INTERFACE CHARACTERIZATION BY TRUE GUIDED MODES

Peter B. Nagy and Laszlo Adler

The Ohio State University
Department of Welding Engineering
Columbus, OH 43210

INTRODUCTION

Guided acoustic waves along interfaces are especially sensitive to specific properties associated with boundary conditions and bond quality since their energy is effectively confined to the region of interest. On the other hand, this inherent advantage turns out to be a significant drawback for generation and detection of such guided waves. There are two basic types of propagating interface modes, which are shown schematically in Figure 1. First, there are leaky modes with higher phase velocity than at least one of the bulk velocities in the surrounding media. These modes "leak" their energy into one or more phase-matching bulk modes as they propagate along the interface and they can be readily excited by these mode-coupled bulk modes at the same incidence angle. In other words, the energy of leaky interface modes is not strictly confined to the boundary region therefore they are relatively easy to generate and detect. Because of their relatively short propagation length, leaky interface modes provide localized information on boundary properties and possible imperfections, which can be taken advantage of in ultrasonic NDE of bonded structures [1].

Fig. 1. Schematic diagram of a leaky (a) and true (b) guided mode propagation along an adhesively bonded interface.
True guided modes of lower phase velocity than any of the bulk velocities in the surrounding media are much more difficult to generate and detect since they produce evanescent fields only in the bonded materials as they propagate along the interface. Such guided modes are especially sensitive to overall boundary properties averaged along the interface to be inspected, but their NDE application is badly limited by their poor accessibility. Figure 2 shows the most commonly used geometrical arrangement for guided interface wave inspection of bond properties. Wedge transducers are used to generate Rayleigh waves on the free surface of one of the joining parts, which are coupled to one or more vertically polarized interface modes over the bonded area. This technique works for true guided modes [2,3] as well as for slightly leaky ones, [4,5] but the awkward geometry required for positioning the surface wave transducers renders this technique useless in many NDE applications.

DIRECT EXCITATION OF INTERFACE WAVES

Figure 3 shows an alternative geometrical configuration for direct generation and detection of interface waves between two bonded half-spaces [6-8]. A contact ultrasonic transducer is placed directly over the boundary region so that it can generate both bulk and interface waves. A vertically polarized symmetric mode produces identical transverse, but opposite normal displacements on the two sides of the boundary, therefore it can be excited by a longitudinal transducer which generates only parallel vibration relative to the interface. In a similar way, a vertically polarized antisymmetric mode produces identical normal, but opposite transverse displacements on the two sides of the boundary, therefore it can be excited by a vertically polarized shear transducer which generates only normal vibration relative to the interface. Finally, a horizontally polarized symmetric mode polarized symmetric mode produces identical transverse vibrations on the two sides of the boundary without any normal components, therefore it can be excited by a horizontally polarized shear transducer.

Figure 4 demonstrates the main concept of energy partition between the generated bulk and interface waves. That part of the transducer, which lies directly over the interface region within approximately one wavelength generates mostly interface wave while the remaining part radiates mostly into the bulk mode. Since the transducer diameter-to-wavelength ratio is proportional to frequency, the two frequency spectra are complementary with the low frequency components carried by the interface mode and the high-frequency ones by the bulk mode. Figure 5 shows the geometrical arrangement used in direct interface excitation experiments. A contact ultrasonic transducer is used to generate the ultrasonic waves as well as to detect the reflected signals from the back wall of the specimen. If the sample is long enough and the interface mode is not too dispersive, two separate signals can be detected independently. In most cases, however, these signals are not fully separated and we have to use spectrum analysis to get velocity and amplitude information on the more interesting interface wave component. In the following, we are going to present two typical examples of direct interface wave generation by contact shear transducers.

TRANSMITTER

Material A

RECEIVER

Material B

Rayleigh Wave

Interface Wave

Rayleigh Wave

Fig. 2. Guided interface wave inspection by Rayleigh wave coupling.