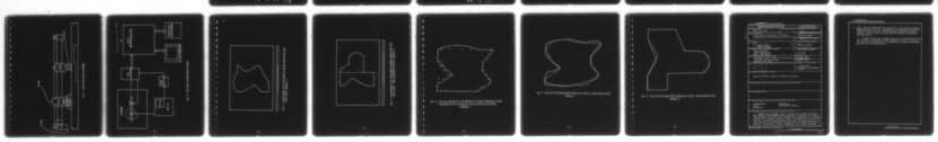
AD-A062 575 DREXEL UNIV PHILADELPHIA PA DEPT OF MECHANICAL ENGIN--ETC F/G 20/1
MICROPROCESSOR UTILIZATION IN ULTRASONIC INSPECTION FLAW GROWTH--ETC(U)
AUG 78 J L ROSE, G H THOMAS N00014-77-C-0607

UNCLASSIFIED NL

| OF |

AD
A062575



END
DATE
FILMED
3-79
DDC

# Microprocessor Utilization In Ultrasonic Inspection Flaw Growth Classification Studies

Joseph L. Rose+

and

Graham H. Thomas++

Department of Mechanical Engineering
and Mechanics
Drexel University
Philadelphia, Pennsylvania 19104



August 31, 1978

Department of the Navy
Office of Naval Research
Structural Mechanics Program
Arlington, Virginia 22217
Contract No. N00014-77-C-0607



+ Professor of Mechanical Engineering

++ Graduate Student in Mechanical Engineering

## Table of Contents

Page


Introduction .......... 1

Selection of a Microprocessor .......... 2

Method of Attack .......... 3

Results .......... 4

Fatigue Crack Study .......... 5

Future Work Tasks .......... 8

References .......... 9

Figures .......... 10

Introduction:

Computers are extremely vital to the work that is being performed in many research and development areas in ultrasonic inspection. The many reasons for the computer's popularity and importance are outlined in a paper by Rose and Rogovsky [1] that was prepared as part of a first year effort on the ONR research program. The overall research program is outlined in Table I.

The first year's effort in the study of microprocessor utilization in ultrasonic inspection for flaw growth determination has encompassed a tremendous work task from the initial concept and problem statement to the selection and construction of the microprocessor system and to the final implimentation. The underlying purpose of this year's work was to demonstrate the applicability of microprocessors to the ultrasonic inspection field. The importance of using microprocessors to perform ultrasonic data acquisition and signal analysis is to allow the large, laboratory based computers used for traditional signal processing to be replaced by smaller, inexpensive, and portable processing units. Thus the computing power now limited to the laboratory could be transported into the field. The emphasis of microprocessor implementation was directed initially towards ultrasonic inspection problems of interest to the U.S. Navy, in particular that problem of inspecting ship hull plates additional details of which are presented in [2]. The task of inspecting ship hull plates was selected because of its practical application as well as its ease of ultrasonic implimentation. The inspection procedure is designed to be instrumental for both quality control during manufacture and inservice inspection. The system allows manual scanning of the area of interest, records the location of the edge of the damaged area and presents a graphical picture of the extent of the damage. The area of interest must first be determined either form a quality control examination, a possible acoustic emission, liquid penetrant, or visual inspection. In addition, this system is designed to monitor the damaged area and to note any growth while the ship is in service. Therefore, as shown in figure 1, the first year's work included the mechanical systems development, introduction to basic microprocessor technology and implimentation to a simple ultrasonic inspection problem.

A second work task was included as part of this microprocessor feasibility study. As illustrated in figure 1, task II efforts consisted of developing an advanced ultrasonic nondestructive test for flaw classification. The particular ultrasonic test considered was that of fatigue crack growth and remaining life prediction for aluminum specimens, additional details of which are presented in [3,4]. A computer derived algorithm was developed to interpret the ultrasonic signals which were reflected from damaged area. The algorithm incorporated pattern recognition techniques, in particular an Adaptive Learning Network, to predict nondestructively the extent of damage incured. This pattern recognition algorithm is then to be programed on the microprocessor to demonstrate the ability of a microprocessor to perform advanced nondestructive testing problems.

## Selection of a Microprocessor

The most important step in developing a data acquisition and signal processing system such as the one being used in our flaw growth inspection system, is the selection of the central processing unit, in this case, a microprocessor. An LSI-11 microprocessor system has been purchased and is being used for studying such problems as storage requirements, computation time, interfacing problems, programming modes and general adaptability to nondestructive testing kinds of problems. The LSI-11 unit was selected for several reasons, the principle reason of which is associated with the availability of a development system in our laboratory, namely the PDP11/05 minicomputer system. Also, the LSI-11 is one of the more versatile microprocessors, with more than sufficient memory capacity for this problem.

