Bonding Condition Assessment of Layered Beam Using Guided Waves

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ABSTRACT

Fiber Reinforced Polymer(FRP) materials have become an attractive alternative for reinforced concrete(RC) beam retrofit and rehabilitation, because of their outstanding strength, light weight and versatility. The goal of this study is to develop a nondestructive evaluation (NDE) technique that can detect debonding between the FRP layer and the host RC beam. Because the thickness of the FRP layer and the wavelengths of the guided waves are much smaller than that of the RC beam, it is expected that the Rayleigh wave belonging to guided waves will be generated in the FRP strengthened RC beams. In order to suggest the theoretical approach for prediction of the wave propagation in this structure, we will extract a feature that is sensitive to debonding between layers with significantly different thicknesses.

INTRODUCTION

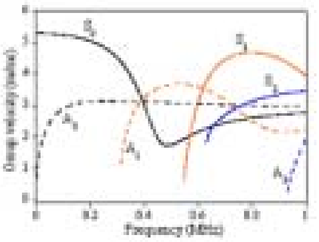
Recently, new structural health monitoring (SHM) techniques based on active sensors or MEMS technology have widely been applied in the civil engineering field. In this study, a damage detection method by using smart-active-sensors and its applicability to civil structures have been investigated. An assessment of bonding condition between FRP and the host media using guided waves generated by the active sensors will be presented.

GUIDED WAVES

The waves generated by the active sensors attached on the surface of FRP would propagate in vertical and horizontal directions accompanied by their reflection and refraction waves. The governing equation of the propagation is expressed as a partial differential equation that is in terms of the displacement of the waves, which is “Navier equation” as shown in equation (1.)

$$(\lambda + \mu)\nabla\nabla \bullet \mathbf{u} + \mu\nabla^2\mathbf{u} = \rho\frac{\partial^2\mathbf{u}}{\partial t^2} \tag{1}$$

The guided waves can be distinguished from bulk waves by which they need boundary conditions in the elastic continua. The wave dispersion equations and curves can be achieved by applying the boundary conditions as follows.



$$\frac{\tan(qh)}{\tan(ph)} = -\frac{4k^2 pq}{(q^2 - k^2)^2} \quad \text{(symmetry mode)}$$

$$\frac{\tan(qh)}{\tan(ph)} = -\frac{(q^2 - k^2)^2}{4k^2 pq} \quad \text{(anti-symmetry)} \qquad (2)$$

PROBLEM DEFINITION AND RESULTS

In order to investigate the guided waves' propagation, numerical and experimental tests were conducted with a steel plate layered aluminum beam in advance. Based on the guided waves' propagation theory in a thin-layered half media, we could extract a feature that is sensitive to debonding between significantly different thicknesses.

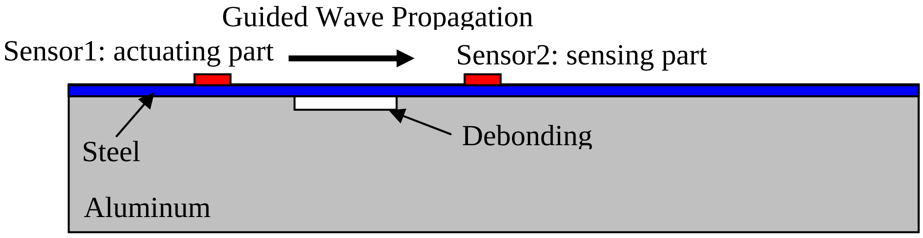
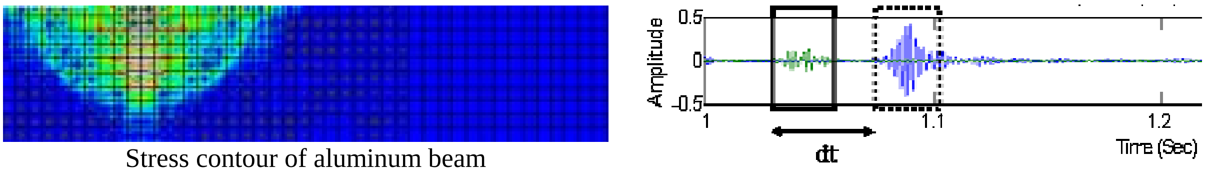


Figure 1. Problem definition



Stress contour of aluminum beam
time=4.0e-4sec, frequency=200kHz

The difference of wave velocity between perfect bonding and debonding conditions

Figure 2. Numerical and experimental results

In this study, we could verify that the velocity of guided waves is a sensitive feature to the bonding condition between two layers and demonstrate the fact through the numerical and experimental tests.

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