CHARACTERIZATION OF DIFFUSION BONDS USING AN ACOUSTIC MICROSCOPE

INTRODUCTION

Solid state bonding is now being used in aircraft fabrication. As a result of this, various groups have considered the destructive examination of such bonds and categorized them in terms of characteristics seen in the examination of micrographic sections [1,2]. A range of studies which employ ultrasonic non-destructive techniques for bond-line characterization have also been undertaken [1,3,4].

A procedure for estimating the bond-line response for compression wave (C-scan) imaging was presented previously [3]. This involves the determination of bond-line reflection and transmission coefficients using leaky Rayleigh wave imaging and gives coefficients that are independent of the system used and sample plate thickness. These coefficients can then be used to estimate the compression wave bond-line response for the same material.

This study has considered the characterization of titanium-titanium and two forms of aluminum-lithium diffusion bonding applied to sheet material typically 3 mm thick. A Pulsed Digital Reflection Acoustic Microscope (PDRAM) (25-100 MHz) has been used to characterize the diffusion bond-lines between sheet material [4] and this work is an extension of an earlier study [3].

ACOUSTIC MEASUREMENT CONFIGURATIONS

A PDRAM operating with various 50 MHz transducers is used to characterize the diffusion bond-lines between sheets of titanium. This system has also been employed in various materials characterization.
studies, and it has been described elsewhere [3,4].

The PDRAM system is used in two different imaging configurations.

Leaky Rayleigh Wave Imaging

For the ultrasonic characterization of the bond-line seen in optical micrograph examination, a spherically focused compression wave transducer is defocused as shown in Fig 1(a). This causes leaky Rayleigh waves to be generated in the surface of the sample [3,4,5,6]. The leaky Rayleigh wave component is then isolated and measurements of signal level made using the gated peak detector in the PDRAM. The resulting data is used to give images and also both V(x) and V(y) curves, measured across and along the bond-line respectively.

The V(x) curve has previously been used for the characterization of several types of surface breaking features [5,6,7,8] and it has been shown to enable the determination of both transmission and reflection coefficient data [5] for surface breaking features.

For an acoustic microscope used with a cylindrical/line focus lens, it has been shown [8] that the relationship between the output of the transducer V(x,z) and the elastic material properties are given by:

\[ V(x,z) = \int_{-k_0}^{k_0} \int_{-k_0}^{k_0} \exp\{i(k_x' - k_x)z\} L_1(k_x') L_2(k_x) S(k_x,k_x') \exp\{i(k_x' - k_x)x\} \, dk_x \, dk_x', \]

(1)

and

\[ S(k_x,k_x') = \left[ R_0(k_x) + \frac{i4\alpha p}{k_x^2 - k_p^2} \right] \delta(k_x - k_x') + \frac{2\alpha}{\pi} \left[ \frac{(T - R - 1)k_x'k_x + (T + R - 1)k_p^2}{(k_x^2 - k_p^2)(k_x'^2 - k_p^2)} \right], \]

(2)

where \( k_x' \) and \( k_x \) are the x components of the incident and scattered plane waves. \( L(k_x') \) and \( L(k_x) \) are the pupil functions for the lens for the incident and scattered plane waves; the crack is taken to be at the origin. \( k_p \) is the Rayleigh pole in the complex \( k_x \) plane. \( \alpha \) describes the strength of coupling of Rayleigh waves to the fluid, and \( R_0 \) is the reflectance function minus the Rayleigh pole.

In this formulation (1) the characteristics of the scatterer are included only as the reflection (R) and transmission (T) coefficients and it has been used to describe various wave/feature interactions including the response for cracks of finite depth, crack closure and different orientations [6]. Line-scans or V(x) data across cracks have been calculated using a computer program based on this formulation [4,7,8]. This program has been employed to determine the V(x) response from diffusion bond-lines, and comparison of the resulting data with experimental measurements will be reported in the near future [4].

![Fig. 1. (a) Leaky Rayleigh wave imaging configuration (b) Compression wave imaging configuration](image-url)