## Method of Attack

The problem of scanning a large steel plate and determining the extent of any damage was divided into four segments. First a mechanical scanner was designed and built to locate accurately the transducer on the plate. The scanner, as shown in figure 2, is attached to the plate at its pivot point by either a magnet or a suction cup. The transducer is attached to a slider which is mounted on an arm that is allowed to turn about the pivot point. A polar coordinate representation of the transducer's location is obtained from potentiometers, one located at the pivot, which provides the angle, and one attached to the slider by a string and pulley system, which provides the radius.

The second part of the system is the data acquisition equipment. The proposed equipment, as shown in figure 3, consists of a USIP-11 flaw detector, a peak detector box and an inexpensive analog to digital converter. The USIP-11 is used to pulse the transducer and to gate out the significant signal. The peak detector will determine the peak voltage of the gated signal and the analog to digital converter will digitize that voltage so it can be stored in the microprocessor. Therefore, each data point will be an element of an array which will be stored in the computer in the form of a radius, an angle, and a voltage $(r, \Theta, P)$.

The third part of this inspection system is the signal processor. The signal processor consists of a LSI-11 microprocessor, a video display terminal, a paper tape reader/punch and the necessary interfacing hardware. This signal processing system must store all the data points and their respective voltage levels, plus determine which data points locate the edge of the damage area. Once the edge points have been separated, a picture of the damaged area can be displayed on the video terminal and punched on paper tape for a permanent record.

The fourth and final segment of this project was to design and machine test specimens for determining the accuracy of the system. Two ship hull model specimens have been designed to test this microprocessor based, C-scan system. Drawings of the two test specimens as shown in figures 4 and 5. These specimens were machined from 1/2" thick steel plates and include various curvatures, right angles, and depths. The manual C-scan apparatus was used to determine the shape of each flaw. An account of the accuracy and reproducibility of the microprocessor based C-scan was gained by using these two models.

## Results

The utility of a microprocessor in an ultrasonic inspection system is certainly demonstrated with the design and implimentation of this microprocessor augmented 'C'-scan system. There are two options for the form of the output from this microprocessor based ultrasonic test apparatus. The output may be displayed on the video termainal by a crude graphics mode. Examples of these plots are shown in figures 6 and 7. Also the microprocessor is able to punch on paper tape the precise coordinates sent to the microprocessor from the potentiometers of the 'C'-scan device. The precise coordinates can be additionally be plotted on a more sophisticated terminal if the microprocessor is directly interfaced for example to a PDP-11 terminal. The graphics package on the PDP-11 terminal was used to demonstrate the accuracy of the microprocessor controlled 'C'-scan system. A PDP-11 drawn plot is shown in figure 8 along with an actual drawing of the flaw.

## Fatigue Crack Study

In order to attack today's complex nondestructive test (NDT) problems, an organized approach making the best use of available inspection procedures, instrumentation and advanced techniques in signal gathering and analysis is required. These elements must be combined with as much physical understanding of the problem as possible. Lack of attention to any of these details can ruin a prospective solution. An example problem attacking the important task of fatigue damage detection and estimation was used to suggest procedures that can be extended to other problems.

Nondestructive inspection techniques seek to improve the reliability of various structures by detecting material flaws and defects either during manufacture or in service. The ultimate goal of nondestructive testing may simply be expressed as the location and complete specification (size, shape, orientation, etc.) of a flaw. This is seldom possible, however.

A fatigue crack growth and remaining life study has been conducted at Drexel University during the previous year with the thought of possibly implimenting the algorithm on a microprocessor. The problem of fatigue damage is certainly an important one. It has been estimated that some 75-90% of all mechanical failures are fatigue related. It is not surprising then that various studies have been carried out to detect or estimate the size of fatigue cracks.

A knowledge of loading conditions, stress analysis, and fracture mechanics indicates that cracks tend to form at certain sites and in certain structural areas, and to grow in certain directions. This is particularly true when artificial sites such as fastener holes, cooling passageways, threaded sections, or keyways are present. This may be less true if the formation sites are natural in form such as voids or metal inclusions. However, the artificial sources have been shown to be the predominant sources of cracking problems.

