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Testing Application of Scanning Acoustic Microscope for Adhesive Characteristics of Explosive/Aluminum-Alloy Interface

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Abstract

The working principle of scanning acoustic microscope (SAM) is introduced, and the acoustic transmission action is analyzed according to the geometrical and structural characteristics of explosive/Aluminum-alloy binding. The adhesive status of the interface in some typical parts of the binding is detected by SAM and 30MHz ultrasonic focal field lens. The results show that the interfaces between the Aluminum alloy and explosive tile adhere perfectly at the central gelatinized area. There is a 40μm-thickness thin interstice layer at most of the fringe nonglue area, but there are also some points less than Φ0.5mm that is tending to cohere. So, SAM is a feasible method to detect adhesive characteristics of interface between thin objects.

Keywords: Scanning Acoustic Microscope, explosive/Aluminum alloy, interface, adhesive characteristics

1 Foreword

The adhesive characteristics of some explosive/Aluminum alloy binding (as shown in figure 1) will produce important effects on performance characteristics of the whole product. So, it is necessary to detect the interface characteristics by a nondestructive method.

The adhesive interface between explosive tile and Aluminum alloy is detected nondestructively and microscopically by Scanning Acoustic Microscope (SAM for short).

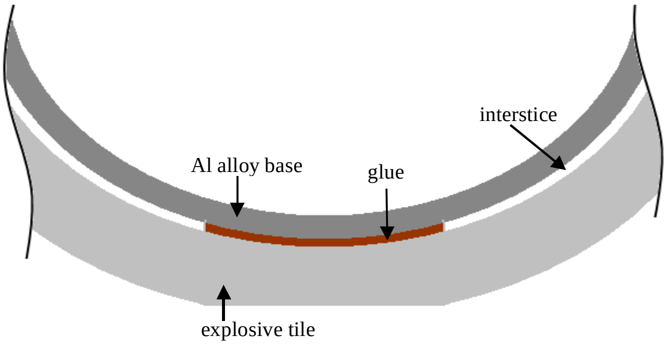


Fig.1 Structure of the binding

2 Method and theory

2.1 Working principle of SAM

Surface and inner microstructure of objects [1] can be detected nondestructively using SAM. The principle is that computer controls scanning system and ultrasonic field lens to scan the object by a raster way to and fro. The focal ultrasonic lens emit ultrasonic wave, which is transmitted into the object after penetrating through couple liquid (distilled water), and receive the reflection ultrasonic signal from the object and then form an acoustics micrograph. The mechanism of the contrast of the micrograph is the different gray value corresponding with the amplitude and time of flight of the reflection wave. So, every pixel of the micrograph corresponds with one signal feedback of a right-angle coordinate point from certain specific depth of the objects [2]. The working principle of SAM is shown in figure 2.

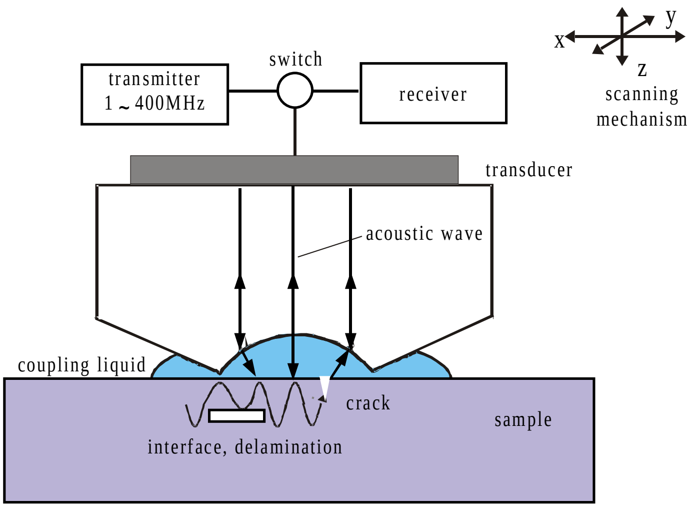


Fig.2 Working principle of SAM

2.2 Detecting method and analysis

The detected surface is required to be vertical to the incident direction as far as possible in order to receive higher energy reflected back.

