Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 510325
UNCLASSIFIED	

TITLE

BACKGROUND RESEARCH LEADING TO THE APHIUS DEVELOPMENT PROJECT

System Number:

Patron Number:

Requester:

Notes: Paper #20 contained in Parent Sysnum #510305

DSIS Use only:

Deliver to: DK

#51 0325- (20)

Background Research Leading to the APHIUS Development Project

by

J. R. Matthews

Defence Research Establishment Atlantic
FMO Halifax, Halifax, Nova Scotia, B3K 2X0

Abstract

DREA Dockyard Laboratory began research in Pattern Recognition of weld defects in 1980. This research was aimed at producing signal processing that would allow the isolation of volumetric and crack like defects in weldments. With this ability a two level condemnation criteria, or weld reject criteria could be employed based on defect type with a projected savings in rework costs in the millions of dollars.

The work began with the generation of basic weld defects for the collection of ultrasonic data and production of software to extract features in the time, frequency, auto correlation, cross correlation and convolution domains. Features were evaluated by producing histograms from twenty signals. In this way we were able to isolate potentially useful features for determining the different defect types.

As soon as the research showed that pattern recognition would be successful, parallel work began with Tektrend to produce a system that would map defects and permit storage of rf waveforms for these defects. It was intended that data thus collected would be analysed in the lab and that defect maps would be produced with defect type determined by pattern recognition.

Three prototype inspection systems have been produced over the past twelve years with more and more power and capability being available to the inspector with real time defect classification and defect mapping now a reality.

This paper is a brief outline of the history of the research and development leading to the present APHIUS system.

Introduction

DREA Dockyard Laboratory began research in Pattern Recognition of weld defects in 1980. This work was part of a new research thrust in submarine materials technology which included welding research, high strain rate fracture research and NDE research. The Pattern recognition research was aimed at producing signal processing that would allow the isolation of volumetric and crack like defects in weldments. With this ability a two level condemnation criteria, or weld reject criteria could be employed based on defect type with a projected savings in rework costs in the millions of dollars.

The work began with the generation of basic weld defects for the collection of ultrasonic data [1]

1. crack like defects

2. geometric defects
3. incomplete fusion and penetration defects
4. slag inclusions
5. porosity

and production of software to extract features in the time, frequency, auto correlation, cross correlation and convolution domains. Features included for each domain included

1. maximum value (not considered in time domain since the waveforms are normalized to the maximum value)
2. minimum
3. area
4. max slope
5. location of max
6. location of min
7. duration
8. location of max slope
9. mean
10. rms
11. standard deviation
12. variance

Features were evaluated by producing histograms from twenty rf signals[1]. In this way we were able to isolate potentially useful features for determining the different defect types[2,3,4].

Pattern Recognition

The main goal of the pattern recognition research was to verify if features in UT signals and their transformations existed which could be used to classify defects according to type and therefore severity. Pattern recognition was conducted in three stages; first transformations were conducted on the rf waveforms, second features were extracted from each transformation and, third histograms were produced to evaluate individual features.

Histograms produced showed features to be either separated, touching or overlapping. In the earliest studies[1], cross correlation of an unknown waveform and reference waveform was the most useful for differentiating between fatigue cracking and slag whereas auto correlation was found to be more useful than convolution, time and frequency domains for separating fatigue cracks from holes. The mean value, RMS, standard deviation, and variance of the five waveforms were observed to be the best features for separating defects.

In later studies angled cracks were included in the library of defects being studied[3]. The RMS of the auto correlation, the standard deviation of the auto correlation, the variance of the time, the standard deviation of the time, and the standard deviation and RMS of the cross correlation, showed good separation in the numerical ranges for each type of defect and were consistent. Cross correlation values were slightly better than the time and auto correlation. The earliest study, which was conducted at a 20 MHz sampling rate, had suggested a wider improvement of cross correlation over the others, than identified in this study at 10 MHz sampling rate.

Many factors were evaluated as to their effect on the reproducibility of pattern recognition results. The most important factor turned out to be the impedance mismatch between the electronics and the transducers. A lot of work was conducted with the aim of developing techniques for the transportability of components, including transducers, while maintaining the same classifiers. It is now felt that this may be unachievable and that each set up, and transducer, will have to be trained separately. This would have been considered a disaster ten years ago but with the current APHIUS system complete training can be accomplished in less than an hour for a given set up and transducer.

Inspection Systems

As soon as the research showed that pattern recognition would be successful, parallel work began with Tektrend to produce a system that would map defects and permit storage of rf waveforms for these defects[5,6]. It was intended that data thus collected would be analyzed in the lab and that defect maps would be produced with defect type determined by pattern recognition.

Several prototype inspection systems[7,8,9,10] have been produced over the past twelve years with more and more power and capability being available to the inspector with real time defect classification and defect mapping now a reality[11,12,13,14].

