DETECTION OF DELAMINATIONS LOCATED AT CERAMIC/METAL JOINTED INTERFACE BY SCANNING ACOUSTIC MICROSCOPY

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INTRODUCTION

Since ceramic/metal joints currently play an important role of the structural parts for applications in electrical, electronic or aerospace industries, techniques must be developed for evaluating the integrity of these joints. Such techniques as collimated X-ray beam radiography [1], indentation fracture, and laser speckle imaging have been developed with limited success. No truly nondestructive techniques for evaluating joint strength have been established to date. If a conventional C-scan mode apparatus could be applied directly for detecting a defect such as a delamination on a joint interface, it might be an attractive solution in terms of visualizing the defect as a first step in the evaluation. The shape of the standard specimen of the ceramic/metal joint is essentially a rectangular bar. When the C-scan mode apparatus is used to visualize the jointed interface, an acoustic wave is required to be incident from the ceramic side of the specimen. When considering the attenuation of an ultrasonic wave in the frequency range from 10 to 100 MHz and the thickness of the ceramic portion of the specimen, the wave may not reach the interface, or the wave reflected from the interface may not be detected. When using frequencies lower than 10 MHz, the interface may be imaged, but with limited resolution. Moreover, the contrast may be poor because of water diffusing into the crack in the surface of the specimen. When a conventional A-mode apparatus such as a digital oscilloscope is used to obtain quantitative data, reflected waveforms might be collected. However, the data might not be good enough to analyze details of a defect, such as caused by a fracturing process. Recent studies have shown that delaminations at a ceramic/metal joint, such as a Si₃N₄/Cu/Steel joint, originate along the periphery of the interface [2].
Therefore, the critical focus should be on the interface. Scanning acoustic microscopy, on the other hand, in the frequency range from 100 to 3000 MHz, is an ultrasonic technique for highly resolving sub-surface. In this study, a scanning acoustic microscope [3] was used to image the surface and sub-surfaces of the Si₃N₄/Cu/Steel jointed plate for detecting defects, such as delaminations. Furthermore, the V(z) curve technique [4-7] as a quantitative technique for measuring the velocity of surface acoustic waves (hereinafter simply called “Vsaw”) was used along the peripheral edges of the delamination to discriminate between normal and defect specimens.

MATERIALS AND SPECIMENS

The specimens used consisted of section of Si₃N₄, Cu, and Steel, all brazed together. The final surfaces were lapped after mechanical polishing (R_max ≤ 1.0 μm). The final shape was a rectangular bar with 3x4x40 mm in dimension. A section of mild steel (S45C) was sandwiched with pressureless-sintered Si₃N₄. The joint strength of the specimen (σ_b) was measured at 350 MPa when a 4-point bending test was implemented. Two kinds of specimens were prepared for this study. One was a specimen having no defect (hereinafter called simply “standard specimen”), and the other is a specimen having a delamination on a joint interface (hereinafter called simply “defective specimen”), wherein the delamination was mechanically introduced by a micro-Vickers indentation.

SIMULATION

The intensities of waves with the use of a 400 MHz acoustic lens defocused at 0 μm and -40 μm were calculated for the standard specimen. Real intensities of acoustic images in the same conditions were obtained. The results of the calculated values were substantially in agreement with the experimental values. Hence, it is clear that the wave pattern was affected by the surface acoustic waves reflected from the jointed interface in the portions where the black stripes or the fringes were observed. The wave was more

![Figure 1. LSM image of defective specimen.](image-url)
affected when the incident portion is more adjacent to the jointed interface. It is clear that the incident wave was affected by the $V_{\text{Saw}}$ within the range observed as the stripe.

**EXPERIMENTAL RESULT**

**Image Analysis**

A specimen having a delamination at a jointed interface was observed alternately with a laser scanning microscope (LSM), a scanning electron microscope (SEM), and a scanning acoustic microscope (SAM). Figures 1, 2, and 3 show each image respectively. As can be appreciated from Figures 1, 2, and 3, the LSM and the SEM are not capable of visualizing the delamination, but the SAM is. In Figure 3(c), the stripes and fringes along

![SEM image of defective specimen.](image)

Figure 2. SEM image of defective specimen.
Figure 3. SAM images of defective specimen at different defocusing distances.
the jointed interface or the cracks caused by the reflection of $V_{saw}$ can be observed. The steel portion of the defective specimen was cut to observe the delamination on the jointed interface between the copper portion and the ceramic portion from the direction parallel to the X axis by the C-scan mode apparatus as shown in the Figure 4. As shown in Figure 4, a significant portion of the delamination is substantially visualized. As mentioned above, when water diffuses into the crack caused by the delamination, the reflected wave from the jointed interface on which delamination exists may not be detected. In this experiment, the delamination located on the side adjacent to the jointed interface is not visualized as shown in Figure 3.

$V_{saw}$ Measured by the $V(z)$ Curve Technique

$V_{saw}$ values at points along the jointed interface of the standard and defective specimen were measured with the $V(z)$ curve technique. Results of the measurements are

Figure 4. Delamination visualized by C-mode apparatus.
plotted in Figures 5(a) and 5(b). As shown in Figure 5(a), a plot of $V_{saw}$ on the standard specimen shows a trend that the $V_{saw}$ values near the jointed interface are faster. As shown in Figure 5(b), when the jointed interface has the delamination, a plot of $V_{saw}$ does not show any trend. Hence it is understood from the results that a specimen having a defect such as a delamination can be easily discriminated.

CONCLUSION

The scanning acoustic microscope is capable of visualizing the delamination located on the jointed interface. The reflected $V_{saw}$ on the discontinuous portion can be simulated as a wave intensity at the transducer. Based on the simulation, the $V(z)$ curve technique can be applied to discriminate the specimen having a defect such as the delamination on the jointed interface.
REFERENCE