Detection optimization of disbond in layered composites with varying thicknesses using an open-ended rectangular waveguide

N. Qaddoumi

R. Zoughi
Missouri University of Science and Technology, zoughi@mst.edu

Stoyan I. Ganchev

Follow this and additional works at: http://scholarsmine.mst.edu/faculty_work

Part of the Electrical and Computer Engineering Commons

Recommended Citation
http://scholarsmine.mst.edu/faculty_work/1152
DETECTION OPTIMIZATION OF DISBOND IN LAYERED COMPOSITES WITH VARYING THICKNESSES USING AN OPEN-ENDED RECTANGULAR WAVEGUIDE

S. Ganchev, N. Qaddoumi, and R. Zoughi
Applied Microwave Nondestructive Testing Laboratory
Electrical Engineering Department
Colorado State University
Fort Collins, CO 80523

Abstract

The detection of air disbonds in layered dielectric composite, which is an important practical issue in many industries, is studied both theoretically and experimentally. Sensitivity of disbonds depends on certain parameters, like the frequency of operation, the distance between the sensor and the first dielectric layer, and the layered composite geometry (conductor backed or terminated by an infinite half-space of air). The impact of all these parameters is investigated theoretically and then verified experimentally.

Introduction and Considered Geometries

An air disbonds between dielectric layers of a composite is a common problem in many industries such as aerospace, construction, rubber industries, etc. The disbonds is usually between the metal plate and a dielectric coating or between dielectric layers. Based on this, the geometries considered are depicted in Fig. 1. Case (a) and (b) pertain to multi-layered composites backed by a conducting plate, and (c) is a multi-layered composite terminated by free-space. These cases cover important practical geometries, namely disbonds (d3) between coating and metal base (a), disbonds (d3) between the dielectric layers in conductor backed case (b), and disbonds (d3) between the dielectric layers in infinite half-space case (c). In all geometries d1 denotes the airgap between the rectangular waveguide sensor and the first dielectric layer, which makes these measurements inherently noncontact.

Theoretical Simulations and Measurements

The theoretical simulations for an open-ended rectangular waveguide radiating into a multilayered dielectric composite has been developed in [1]. Here, only calculations and measurements of the phase of the reflection coefficient are considered, since this parameter has shown to be more sensitive (than the modulus of the reflection coefficient) with respect to geometry variations [1-3].

Fig. 1: Open-ended rectangular waveguide sensor radiating into different layered dielectric composite geometries: (a) a three-layer conductor backed, (b) a four-layer conductor backed, and (c) a four-layer backed by an infinite half-space of air.

To illustrate the frequency dependence on the detection sensitivity for a disbonds between two dielectric layers backed by conductor (Fig. 1(b)), the following theoretical simulation was carried out. The dielectric layers have dielectric constants of \( \varepsilon_r = 9 - j1 \). Referring to Fig. 1(b), the air gap is \( d_1 = 5.5 \text{ mm} \), \( D = d_2 + d_3 + d_4 \) is 7.2 mm.
or 8.2 mm, the air disbond \(d_3\), takes values of 0 mm, 0.076 mm, 0.127 mm, and 0.178 mm. The disbond is always in the middle, so the two dielectric layers \((d_2, d_4)\) have equal thicknesses, and the disbond thickness increase is compensated with equivalent decrease of dielectric layer thicknesses. For each case (no disbond, and the three disbond thicknesses) phase vs. frequency in X-band region (8.2 - 12.4 GHz) is calculated. Fig. 2 depicts the absolute value of the phase differences for each disbond value and the no disbond case.

It is clear that depending on the overall thickness, \(D\), there is a frequency range with the best sensitivity (11.5 GHz for \(D = 7.2\) mm, and 10 GHz for 8.2 mm). It is also obvious that outside these frequency ranges the detection sensitivity is worse or even negligible. For a fixed frequency of operation the sensor may be calibrated to give information about the disbond thickness. In a similar fashion the significance of the airgap value \((d_1)\) and the composite geometry (conductor backed and terminated by air) as well as the relative depth of disbond will be discussed. Extensive measurements to support the theoretical calculations are also presented in application to disbond layers as thin as a few microns at X-band frequencies.

**References**

