C-SCAN ULTRASONIC EVALUATION OF Al/Ti BRAZED JOINT

G. V. S. Murthy*, G. Sridhar*, Anish Kumar+ and T. Jaykumar+

*** Materials Science and Technology Division, National Metallurgical Laboratory, Jamshedpur-831007, INDIA**
+ NDE Division, Indira Gandhi Center for Atomic Research , Kalpakkam-603102 INDIA

ABSTRACT: An indigenously developed brazed joint of Al/Ti was characterized by ultrasonic C-scan method. The study revealed certain debond locations in the brazed joint suggesting metal and air interface. These debond locations would have resulted due to the failure of filler material's joining ability. In spite of certain amount of load applied on the braze base metals, the above debonding happened. The debond locations further confirm that the pressure was not sufficient and therefore the debonds are present at exactly the same location where there were gaps in the fixture. Further analysis revealed that these debonds were present at the interface between the braze material and Al-plate. It is concluded that ultrasonic C-scan can be effectively used to evaluate the bond characteristics in a brazed joint between dissimilar metals

KEY WORDS:

Al/ Ti Brazed joint, C-scan, A-scan, Acoustic impedance.

INTRODUCTION:

Brazed joints have been used widely in the recent years as they offer many advantages. Advantages such as the ability to join two or more dissimilar materials, improved stress distribution in the joint, more flexibility in the product design and improvement in corrosion resistance, have made them attractive to use. However, limitations, such as necessity for surface pretreatment, temperature limitations, and non-destructive quality testing has hindered their application considerably in the cases where high reliability is required. In the automotive and aerospace industries, brazed joints are used very cautiously, due to the extreme consequences of failure. They are either over designed to satisfy generous safety factors requirements or used as an additional fastening element where other methods are used as primary fasteners. Ideally a non-destructive testing technique that would be able to confidently separate the 'good' from the 'bad' joints would provide a solution to the dilemma of using brazed joints liberally in all applications.

Compared to various non-destructive testing (NDT) techniques, viz. magnetic Barkhausen emission (MBE), X-ray diffraction (XRD) and eddy current (ECT), ultrasonic testing can only be used for characterization of both surface as well as the full thickness of the materials, irrespective of their electrical and magnetic properties. Ultrasonic data can be collected and displayed in a number of different formats. The three most common formats are known as A-scan, B-scan and C-scan presentations. Each presentation mode provides a different way of looking at and evaluating the region of material being inspected.

A-scan presentation displays the amount of received ultrasonic energy as a function of time. The relative amount of received energy is plotted along the vertical axis and the elapsed time (which may be related to the sound energy travel time within the material) is displayed along the horizontal axis. In an A-scan presentation, relative discontinuity size can be estimated by comparing the signal amplitude obtained from an unknown reflector to that from a known reflector. Reflector depth can be determined by the position of the signal on the horizontal sweep.

B-scan presentation is a profile (cross-sectional) view of the test specimen. In the B-scan, the time-of-flight (travel time) of the sound energy is displayed along the vertical axis and the linear position of the transducer is displayed along the horizontal axis. From the B-scan, the depth of the reflector and its approximate linear dimensions in the scan direction can be determined.

C-scan provides a plan-type view of the location and size of the test specimen features. The plane of the image is parallel to the scan pattern of the transducer. C-scan presentations are produced with an automated data acquisition system, such as a computer controlled immersion scanning system. Typically, data collection gate is established on the A-scan and the amplitude or the time-of-flight of the signal is recorded at regular intervals as the transducer is scanned over the test piece. The relative signal amplitude or the time–of-flight is displayed as a shade of gray or a colour for each of the positions where data was recorded. The C-scan presentation provides an image of the features that reflect and scatter the sound within and on the surfaces of the test piece.

EXPERIMENTAL:

In the present study, commercially pure titanium (Cp Ti) sheets (22 cm x 3 cm x 0.6 cm) and aluminum alloy 3003-O sheets (22 cm x 3 cm x 0.3 cm) were used as base materials and 0.5 mm thick aluminum alloy clad sheet (containing 3003-0 aluminum alloy as core metal with 4004 aluminum alloy as clad metal on both sides of the core metal) was used as a filler metal for the brazing process. The base materials along with the interfacing filler metal were assembled in a fixture (of stainless steel) having top and bottom plates. After placing the base materials and filler metals in between the top and bottom plates of the fixture, the entire assembly was further tightened by nuts and bolts manually in order to keep the base materials with the interfacing filler metal under pressure. To keep the weight of the fixture as low as possible and to distribute the heat uniformly in the core, intermittent holes were provided on top and bottom plates of the fixture. Now the fixture was kept in a resistance heating vacuum brazing furnace (capacity: 60 KW and maximum operating temperature: 700^0C) and the brazing process of Al/Ti was performed at 650^0C for 10 minutes in vacuum atmosphere (~ $5x10^{-5}$ mbar).

