THE SUMMARY OF Ph. D. DISSERTATION

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Title

Fundamental Research on Quantitative Nondestructive Evaluation of a Flaw inside a Structural Component Using Electromagnetic Acoustic Transducers

Abstract

Quantification of non-destructive evaluation (NDE) techniques is strongly desired to fulfill severe requirements of safety and reliability of structures such as aircrafts and nuclear power vessels. In this research, phenomena of transmission and detection of ultrasonic waves by electromagnetic acoustic transducers (EMATs), one of promising methods of realizing the quantification, were analyzed numerically, and methods of quantitatively evaluating a flaw inside a structural component were proposed.

An EMAT, consisting of a coil to induce eddy current at the surface of a specimen and magnets to supply magnetic field, can transmit ultrasonic waves using electromagnetic force for the conductive specimen out of any contact with it. Detection of ultrasonic waves by an EMAT is also possible by the inverse procedure. These processes can be described by the equations of quasi-static electromagnetic field derived from Maxwell's equations and by the equation of motion of an elastic solid. Numerical simulation for an unflawed specimen visualized how ultrasonic waves propagate, reflecting at the surface with mode conversion of P and S waves,

i.e. longitudinal and transverse waves respectively. Computed electromagnetic fields clarified effects of the propagated waves on the receiver signals: voltage of the receiver coil correlates with particle velocity of the specimen at the surface near the coil. Simulation for a specimen with a cylindrical cavity modeling an internal flaw showed that reflection and diffraction of the waves at the cavity influence the receiver signals. Relation between the signals and parameters of the cavity, i.e. the diameter and the location of it, was explained in detail: peaks of the signals due to P wave directly propagated from transmitter and due to multiple reflection between the surface of the specimen and that of the cavity well represent the parameters. Numerical analysis in this research was verified by comparing numerical and experimental results of receiver signals.

Next, two methods of flaw identification were proposed. One is a method using the remarkable features of the receiver signals stated above the other is a method through inverse analysis of the receiver signals. The latter method was formulated as a problem of parameter optimization, and the condition that the initial guess must fulfill was described. The estimation by the former method satisfied this condition. An internal cavity was successfully identified from numerical and experimental results of receiver signals by using these methods.

The above results suggest that numerical analysis of the EMAT phenomena and application of inverse analysis are potential approaches to quantify flaw evaluation.