## INTRODUCTION

Acoustic emission (AE) is the phenomenon in which elastic or stress waves are emitted from a rapid, localized change of strain energy in a material. AE as a technology has rapidly become accepted as a non-destructive methodology. It has become in recent years the basis of a number of recommended practices and inspection codes of several societies. The applications of AE which involves the detection of AE signals and possibly their characterization are diverse. Most commonly, they include the monitoring of manufacturing and other dynamical processes, the integrity of structural components as well as fundamental investigations of failure processes of engineering as well as geological materials.

In the last decade the science, technology and applications of AE progressed significantly. In order to provide a forum for reporting important, recent developments and to provide an opportunity to critically review the directions in which this field is moving, the *Acoustic Emission Working Group* with the endorsement of other technical societies, including ASTM Committee E-7, ASNT, IEEE, and SEM, organized the *World Meeting on Acoustic Emission* which was held 20-23 March 1989 in Charlotte, North Carolina. Eighty-seven papers from nineteen countries were presented at the conference. The thirty-four comprising this ASTM *Special Technical Publication (STP)* volume were selected for their topical content and international appeal.

The first section of this book focuses on AE sensors and systems. The calibration of AE sensors and AE systems using the pencil break and a reciprocity technique is discussed by Higo and Inaba. The development of an integrated AE sensor suitable for use in harsh, industrial environments and its use in diverse process monitoring applications is reported by Holroyd et al. The application of non-contact, electro-magnetic acoustic sensors (EMAT's) in an AE weld monitoring application is described by Crostack et al.

The second section of the book deals with fundamental investigations of AE sources and the propagation of simulated AE signals through a structure for materials characterization applications. The case of point sources modeling the formation of microcracks in brittle solids is reviewed by Enoki and Kishi while the signals from line sources are described in the paper by Kim and Sachse. Heiple et al. describes a study of the AE accompanying the fracture of boron particles in an aluminum matrix which may serve as an AE system calibration signal. The use of a point source generating broadband ultrasonic signals in a large number of directions in a material, forms the basis of tomographic technique described by Maxwell et al. to determine the velocity structure of a specimen which may find application in the future to image the distribution of stresses or cracks in materials. Another application utilizing simulated AE signals is in the so-called *acousto-ultrasonic*, or *AU* technique, which

was developed by Vary. In this volume he reviews recent developments and considers its further potential and some of its limitations. A theoretical foundation of the *AU* technique based on Lamb plate modes is described by Kiernan and Duke.

The next section contains four of the papers at the conference which dealt with new signal processing approaches for AE signals. Description of a high-performance AE system capable of rapidly extracting a number of waveform parameters from the detected signals is given by Yamaguchi et al. A similar approach, but based on an envelope processing of the AE signals, is the basis of an in-flight AE system reported by McBride et al. The application of expert systems to assist in interpreting AE data is considered by Wood and Harris. The last paper in this section by Grabec et al. reports the development of a neural-like processing procedure for extracting the location and characteristics of an AE source from the signals detected at a number of sensors.

The use of AE in structural monitoring applications is the focus of the following section. Included is a paper by Barthélémy describing an AE-based inspection procedure for evaluating the integrity of compressed gas cylinders used in transportation systems. The second paper in this section is by Sklarczyk and Waschkies who demonstrate that AE signal parameters such as risetime, provide a means for delineating between growing and non-growing defects in reactor pressure components.

Five papers comprise the section focusing on AE used in deformation studies and in investigations of environmental and cyclic loading effects. The results of an investigation of the effect of pre-exposure to water on the AE behavior of an aluminum-lithium alloy are summarized in the paper by Zeides and Roman. A study of AE generated during tensile deformation and fracture in austenitic alloys is described by Raj and Jayakumar. The use of AE to investigate the effect of flaw size on the fracture of $Si_3N_4$ ceramics is reported by Mori and Kishi. A study of the AE from the fracture and decohesion of graphite nodules in ductile cast iron is reported by Carpenter and Zhu. The last paper in this section by Obata et al. describes the successful application of AE to monitor the growth of a fatigue crack in a carburized gear.