In the present investigation, C-scan studies were carried out on the braze joint interface utilizing a 2 channel scanning system known as ULTIMA 200 M2. The details of the system hardware and software are described elsewhere. (ref).

RESULTS AND DISCUSSION:

Ultrasonic testing is one of the most versatile and popular non destructive testing technique for evaluation of bond quality and defects such as delaminations. The amplitude of the interface echo is dependent upon the acoustic impedance Z given by

$$Z = \rho V,$$

where ρ is the density and V the velocity of the ultrasound in the media. At an interface when two media are encountered, the reflection coefficient is given as:

$$R = (Z_2 - Z_1)/(Z_1 + Z_2),$$

where Z_1 and Z_2 are the acoustic impedances of the first and the second media respectively. In the case of a good bond, the amplitude of the interface echo is less, because of the small difference between the acoustic impedances of the two metals. Whereas in the case of any debond, because of the presence of metal-air interface, all the energy gets reflected back due to the large difference in acoustic impedance between the metal and the air and hence a signal with amplitude is observed. This is usually indicated as a gray or black area in the C-scan.

C-scan ultrasonic studies were carried out on the brazed joint using a 6MHz point focused immersion transducer, focused at the interface.

Figs. 1a and 1b show the photographs of the brazed joint of Al/Ti. While Fig. 1a exhibits the top view of the joint, Fig. 1b shows the same from the side view. Both the photos in Figs. 1a and 1b illustrate four circular marks which appeared physically on the surface of the base metals. The presence of these circular marks was due to the holes on top and bottom plates of the fixture and they were none other than the fixture markings. Fig. 2 shows the C-scan image taken from the CpTi-side. The C-Scan image shows the reflection amplitude from the interface: Higher the amplitude,-darker the image, and hence the presence of de-bonding regions at four locations as shown by dark patches.

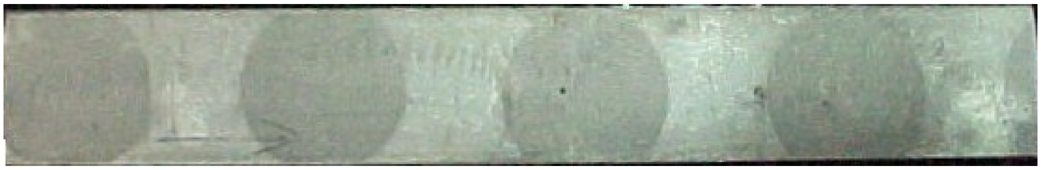

Fig. 1a. Photograph of the brazed plate (Top view)

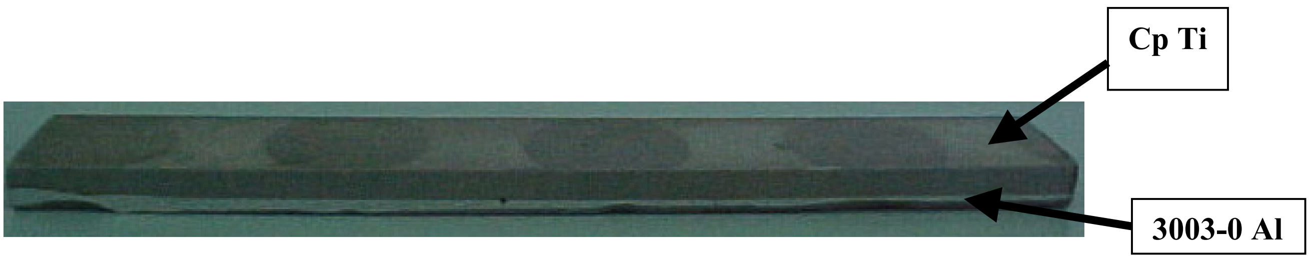

Fig. 1b. Photograph of the brazed plate (Side view)

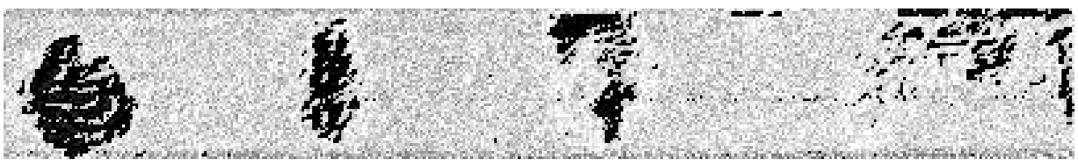

Fig. 2. C-Scan image of the interface region in the brazed joint indicating lack of bond as shown by black patches.