According to the structural characteristics of curved surface of the binding and its acoustic transmission characteristics, the typical parts of the binding, that is, central gelatinized area and fringe nonglue area, are both detected respectively by selecting 30MHz focus-transducer, taking inner surface of the binding as incident surface of ultrasonic beam. And the detected surface is always kept vertical to the incident direction of ultrasonic beam by laying cushiony block under the binding while being detected. It is shown in figure 3.

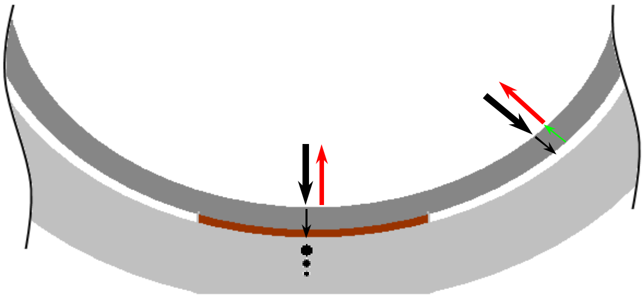


Fig.3 Ultrasonic transmission and reflection in typical parts of the binding

The intensity of ultrasonic echo lies on the ultrasonic impedance of the sample (ultrsonic impedance equals the product of density and sound velosity, $Z = \rho \times C_L$). When incident ultrasonic beam is vertical to the interface between two different-impedance mediums, some energy of the incident ultrasound (sound intensity, I_0) enters medium Ⅱ, that is transmission wave (sound intensity, I_t); and the other energy is reflected by the interface, that is reflection wave (sound intensity, I_r) [3]. It is shown in figure 4.

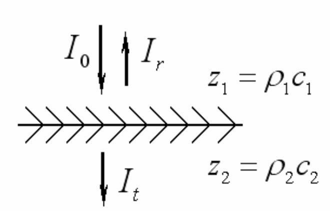


Fig.4 Reflection and transmission of vertical incident wave at interface

Reflectance and transmissivity of sound pressure are r and t respectively.Then:

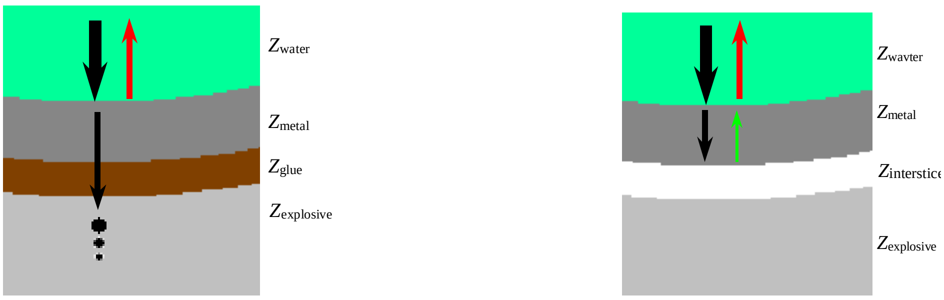
$$r = \frac{z_2 - z_1}{z_2 + z_1} \quad (1)$$

$$t = \frac{2z_2}{z_1 + z_2} \quad (2)$$

The structure of the binding is equivalent to a heterogeneous thin layer between Aluminum alloy and explosive tile. In the central gelatinized area of the binding, the heterogeneous thin layer is glue layer; and on the fringe area of the binding, the heterogeneous thin layer is interstice layer.

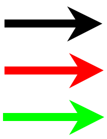
In the central gelatinized area, when ultrasound enters the interface between water and Aluminum alloy, some energy is reflected back from the interface, that is the reflection of sound waves from the surface of the Aluminum alloy; the other energy enters the Aluminum alloy and go on to be transmitted. The differences of impedance among Aluminum alloy, glue layer and explosive tile are slight. So the reflectance of sound pressure reflected from the Aluminum alloy/explosive interface is small according to formula (1), and the energy is mainly transmitted into the explosive tile and attenuated gently with the increase of the distance sound travels, as shown in figure 5a).