The next section of the book contains a number of papers reporting novel applications of AE measurements. Included here is the paper by Buttle and Scruby who apply quantitative AE techniques to determine the impact source and hence the sizes of small particles striking a plate. The development of a digital AE-based system for machinery diagnostics applications is described in the paper by Sat et al. Derakhshan et al. report the use of rms AE measurements to monitor cavitation-generated pressure pulses in a hydroturbine. The final two papers of this section deal with the application of AE to monitor metal machining processes. Roget et al. address the problems related to the application of AE measurements for delineating between tool breakage detection and tool wear monitoring. Dornfeld reviews the generation of AE and its use as a monitoring procedure during a metal cutting process. He explores the use of adaptive and neural processing

procedures for analyzing the detected AE signals.

Three papers comprise the section dealing with geotechnical applications of AE. A survey of AE source characterization studies yielding the moment tensor components and the ability of characterize the crack type and its orientation in geological specimens is described by Ohtsu. The use of AE to detect microstrains in the earth prior to an earthquake is considered by Armstrong and Valdes. The next paper in this section reports on the use of a novel amplitude analysis procedure to delineate between several deformation mechanisms in geological materials is described by Sun et al. The final paper in this section by Falls et al. describes the novel combination of AE source studies and ultrasonic tomographic imaging to investigate the failure mechanisms in rocks. If applied properly, such multi-measurement techniques can yield significantly more information about a process than when used individually.

The final section of the book focuses on the application of AE measurements for investigation failure processes in composite materials. The AE parameters that can be used to identify the failure mechanisms initiated by bending, flexure, and tensile tests of a thermoplastic carbon fiber-PEEK composite are reported by Ono et al. Ghaffari and Awerbuch describe the correlation they establish between AE and the initiation, accumulation and progression of matrix splitting in unidirectional graphite/epoxy specimens. Wevers et al. describe the use of an energy-related measure of the AE signals to monitor the damage development in a fatigue-loaded carbon fiber/epoxy laminate. Whittaker and Brosey describe the use of a cyclic thermal loadings to generate AE by which impact damage in Kevlar$^{R}$-wound aluminum spheres can be detected. The last paper, written by Beall, reports the use of AE to monitor the contact drying process of a wood veneer.

The editors express their deep appreciation to the more than fifty reviewers who so carefully read all the manuscripts and provided critical reviews of them.

There were two sessions at the conference for which no papers are included in the book. A panel discussion was organized which was chaired by D. G. Eitzen (USA) and which was used to exchange information about the status of AE-related codes and standards in several countries. Other members of the panel included Y. Higo (Japan), J. Roget (France) and P. Tscheliesnig (Austria). Each panel member presented an overview of recent developments and trends in his country. It was agreed that a continuing exchange of information about the development of AE-related codes and standards among AE groups would be desirable and an important undertaking.

Unique to this conference was an evening discussion session focusing on the topics "Critical AE Problems for the Researcher," which was led by A. Pollock[1] (Physical Acoustics Corp.) and "Critical Instrumentation Issues," which was led by A. Beattie (Sandia National Laboratories).

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[1]*Journal of Acoustic Emission (1990). In Press.*

The discussors identified the following issues for further investigation: (1) The development of a coherent, unified theory of acoustic emission to explain phenomena such as the Kaiser and Felicity effects for materials subjected to repeated loadings or load-hold tests; (2) The development of rational guidelines for the realistic stimulation of AE in structures which may be subjected to multi-dimensional states of thermal or mechanical stress in service; (3) The development of realistic artificial sources for AE system calibration application; and (4) Ways of obtaining more information from the detected acoustic signal, both by improved detection methods and by new or novel methods of signal processing.

A number of additional topics were identified by members of the audience for future investigation. These included: Study of AE signal cascades; Investigation of large amplitude AE burst-type emission before and during yield of some materials; Additional investigation of elastic waves in plates and shells for source location and characterization applications; Quantitative AE from frictional sources; Exploration of AE in conjunction with other NDT techniques; Absolute acoustic measurements; Application of chaos theory to AE; Application of neural networks to analyze AE signals; New and imaginative AE applications.

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