Detailed A-scan analysis of the debond has been carried out to understand the location of the debond. Fig. 3a below shows the A-scan ultrasonic signal obtained from Ti-side, when the joint is good. A small echo from the interface is due to the difference in the acoustic impedance between Ti and Al. Ti has higher acoustic impedance as compared to Al since V_{Ti}~6150 m/s; V_{Al}~6300: ρ_{Ti}~4400 kgm^{-3}; ρ_{Al}~2600 kgm^{-3}, Acoustic impedance $Z=\rho V$; Z_{Ti}~ 2.7e7; Z_{Al}~ 1.64e7. Both the echoes from the interface and the other end of Al plate are in phase, as at both the interfaces ultrasonic beam is getting reflected into the higher acoustic impedance material. $\left(R = \frac{Z_2 - Z_1}{Z_2 + Z_1} \right)$.

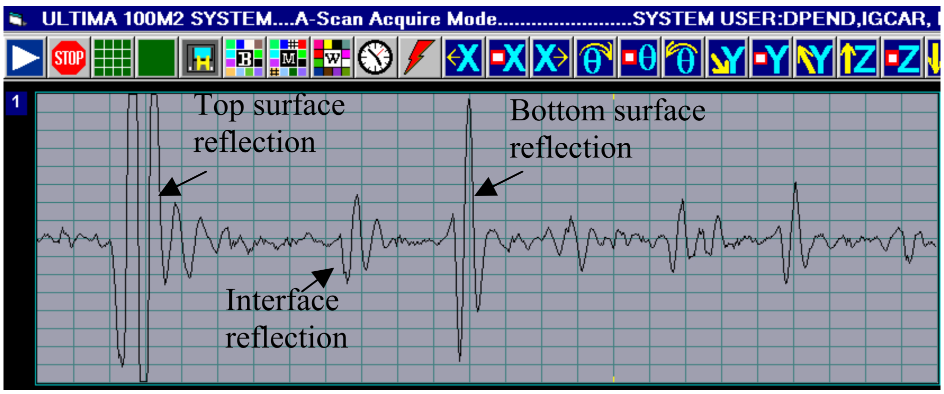

Fig. 3a. A-scan ultrasonic signal obtained from Ti-side, where the joint is good.

Similarly in the Fig. 3b below the echo from the interface is phase reversed as compared to the back wall echo, as at the interface ultrasonic wave is reflected into the lower acoustic material, in this case being Al ($Z_{Al} < Z_{Ti}$)

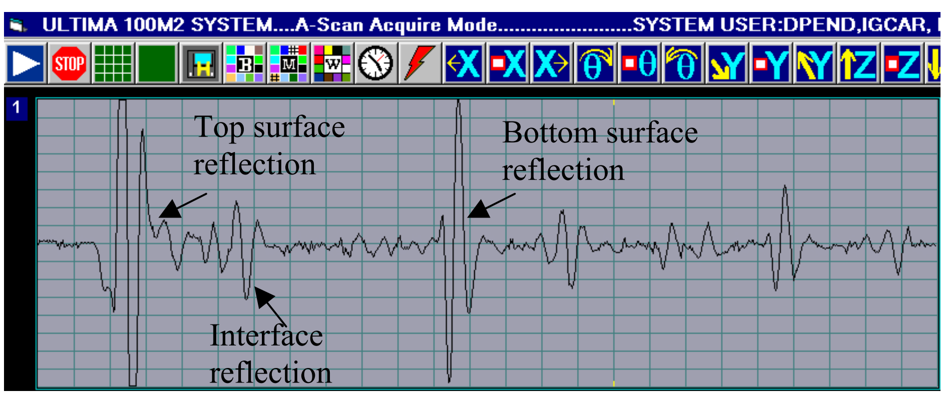

Fig. 3b. A-scan ultrasonic signal obtained from Al-side, where the joint is good.