The early prototypes[7], of which there were several versions, were called SLAM(signal location and acquisition module). SLAM included a high speed 50 MHz digitizer with a 1024 data point buffer and an air-borne sonic location system. The system provided an easy and simple interface for an ultrasonic inspector to acquire data in the field with complete data record storage on magnetic cartridge tape that could be analyzed by an expert later in the laboratory. The recorded data included x,y coordinates and the complete rf waveform. The operators used a standard UT unit for the inspection and data was recorded when the operator depressed a button on the transducer. The rf signal was taken directly from the standard UT unit.

The later prototypes[11], designated APHIUS(Automated Pressure Hull Intelligent Ultrasonic System) were designed around IBM PC systems. These later prototypes combined a computer-based ultrasonic analysis work station with a computer-based ultrasonic field inspection capability. On-line, the systems performed complex signal processing including feature extraction and classification. The recognized defects were immediately available on a defect map. Off-line, the systems could be used as a signal examination machine and also used to train and develop classifiers. APHIUS was designed on the PC 80X86 open architecture to provide for expandability, growth and modification of the system as requirements and technology evolved. The ultrasonic capability was incorporated through a pulser/receiver on an expansion board as was data acquisition using an A/D conversion expansion board for complete waveform recording. Real time, on-line decision-making was made possible using the 80X87 numeric coprocessor chip and high-speed FFT and DSP expansion cards.

Conclusions

This paper has given a brief outline of the history of the research and development leading to the present APHIUS system.

References

1. J.P. Slade and J.R. Matthews, "Selection of Optimal Features for a Pattern Classifier to Identify Weld Defects," DREA RN/DL/82/3, September 1982.

2. J.R. Matthews and J.P. Slade, "Optimal Features for a Pattern Classifier to Identify Weld Defects in Submarine Pressure Hulls," Presented at 1983 ASNT Spring Conference, Orlando, Florida, 7-10 March 1983.

3. G.A. Sutherland and J.R. Matthews, "Effect of Crack Orientation on the Selection of Features for a Pattern Classifier to Identify Weld Defects Using Ultrasonic Techniques," DREA RN/DL/85/2, January 1985.

4. J.R. Matthews and G.A. Sutherland, "Selection of Features for a Pattern Classifier to Identify Weld Defects in HY 80 Weldments," Abstracts and Summaries of the CF/CRAD Meeting on Research in Fabrication and Inspection of Submarine Pressure Hulls, May 1985., May 1985.

5. J.R. Matthews, D.R. Hay, R.W.Y. Chan, "Automated Ultrasonic Inspection and Data Collection System," Presented at Ultrasonics International 83, Dalhousie University, Halifax, N.S., 12-14 July 1983.

6. D.R. Hay, "Automated Ultrasonic Inspection and Data Collection System", Tektrend International Inc., DREA Contractor Report, CR/85/413, August 1985.

7. R. Chan and D.R. Hay, "Automated Ultrasonic System for Submarine Pressure Hull Inspection", Tektrend Int., DREA CR/87/401, January 1987.

8. D.R. Hay, J.R. Matthews, and H.A. MacDonald, "Automated Ultrasonic System for Submarine Pressure Hull Inspection," in proceedings of the NATO Advanced Research Workshop on Signal Processing and Pattern Recognition in Nondestructive Evaluation of Materials, Quebec City, Canada, August 19 -22, 1987.

9. D.R. Hay, J.R. Matthews, and H.A. MacDonald, "Automated Ultrasonic System for Submarine Pressure Hull Inspection," Presented at the 2nd CF/CRAD Meeting on Research in Fabrication and Inspection of Submarine Pressure Hulls, Halifax, N.S., May 26-28, 1987.

10. J.R. Matthews, D.R. Hay and R.W.Y. Chan, "Computer Aided Ultrasonic Inspection of Submarine Pressure Hulls", in proceedings of Review in Progress in Quantitative NDE, Bowdoin College, Brunswick Maine, July 1989.

11. D.R. Hay and R.W.Y. Chan, "Automated Ultrasonic System and Pattern Recognition for Submarine Pressure Hull Inspection", Volume I: Main Report, prepared by Tektrend Inter. Inc., contractor report, DREA CR/90/409, Vol I, April, 1990.

12. R.W.Y. Chan, A. Pelletier and G. Borghi, "Automated Ultrasonic System and Pattern Recognition for Submarine Pressure Hull Inspection", Volume II: Aphius User's Manual, prepared by Tektrend Inter. Inc., contractor report, DREA CR/90/409, Vol II, April, 1990.

13. "Automated Ultrasonic System and Pattern Recognition for Submarine Pressure Hull Inspection", Volume III: Aphius Program Documentation, prepared by Tektrend Inter. Inc., contractor report, DREA CR/90/409, Vol III, April, 1990.

14. D.R. Hay, J.R. Hay and G. Borghi, "Automated Ultrasonic System and Pattern Recognition for Submarine Pressure Hull Inspection", Volume IV: Pattern Recognition Results, prepared by Tektrend Inter. Inc., contractor report, DREA CR/90/409, Vol IV, April, 1990.