Most of the investigators to date have tried to detect a crack of a certain size. In some cases this "crack" was a saw cut or a machined slot, in others a fatigue crack grown from a starter scratch or notch, and in a few cases actual cracks have been used. The work presented in this paper uses a plate fatigue specimen containing a through hole as a crack initiation site. No modification of the through hole was made to produce a single crack. In fact, a multiple crack was always formed in the vicinity of the hole due to the cyclic reverse bending applied to the specimen.

At various points in their fatigue life, the test was stopped, and the specimens were interrogated using a simple ultrasonic shear wave test arrangement. The entire inspection was made from one side of the plate. Fixtures were used to locate the transducer normal to the expected direction of crack propagation at two predetermined locations with respect to the through hole. The ultrasonic waveforms were digitized, stored, transformed, and analyzed on a computer. An adaptive learning network (ALN) was used to develop a correlation between the characteristics of the signal and the percent of fatigue life seen by the specimen.

This produced a detection of fatigue damage after 10% of the fatigue life with a 92% success. Estimates of damage were made within $\pm$ 20 of the actual fatigue life percentage for 76% of the data. A study of fracture surfaces indicates that the single crack size at the limit of detection was approximately .020 in. in length and .030 in. in depth.

It should be noted that this procedure avoids progressing from measuring crack size, through a fracture mechanics analysis, and to a calculation of criticality. Rather it goes directly to a prediction of system performance. It should also be noted that the ultrasonic test procedure was realistic for inservice use.

Major conclusions of the fatigue crack study are listed below.

1) The use of only amplitude-time information is usually not sufficient to characterize the flaw. By transforming the amplitude-time signal into the frequency domain the task of classifying flaws is in general simplified. Thus a major portion of NDT inspection is involved in signal processing which depends on the use of digital computers.

2) The ultrasonic test employed was designed to be realistic and simple, to tend to remove operator influences from the testing and to perform the complete inspection from one side of the plate. It should be noted that even sophisticated signal processing and pattern recognition schemes are doomed to failure unless the basic test equipment is well understood and the testing procedure well conceived.

3) A computer based test system is required to handle the volume of data generated in this type of study and to quickly process the signal information. Such a system also provides unbiased handling of the data and thus promotes inspector objectivity.

Future Work Tasks

It is proposed to continue this microprocessor oriented study for determining the applicability of microprocessors for advanced ultrasonic inspection and for structural dynamics assistance. The work for the second year of this ONR research program will consist of two additional tasks, which are shown in figure 1 as tasks III and IV. Tasks III efforts involve developing software and hardware to improve the accuracy, speed, and reproducibility of the existing microprocessor based "C" scan system. Several techniques that could be useful for improving the accuracy of the "C" scan system are incorporating a second generation improved manual scanner, more sophisticated ultrasonic inspection equipment, and more intricate signal processing schemes.

Task IV is proposed to develop an algorithm to solve a contemporary and challenging ultrasonic nondestructive test problem using our laboratory based minicomputer in a generalized systems approach to the inspection problem. Once the computer software has been designed with generalized coefficients and computation routines, task IV work would then be to implement the software on the LSI-11 microprocessor system. There are several anticipated difficulties involved in the transition of the software from Drexel University's PDP11/05 minicomputer to the LSI-11 microprocessor. First, due to the limited core storage of the microprocessor, the higher level language used to program the minicomputer will have to be translated into assembly language, which uses core storage more efficiently, to program the microprocessor. Also, the microprocessor will have to be modified so that it may interface with more sophisticated peripheral devices such as real time analog to digital converter. Once the capability to translate programs from the minicomputer's higher level language to the LSI-11's assembly language, plus the ability ot interface the microprocessor with ultrasonic equipment has been developed, many Navy oriented ultrasonic inspection problems can be readily solved by a microprocessor.

