N92-22687

HIGH RESOLUTION ULTRASONIC SPECTROSCOPY SYSTEM FOR NONDESTRUCTIVE EVALUATION - SBIR PHASE III

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ABSTRACT

With increased demand for high resolution ultrasonic evaluation, computer-based systems or work stations become essential. In this project, the ultrasonic spectroscopy method of nondestructive evaluation (NDE) has been employed to develop a high resolution ultrasonic inspection system supported by modern signal processing, pattern recognition, and neural network technologies. The basic system which has been completed consists of a 386/20 MHz PC (IBM AT compatible), a pulser/receiver, a digital oscilloscope with serial and parallel communications to the computer, an immersion tank with motor control of X-Y axis movement, and the supporting software package, IUNDE for interactive ultrasonic evaluation. Although the hardware components are commercially available, the software development is entirely original. By integrating signal processing , pattern recognition, maximum entropy spectral analysis, and artificial neural network functions into the system, many NDE tasks can be performed. The high resolution graphics capability provides visualization of complex NDE problems. The Phase III efforts of this SBIR project involve intensive marketing of the software package and collaborative work with industrial sectors.

INTRODUCTION

This paper presents a low cost high resolution ultrasonic inspection system that provides extensive software suppoort to many nondestructive tesing tasks. Ultrasonic method of inspection is least costly but its capability can be limited because of hardware constraints. In any test and evaluation, a good set of measurements is most desirable. In practice the information available from the measurements is limited. Digital processing of the measurements offers the possibility to extract a lot more information from the data with the use of modern signal processing and related techniques. The design approach of the system developed is to rely entirely on the digital signal processing, pattern recognition and neural networks for defect characterization, detection and classification. Fig. 1 shows a block diagram of the system which consists of a Panametrics 5052UA pulser/receiver, a LeCroy 9400 digital oscilloscope, a National Instruments GPIB board, a Dell System 310 computer with math co-processor, a Testech immersion tank with X-Y axis motor control unit, a line printer and a plotter. Fig. 2 is a photo showing the pulse echoes from a small lead ball in the immersion tank. The lower figure is a smoothed digital signal of the upper figure taken from the digital scope. There are many other commercial components which may serve the same NDE purpose. The idea is that only commercially available parts are used. The innovative element of the system is the extensive signal processing software support which will be described in the next section.

The term "ultrasonic spectroscopy" was probably first usad by Otto R. Gericke of US Army Materials Technology Laboratory in early 60's, who found experimentally a strong correlation between the frequency spectrum of the pulse echoes and the geometries of the hidden defects. Although there were a number of subsequent efforts in the NDE community to use ultrasonic spectroscopy in other material testing problems, the success has been limited because of the lack of quantitative relationships between the defects and the frequency spectrum. However, the spectral domain methods are fundamental to modern signal processing, and by expanding ultrasonic spectroscopy to a larger class of spectrum based signal processing techniques, much more information about the defects can be extracted from the data. The word "high resuliton" refers to the cability to examine fine details of the signal and thus the defects. Such high resolution capability can only be offered by the software without added cost to the system.

THE IUNDE VERSION 2.3

Currently the software package IUNDE is in Version 2.3 and contains three parts.

Part 1. The signal processing package.
Signal acquisition: acquire signal from a disk file (in ASCII format), acquire signal from STR*825 board, acquire signal from LcCroy 9400 digital scope.

Power spectra: the fast Fourier transform (FFT), the Burg's maximum entropy spectrum analysis; the chirp-z transform; correlation; bicorrelation and bispectrum.

Deconvolution by Wiener filtering, by spectral extrapolation and by least mean square error (LMSE) criterion.

Special transforms: analytic signals, Hilbert transform, power cepstrum, discrete pseudo Wigner distribution (DSWD) and wavelet transform for time-frequency analysis.

Preprocessing: mean removal, moving average, circular shift, zero-padding, and amplitude normalization.

Graphic display using GraphiC software version 5.0 for 1-D, 2-D, 3-D and multi-window displays.

Feature extraction which extracts the following features: mean and maxima, peak correlation with reference, amplitude ratio, frequency ratio, moments of the spectrum, bandwidth and frequency of peak power, fractional power distribution in 8 bands.

Automated defect classification using Nestor's NDS-100 Neural Network.

Automated defect classification using back-propagation neural network.

Part 2. The pattern analysis package

In IUNDE, two different approaches to pattern recognition are available. The first approach is by using traditional statistical pattern recognition techniques with functions including the k-mean clustering, the nearest neighbor classification, Bayesian classification, Foley-Sammon transform, multiple Fisher's linear discriminant as well as nonlinear mapping. The second approach uses the neural network as described in Part 1.

Part 3. The MESA (Maximum Entropy Spectral Analysis) package

It includes four methods of spectral estimation: Burg, modified covariance, FFT and Broyden methods, with up to 4096 data points allowed as input and up to 8000 output spectral points.

REPORT OF THE PHASE III

The results of Phase II were presented in detail in the Final Report submitted to the Materials Technology Laboratory (MTL) in December, 1990. Since then continued work has been done to improve the software package. Intensive marketing of the software package has been the major Phase III effort. Eleven US companies and five foreign companies representing four countries have installed the software package in their NDE systems. Collaborative work is performed with one company to adapt the package to NDE of composite materials. Much more effort is needed to seek for companies which are interested to fund the collaborative work.