For the impedance of Aluminum alloy and explosive far from interstice layer, the energy are fully reflected from the Aluminum alloy/interstice interface besides reflective wave from interface of water and Aluminum alloy at the fringe nonglue area shown in figure 5b).



a) central gelatinized glue area   b) fringe nonglue area

Fig.5 Ultrasound reflection and transmission in binding



incident wave and transmission wave

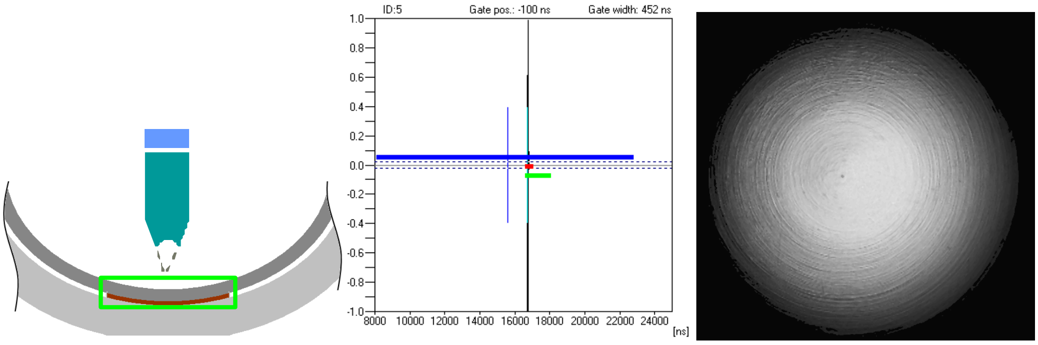
reflection wave from water/aluminum alloy interface

reflection wave from Aluminum alloy/ interstice interface

3 Results and discussion

the central area and the fringe area of the binding are tested nondestructively with WINSAM Vario Ⅲ type SAM and 30MHz transducer.

The results tested for the central area are shown in figure 6. The tested area is shown in figure 6a). Figure 6b) shows only one reflection wave from the central area, which proves that the ultrasound is not reflected from the Aluminum alloy/glue/explosive interface, but is transmitted and attenuated gradually to vanish, as though the interface never exists. It shows that, the explosive and the Aluminum alloy are conglutinant firmly with each other. Figure 6c) shows the SAM image of the upper surface of the Aluminum alloy.

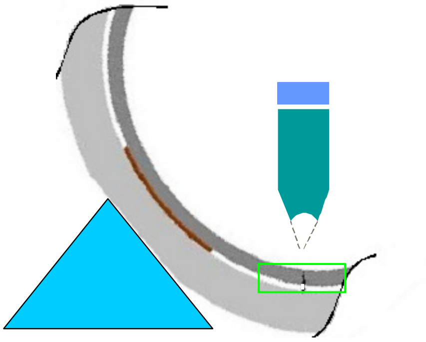


a) tested area b) reflection wave c) SAM image of the Aluminum-alloy upper surface

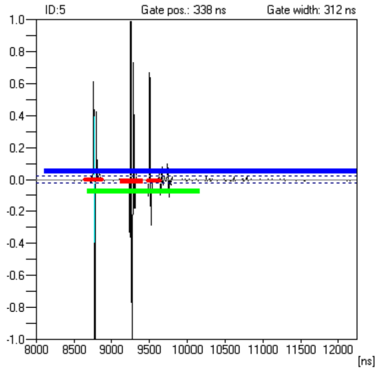
Fig.6 Results tested for central area of binding by SAM

Figure 7 shows the results tested for the fringe nonglue area by SAM. Figure 7a) shows the area tested. Figure 7b) shows two reflection waves from water/Aluminum alloy interface and from Aluminum alloy/interstice interface respectively. That is, ultrasound is reflected not only from water/Aluminum alloy interface, but also from Aluminum alloy/interstice interface. It shows that there is a thin layer, whose sound impedance is very small comparatively to Aluminum alloy base and explosive tile.