In the Fig. 3c below presence of de-bond is manifested by the increase in reflection amplitude near the interface and no back-wall signal from the other end of aluminum plate. The echo from the Ti-braze material is still present indicating the de-bond at braze material - Al plate interface. Now if we see the Fig. 3d below, the echo from the interface is phase reversed as compared to that in the case of proper bond. This is due to the presence of de-bonding, ultrasonic wave is getting reflected at the interface between Al-plate and air.

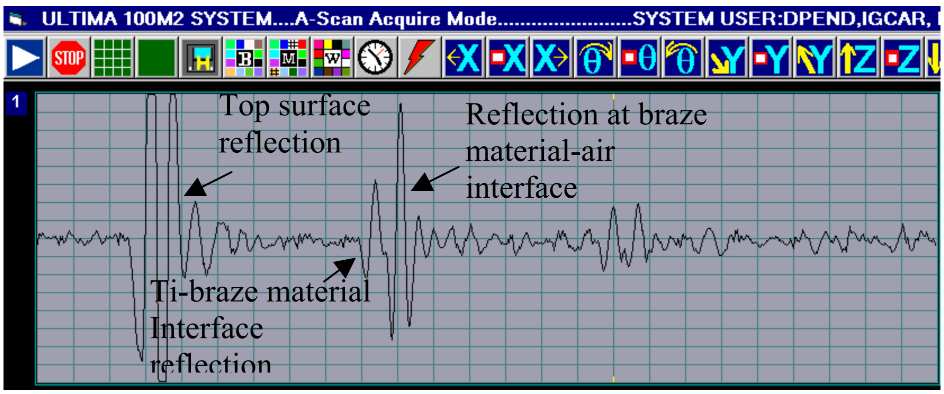

Fig.3c.A-scan ultrasonic signal obtained from Ti-side where there is a de-bond.

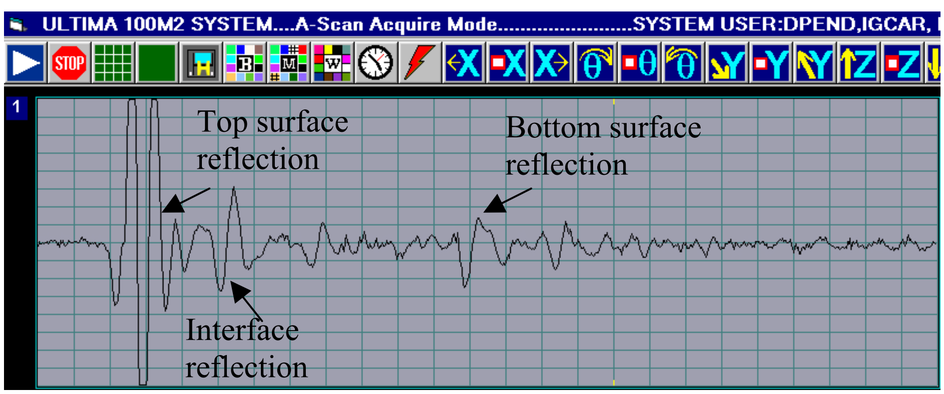

Fig.3d.A-scan ultrasonic signal obtained from Ti-side where there is a de-bond.

Thus from the above study it is clear that C-scan can be effectively used for assessing the bond integrity of a Brazed joint in a Non-destructive way. The detailed analysis also can pinpoint the de-bond location and help in the accept/reject criteria for such joints

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CONCLUSIONS:

In the present study, ultrasonic C-scan evaluation was carried out on Al/Ti brazed joint. The study revealed that there were some debonds present in the joint. Detailed analysis showed that debonds were present at exactly the same location where there were gaps in the fixture. Further analysis revealed that these debonds were present at the interface between the braze material and Al-plate. It is concluded that ultrasonic C-scan can be effectively used to evaluate the bond characteristics in a brazed joint between dissimilar metals

Figure captions

Fig. 1a. Photograph of the brazed plate (Top view)

Fig. 1b. Photograph of the brazed plate (Side view). The dark circular marks are from the gaps in the fixture.

Fig. 2. C-Scan image of the interface region in the brazed joint indicating lack of bonding as shown by black patches.

Fig. 3a. A-scan ultrasonic signal obtained from Ti-side, where the joint is good.

Fig. 3b. A-scan ultrasonic signal obtained from Al-side, where the joint is good.

Fig. 3c. A-scan ultrasonic signal obtained from Ti-side where there is a de-bonding.

Fig. 3d. A-scan ultrasonic signal obtained from Al-side where there is a de-bonding.

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