Debonding defect detection of metal and composite bonding structures

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Abstract. Metal and composite bonding structures are widely used in many industrial fields. But in the material production and processing and bonding process, the adhered surface is not clean, is between the two surface bonding with adhesive is not strict, the existence of gas, dust and other reasons, the adhesive structure foaming, deboning, bonding strength decreased, durability and reliability reduce etc. In this paper, a kind of typical metal and composite bonding structure was studied by electromagnetic ultrasonic testing. The results show that the results are obvious. The electromagnetic ultrasonic can be used to test the adhesion of metal and composite materials.

1. Introduction
With the rapid development of industrial economy and science and technology, bonding structure of metal and composite materials have been widely used in many industrial fields, such as automobile shock damping device of rubber bonding lining layer, engine braking device in nonmetallic friction materials and metal components of the adhesive, oil and gas pipelines and anti-corrosion materials bonding [1]. But in the process of material production and processing and bonding, the adhered surface is not clean, is between the two surface bonding with adhesive is not strict, the existence of gas, dust and other reasons, makes the bonding structure of bubbles, deboning, bond strength decreased, durability and reduced reliability[2]. Application of electromagnetic ultrasonic testing technology to detect the adhesion of metal and composite materials, without coupling agent, more convenient, the results are also better[3].

2. Electromagnetic ultrasonic working principle and Detection of shell and adiabatic layer deboning principle

2.1. Electromagnetic ultrasonic working principle
EMAT is the core tool of electromagnetic ultrasonic testing technology. The EMAT consists of three parts - a magnet that provides a bias magnetic field, a coil that generates a pulsed magnetic field, and the measured pattern of exciting and propagating ultrasonic waves in the interior, as shown in figure1.
Figure 1. Basic structure of EMAT.

The process of coupling of electromagnetic field, force field and sound field and so on, which constitute the working principle of the electromagnetic transducer. The excitation coil in the bias field and high frequency pulse interaction around the radiation induced dynamic electromagnetic field; and in the dynamic electromagnetic field under the surface of the measured body feeling stimulating pulsed eddy current equal and opposite with the birth; interaction of the vortex in the influence of bias magnetic field, dynamic electromagnetic field and other physical processes under a stress field, the measured particle surface generated by vibration, acoustic form spread out, which is the principle of ultrasonic excitation [4-8].

In the process of EMAT energy conversion, the force field which is measured by the measured body is generally composed of Lorenz force, magnetic force and magnetic force, and the force field is formed by the interaction of the three force fields [4].

2.2 Detection of shell and adiabatic layer deboning principle
As shown in Figure 2, ultrasonic propagation in the measured body, when acoustic wave I₀ reaches the surface of the shell and adiabatic layer, without bubbles, cracks and other deboning defects, most sound waves pass through the first interface, reflecting very little acoustic waves. Therefore the received signal energy is low; if it is in the deboning interface, because of the large acoustic impedance of air, acoustic I₀ almost total reflection, the energy of receiving echo signal is obviously higher than that of good bonding quality. The echo generated by the multiple reflection of the ultrasonic wave in the interior of the measured body has strict repeatability, the waveform characteristic is obvious, and the echo energy is used to judge whether the adhesive surface of the metal and the nonmetal layer is free from sticking [2,9].

Figure 2. The propagation of sound waves in different interfaces.

The main information source of the deboning judgment is the received electromagnetic echo signal, which carries the characteristic information of the deboning. As shown in Figure 3, for a typical off stick echo signal.
It can be seen that the first echo is very obvious, but second times and third times after the echo signal is not so obvious, disturbed by the noise signal. How to deal with the signal to obtain the ideal result is also the key to detect the first interface bonding. In this paper, we select wavelet threshold to process the echo signal. The application of wavelet analysis of acoustic emission reduction technology, accurate and fast noise reduction, extraction of useful information. Select Sym8 wavelet, as shown in Figure 4.

Wavelet noise reduction of the basic processes are as follows figure 5:

Sym8 wavelet function is used to deal with the original signal, and the result is shown in Figure 6:
It can be seen that the Sym8 wavelet is used to deal with the signal relatively smooth, the feature information is retained more, and it is easier to identify the characteristics of deboning.

3. Test case
The detection of bonding between metal and composite material on the inner wall of rocket shell is taken as an example. We are in the bonding quality good place and artificial deboning place detection. The detected echo signal is displayed on the oscilloscope after wavelet threshold processing. Good bonding area detection and Detection of bad adhesion of the rocket shell. In the detection of bad adhesion of the rocket shell at the echo, as shown in Figure 7 received signal, we can see a number of equidistant and decreasing amplitude of echoes, through two adjacent echo time difference of rocket shell thickness can be calculated from viscosity of about 4mm. The echo signal received by the good bonding area is shown in figure 8, the signal is similar to the bad adhesion, and only all signals appear to have an overall attenuation. In contrast to the first echo amplitude of the two detection signal, the peak attenuation of the first peak value of the non-sticking point is found to be about 30%. This is because the adhesive material of the non-sticking point has a certain absorption attenuation of the ultrasonic wave.

![Figure 7. The echo signal received by the deboning area (An echo V pp is about 1040[mv])](image)

![Figure 8. The echo signal received by the good bonding area (An echo V pp is about 760[mv])](image)

Because the electromagnetic ultrasound does not need coupling agent, we directly use electromagnetic ultrasonic probe to detect the shell. The whole process is short, detection results directly in the oscilloscope display, the signal is obvious, very easy to distinguish. Electromagnetic ultrasonic can be used to measure the deboning of the first interface of solid rocket.

4. Conclusion
The adhesion of a typical metal and composite material, i.e., the solid rocket motor case and the bonding structure of the thermal insulation layer, was measured. The first peak of the signal at the deboning site was reduced by 30%. Can rapidly and accurately judge the position of sticking out. Electromagnetic ultrasound can be used to detect the bonding quality of metal and composite materials.

Acknowledgments
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