CONCLUDING REMARKS

Technically speaking, the system with the software package has incorporated the best available signal processing, pattern recognition and neural network technologies in the ultrasonic NDE of materials. The use of modern signal processing and related techniques as reflected in the entire system design can offer the truly high resolution ultrasonic NDE capability much needed for many applications. Future NDE systems are likely to equip with many of such techniques. The rapid development in signal processing hardware (such as the DSP chips) and advances in computation capabilities will make such systems even most cost effective. There is no doubt that the trend in NDE industry is to make increased use of digital signal processing software and hardware. On the other hand, the market place has been slow to follow such trend. Also a good communication between the digital scope and the computer is not an easy problem. Other hardware designs have incorporated the the pulser/receiver and the high speed digitizer in the computer but the role of digital scope is not fully served with such arrangement. Continued software and hardware improvements are definitely needed to effectively utilize such a high resolution system in a variety of NDE tasks.

ACKNOWLEDGEMENTS

I am most grateful to Dr. Otto R. Gericke of MTL (now retired) for his guidance and encouragements throughout most of this contract (Phases I & II). I also would like to thank all members of MTL Nondestructive Evaluation Group for their encouragements and interests in this work.

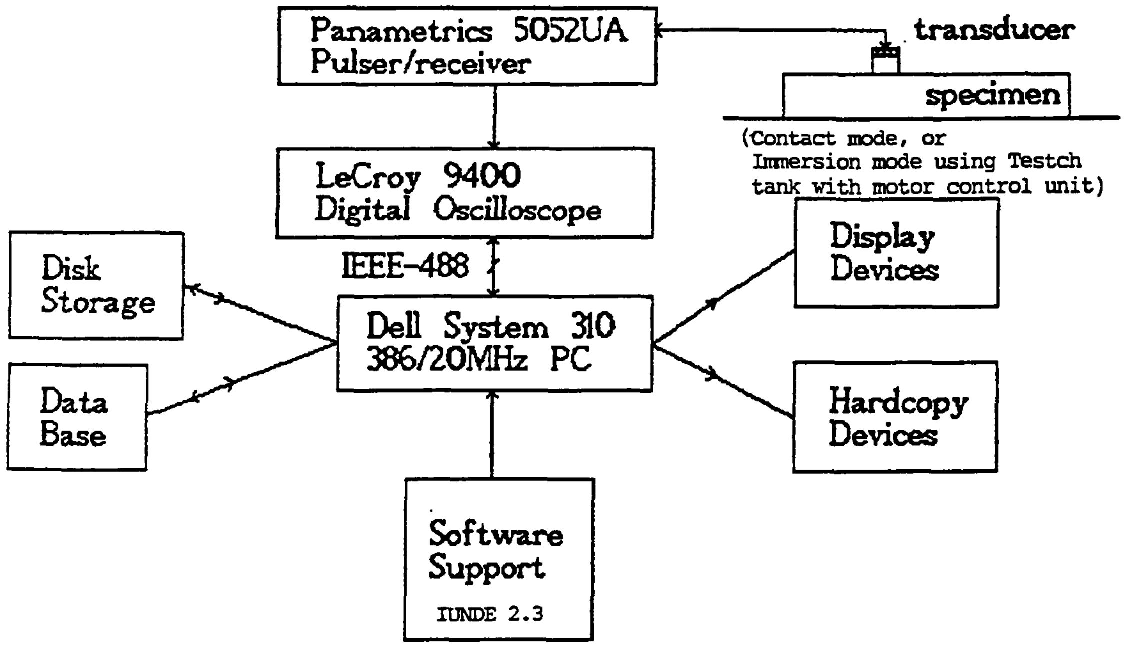

Figure 1. A block diagram of the high resolution ultrasonic spectroscopy system

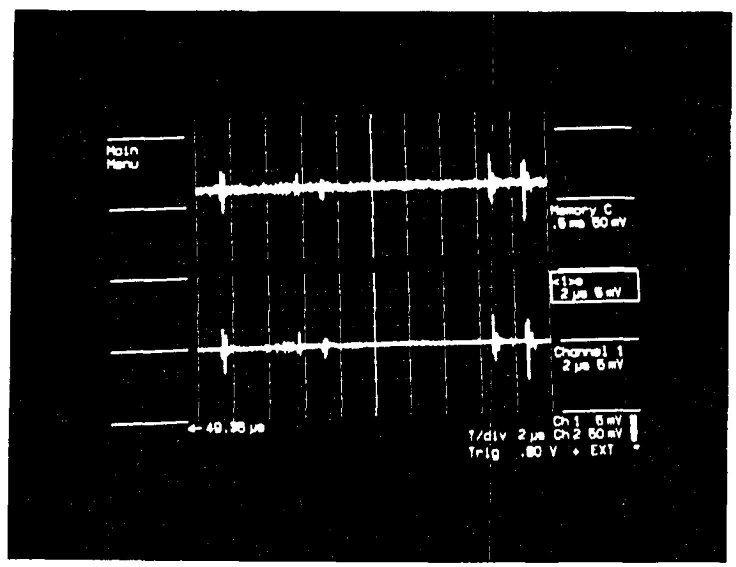

Figure 2. A typical long-window signal shown in digital scope. The upper figure shows the pulse echoes from a small lead ball in the immersion tank with a 10MHz transducer. The lower figure is the smoothed signal of the upper figure. Only two channels of signals are shown here.