Sizing of Disbonds at a Thin-Layer Substrate Interface from Spectral Peaks

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Abstract. An ultrasonic through transmission technique is used to inspect the interface of a thin layer and a substrate. An experiment is performed using a specimen constructed of a 0.040 inch (1.02 mm) polycarbonate layer bonded by an adhesive film to an aluminum plate. Circular flaws are induced with paper placed between the adhesive film and the polycarbonate layer to create disbonds. The flaws range in size from 0.5 inches (12.7 mm) to 0.067 inches (1.70 mm) in diameter. A through transmission ultrasonic inspection technique, which uses a flat transducer as a transmitter and a focused transducer as a receiver, is employed. Time signals from the receiving transducer are recorded for each flaw, transformed to the frequency domain by use of a fast Fourier transform (FFT), and are linearly deconvolved with the FFT of the time signals of the aluminum plate alone. The peaks of the resulting frequency response functions for each flaw predict the resonant frequencies of the flaws. The area of the thin layer above a disbond is modeled as a thin plate which is excited by the incident ultrasonic wave motion at its edges. The resonance peaks at the center of the plate are related to the size of the flaw. The principal result of the paper is that, based on the theory presented here, the size of the disbond can be obtained from measurements of the resonance peaks.

Introduction

The nondestructive evaluation of adhesive bond quality has recently been reviewed in some detail [1]. Though adhesively bonded layers are being used increasingly, reliable NDE inspection techniques remain a critical requirement for further use of such bonds. Much work on the ultrasonic inspection of thin layer adhesive bonds has been carried out [1–4]. Techniques other than ultrasonic ones have also been reported [5–6].

There are three important types of defects of an adhesive bond that must be detectable by NDE methods. Voids occur when gas bubbles are formed in the interface. Disbonds, which are areas in the interface where no adhesion has

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occurred, happen when there are contaminants at the interface prior to bonding. The other important flaw is lack of adhesive or cohesive strength [3–4].

This study is concerned with the sizing of disbonds in an interface between a thin layer and a substrate by an ultrasonic method. The work includes a theoretical and an experimental portion. In the theoretical part, the area of the thin layer above the disbond is considered as a thin plate which is excited by the incident ultrasonic wave motion at its edges. The resonance peaks at the center of the disbond are related to the size of the flaw. Hence, based on the theory presented here, the size of the disbond can be obtained from measurements of the resonance peaks.

To check the theory, an experiment was performed using a specimen constructed of a 0.040 inch (1.02 mm) polycarbonate layer bonded by adhesive film to an aluminum plate. Circular flaws were induced with paper placed between the adhesive film and the polycarbonate layer to create disbonds. The flaws range in size from 0.5 inches (12.7 mm) to 0.067 inches (1.70 mm) in diameter.

A through transmission ultrasonic inspection technique, which uses a flat transducer as a transmitter and a focused transducer as a receiver, has been employed. Time signals from the receiving transducer have been recorded for each flaw, for an unflawed region of the specimen, and for an aluminum plate alone. The time signals are transformed to the frequency domain by use of a fast Fourier transform (FFT) and are linearly deconvolved with the FFT of the time signals of the aluminum plate alone. The peaks of the resulting frequency response functions for each flaw are compared with the calculated resonant frequencies of a clamped circular plate. From this comparison, estimates of the flaw radius have been calculated. The flaw radii deduced from the ultrasonic experimental data agree well with the actual flaw radii.

**Experimental Investigation**

**Specimen**

To check the theory proposed in this paper, a special specimen was manufactured which consists of a thin layer bonded to a plate with circular disbonds created at the interface between the layer and the plate. The thin layer above the disbonded area can then be modeled as a circular plate.

An aluminum plate approximately 1/8 inch (3.2 mm) thick, 3 inches (7.6 mm) long, and 2 inches (5.1 mm) wide was used as the substrate. A thin film adhesive was used to bond the layer to the substrate. Such an adhesive has the advantage, over liquid adhesives, of being dimensionally stable. It is easy to work with, and is cured in a hot press under vacuum so that no air bubbles are present in the bond. The flaws were made by inserting paper, cut in circles of known diameters, between the adhesive and the layer. The flaw diameters were chosen to represent a large range of flaw sizes. The unbonded region of the layer over the flaw is free to vibrate since the adhesive film will hold the paper flaw away from the layer. The material chosen for the thin layer was Lexan, a polycarbonate material. This material is transparent, so the flaws can be seen in the finished specimen. A 0.040 inch (1.02 mm) thick layer of Lexan was chosen. Figure 1 shows the completed specimen. The flaw sizes are listed in Table 1.