THE ACOUSTO-ULTRASONIC APPROACH TO THE CHARACTERIZATION OF THE MECHANICAL PERFORMANCE OF ENGINEERING MATERIALS AND STRUCTURES

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Acousto-ultrasonic is a relatively new NDE method which combines desirable aspects of conventional ultrasonic and acoustic emission techniques. In this paper we aim to assess the feasibility of utilizing the acousto-ultrasonic technique in the characterization of mechanical performance and prediction of strength of engineering materials and structures. The basic principles of the acousto-ultrasonic approach are discussed. The instruments, operating procedures and factors affecting acousto-ultrasonic measurements are explained. Experimental results obtained in a series of characterization tests on different classes of engineering materials and structures under diverse environmental conditions are presented.

INTRODUCTION

In recent years, there has been remarkable interest in the subject of wave propagation in engineering materials and structures. The increased interest in the subject matter has been motivated by the increasing number of applications and, as well, by the contributions provided by such studies to a better understanding of the mechanisms of the deformation of such material systems. This interest has been incited primarily by the advancement in testing and measurement techniques. This has been particularly pronounced in important fields of nondestructive testing such as ultrasonics (UT) and acoustic emission (AE). The combination between the two techniques has led further to the newly developed acousto-ultrasonic (AU) technique as a modern nondestructive tool for the evaluation and prediction of the mechanical properties of materials.

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The ultrasonic technique utilizes high frequency (1-20 MHz) acoustic waves to investigate the wave propagation characteristics in engineering media and also to interrogate the existence of individual discontinuities such as cracks or flaws in such media. The UT technique is particularly powerful in case of elastic materials. In situations involving viscoelastic materials, the UT technique, however, suffers from certain theoretical difficulties of interpretation concerning the relation between group and phase velocities of the propagation wave; see, e.g., Kolsky (1).

Acoustic-emission, on the other hand, is a spontaneous emission of sound pulses from the microstructure when the material is subjected to external loading. Such emission is often a result of sudden relief of internal stresses in the microstructure of the material. This could be due, for instance, to the nucleation and propagation of fissures or as a result of internal deformation processes such as the slip of existing dislocations, twinning and slip of grain boundaries. The frequency spectrum of acoustic-emission depends primarily on the sound waves produced whereby the frequency would range generally from audible to ultrasonic. In the AE technique, frequency is often used to indicate rate of emission, the number of bursts or counts per second.

As discussed below, the acousto-ultrasonic technique combines desirable aspects of acoustic emission practice with ultrasonic material characterization methodology (2-5).

ACOUSTO-ULTRASONIC

The acousto-ultrasonic testing approach is, in effect, an acoustic emission simulation with ultrasonic sources whereby stress waves are simulated in the microstructure of the material. These waves are generated by an external localized source, e.g., a piezo-transducer and resemble acoustic emission waves propagating in the material specimen but without disturbing the microstructure. As illustrated in Fig. 1, a broad hand transducer is often used in the AU technique to transmit a repetitive series of ultrasonic pulses into the test specimen. Meantime, a receiving AE transducer is placed on the same side of the specimen at a specific distance from the transmitting transducer to interpret the propagating stress waves resulting from the injected pulses. During their travel in the material, all stress waves would be affected by the physical and morphological properties of the microstructure and, hence, can be correlated to the material mechanical performance. A basic hypothesis in the AU approach is that the decrease in stress energy flow in the microstructure would generally correspond to a decrease in resistance to fracture of the material (2). In other words, it is considered in the AU technique that more efficient strain energy transfer and proper evolution of the strain distribution in the microstructure during loading would generally correspond to increased strength and fracture resistance. Recent studies, see, e.g. (2,3), have reported that there is, in fact, a strong correlation between the stress wave propagation characteristics as determined by acousto-ultrasonics and various mechanical properties of the material.

THE RESEARCH

The aim in this research is to assess the feasibility of utilizing the acousto-ultrasonic technique in the characterization of the mechanical performance of different classes of engineering materials. In this context, characteristic data concerning wave propagation properties in various material systems of different geometry and subject to different boundary conditions are established and correlated with the mechanical performance of such systems. An advanced AU testing system has been designed for the purpose of the present research.

INSTRUMENTATION

The designed AU testing system is based on artificial intelligence with built-in training classifiers capability. The system configuration is based on 20 MHz/386 computing core with the integration of the following software and hardware (see Figure 1).

(i) ICEPAK software*
It provides pattern recognition capability for on-line classification of inspection signals. This software include five application modules: Set-up, Classifier, Signal View, Facts, Tutor.

(ii) ARIUS software*
It is an automated real-time intelligent system. It uses the classifiers established by ICEPAK in (i) above for on-line interpretation of the received signals. ARIUS software provides the following functions:
- Acquisition of data
- Continuous storage of waveform
- Inspection of signals
- Interpretation and classification of signals
- Recognition capability of classes of real-time signals

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(iii) AET 5500 hardware**
This inspection system interacts with ICEPAK and ARIUS. In addition the system has its own software whereby the following three modules are provided
Scan/Acquisition
Playback/Analysis
Characterization/Report

(iv) General Research PCPR-/00+ pulser/receiver

(v) Sonotek STR 825+ analog to digital converter

(vi) SKY 321- PC+ digital signal processer

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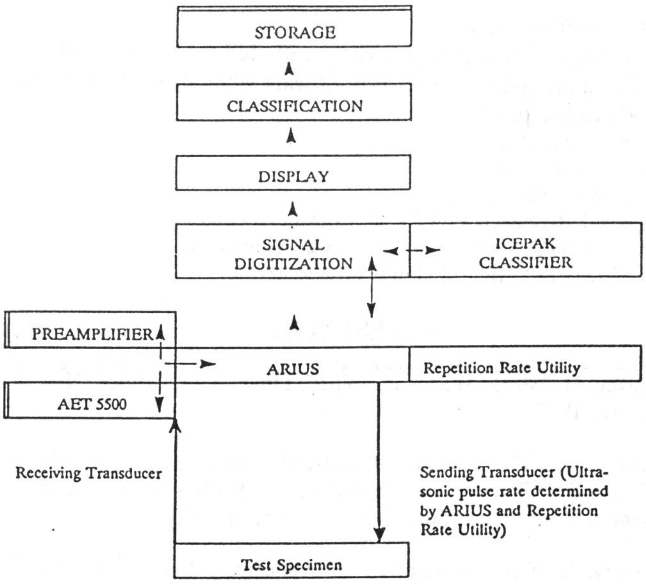

Figure 1 An intelligent testing system for acousto-ultrasonics applications