The SAM images of water/Aluminum alloy interface and Aluminum alloy/interstice interface formed by the two reflection waves with different time of flight are shown in figure 7 c) and figure 7 d) respectively. Reflection waves of lighter point A and darker Point B in figure 7 d) are shown in figure 7 e) and figure 7 f) respectively. There are two reflection waves at point A as shown in figure 7e). The second echo with higher amplitude is reflected from Aluminum alloy/interstice interface. It explains that there is a thin interstice layer between Aluminum alloy and explosive. That is, explosive and Aluminum alloy are not conglutinated. The thickness of the interstice layer between Aluminum alloy/explosive interface is about 40μm according the sound velocity and time of flight (the formula is shown in figure 7 e)). As shown in figure 7 f), there is only one reflection wave at point B from water/Aluminum alloy interface, and there is no reflection wave from Aluminum alloy/explosive interface, that is, explosive and Aluminum alloy are well conglutinated. The ratio of adhesive area to that of nonglue is about 7% by using image processing software.

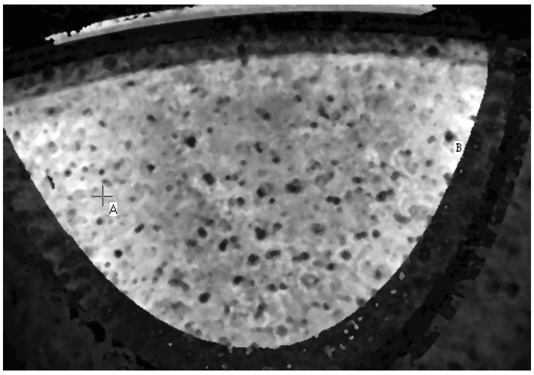


a) tested area

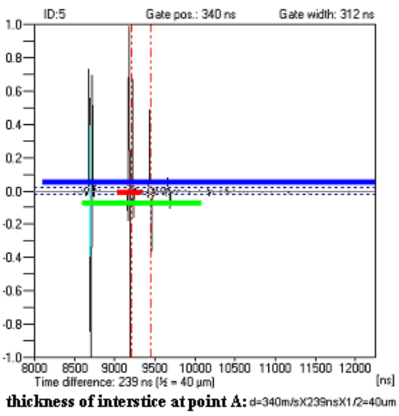


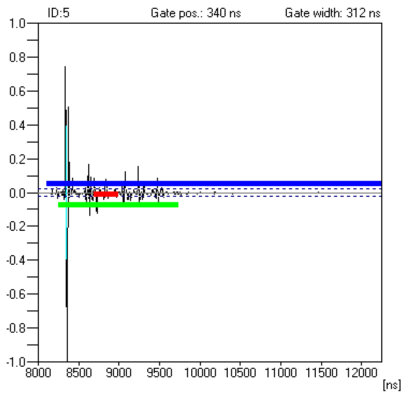
b) reflection waves

c) SAM image of water/Aluminum alloy interface：formed by the first reflection wave in fig. 6 b)



d) SAM image of Aluminum alloy/interstice interface: formed by the second reflection wave in fig. 6 b)





e) wave form of point A in fig. 6 d)

f) wave form of point B in fig. 6 d)

Fig.7 Results tested for fringe nonglue area of binding by SAM

To sum up the above arguments, in most part of fringe nonglue area, there is a 40μm-thickness thin interstice layer between explosive and Aluminum alloy; and only in some few points, whose diameter is not greater than Φ0.5mm, explosive and Aluminum alloy are tending to cohere.

4 Conclusions

The typical parts of the binding are detected nondestructively and analyzed by SAM according to the structural characteristics of the binding and its acoustic transmission characteristics. Cushiony block is laid under the binding to ensure the detected surface and the incident direction vertical to each other. We draw a conclusion that:

(1) In the central gelatinized area, explosive tile and Aluminum alloy base are well cohering.

(2) In most part of the fringe nonglue area, there is a 40μm-thickness thin interstice layer between explosive and Aluminum alloy. Only in a few points, whose diameter is less than 0.5mm, explosive and Aluminum alloy are tending to cohere. The ratio of adhesive area to nonglue area is about 7% by using image processing software.

(3) The interface of binding can be tested on the submicrocosmic scale and form image microscopically. And the adhesive status of interface can be analyzed and concluded.

Acknowledgements

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