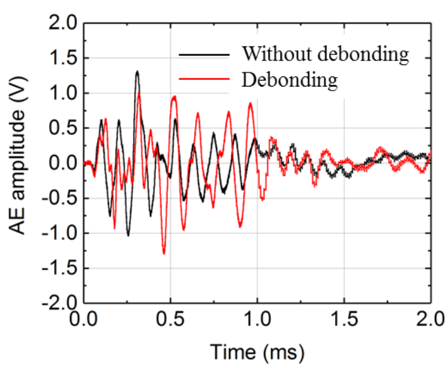

FIGURE 3: Received signal from AE sensor [4]

3. NUMERICAL SIMULATION OF EPAT METHOD

The numerical simulation of the EPAT method is performed by using COMSOL software. The EPAT method is simplified to the two-dimensional case. The geometry and size of the simulation are shown in Figure 4. Due to the complexity of FRP, simpler metal/plastics adhesive joints are considered in the analysis. An adhesive joint specimen with acrylic plate and aluminum is used in the calculation. In the middle of the adhesive joint component, a debonding part is formed as void. A case with debonding is compared with a case without debonding. The excitation coil is simplified to a straight wire with a circular cross-section. This is a reasonable simplification because the coil shape has almost no effect on vibration far from the source. The coil is placed directly over the acrylic plate, which means that the lift-off of the coil from the upper acrylic plate surface is 0 mm. The coil diameter is 1 mm, and the drive current density is shown in Figure 5. This is half of a sinusoidal wave with a central frequency of 5 kHz. To minimize the reflection of vibration, the boundary conditions on both sides are set as absorbing boundary conditions.

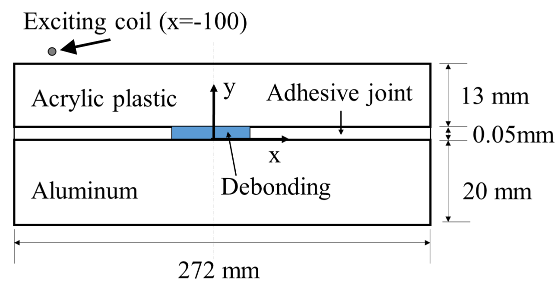

FIGURE 4: Geometry of numerical simulation model

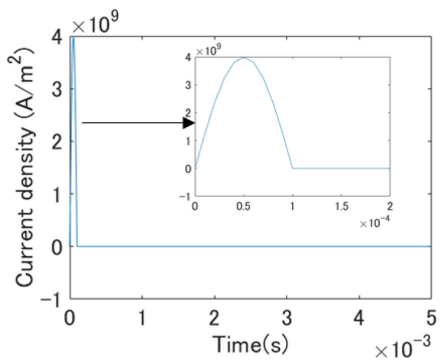

FIGURE 5: Profile of exciting current density

In the EPAT method, acoustic emission sensors are used to receive vertical vibration signals from the upper surface. Therefore, the vertical displacement on the upper surface of the acrylic plate is studied. We show the result above the debonding part in Figure 6. It is similar to the experiment result in the above, and due to the effect of debonding, the starting time of vibration at the study point was slightly later than that without debonding. However, the simulation just considers displacement, not AE sensor signal; it contains the characteristic vibration of the structure.

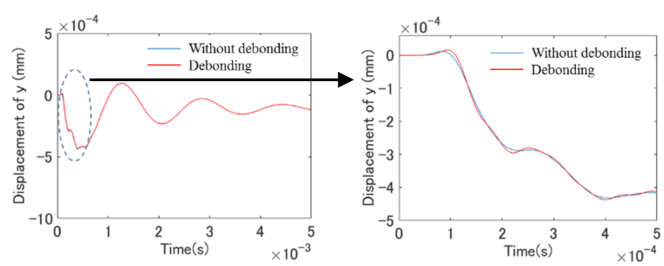

FIGURE 6: Simulated vertical displacement at point (0,13.05) in the upper surface of the acrylic plate.

4. DATA PROCESSING

As can be seen from figures 3 and 6, the signal arriving at the AE sensor is delayed when there are debonding parts. However, it is sometimes difficult to distinguish whether there is debonding or it is intact from the received signals. Therefore, the FFT is applied to the received signals of figures 3 and 6, obtaining the frequency domain signals, which are shown in figures 7 and 8, respectively. Figures 7 and 8 show that a high-frequency vibration of around 16 kHz occurred in the case of debonding, which is not found in the case without debonding.

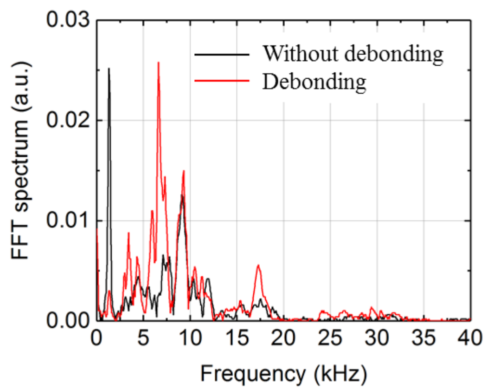

FIGURE 7: FFT spectrum of the received signal from AE sensor

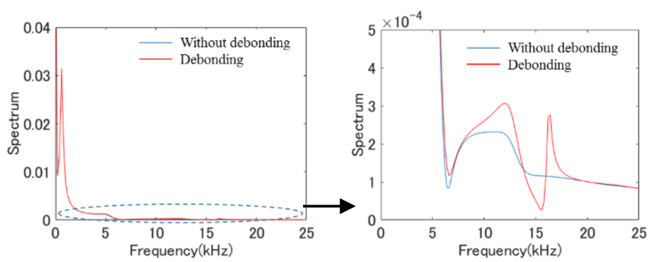

FIGURE 8: Simulated FFT spectrum on vertical displacement at point (0,13.05) in the upper surface of the acrylic plate.

Frequency domain signals also show the difference between intact and debonding signals. The development of the data processing method will be helpful in the detection of debonding by the EPAT method.

5. CONCLUSION

This paper introduced the EPAT method for debonding detection in metal/composite or metal/plastics adhesive joints. The EPAT system for detecting debonding in FRP/Alumina was used in an experiment. Meanwhile, this paper showed a numerical simulation result of EPAT method. The experiment and simulation results show that the signal arriving at the AE sensor is delayed when there are debonding parts. However, it is sometimes difficult to distinguish whether there is a debonding part from the received signal. By processing received signal using FFT method, frequency domain signals also show the difference between intact and debonding signals. The development of data processing for the EPAT method is required in future works.

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