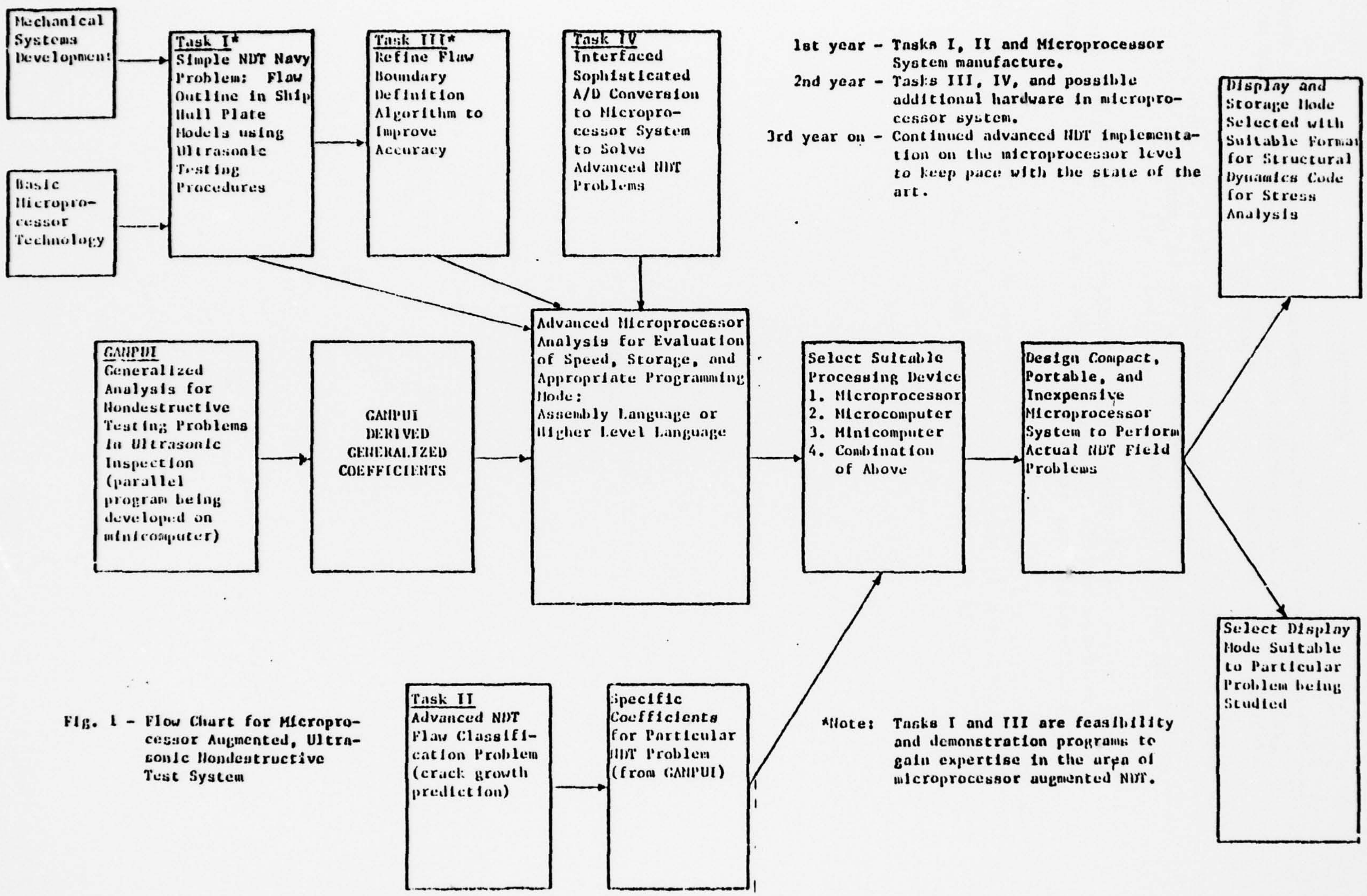
## References

1. Rose, J.L. and Rogovsky, A., "Computer Assisted Ultrasonic Nondestructive Evaluation," to be presented at the International Symposium on Fracture Mechanics, in Washington, D.C., September 11-13, 1978.

2. Rose, J.L. and Thomas, G.H., "An Accurate, Fast, Microprocessor C-scan System for Flaw Growth Determination," To be presented at Fall Conference of ASNT in Denver, Colorado. October 2-5, 1978.

3. Carson, J.M., "An Ultrasonic Test Procedure for the Early Detection of Fatigue Damage and the Prediction of Remaining Life," PH.D. Thesis, Drexel Univeristy, May 1978.

4. Carson, J.M. and Rose, J.L., "An Ultrasonic Test Procedure for the Early Detection of Fatigue Damage and the Prediction of Remaining Life," To be presented at Fall Conference of ASNT in Denver, Colorado. October 2-5, 1978.




1st year – Tasks I, II and Microprocessor System manufacture.

2nd year – Tasks III, IV, and possible additional hardware in microprocessor system.

3rd year on – Continued advanced NDT implementation on the microprocessor level to keep pace with the state of the art.

*Note: Tasks I and III are feasibility and demonstration programs to gain expertise in the area of microprocessor augmented NDT.

Fig. 1 – Flow Chart for Microprocessor Augmented, Ultrasonic Nondestructive Test System

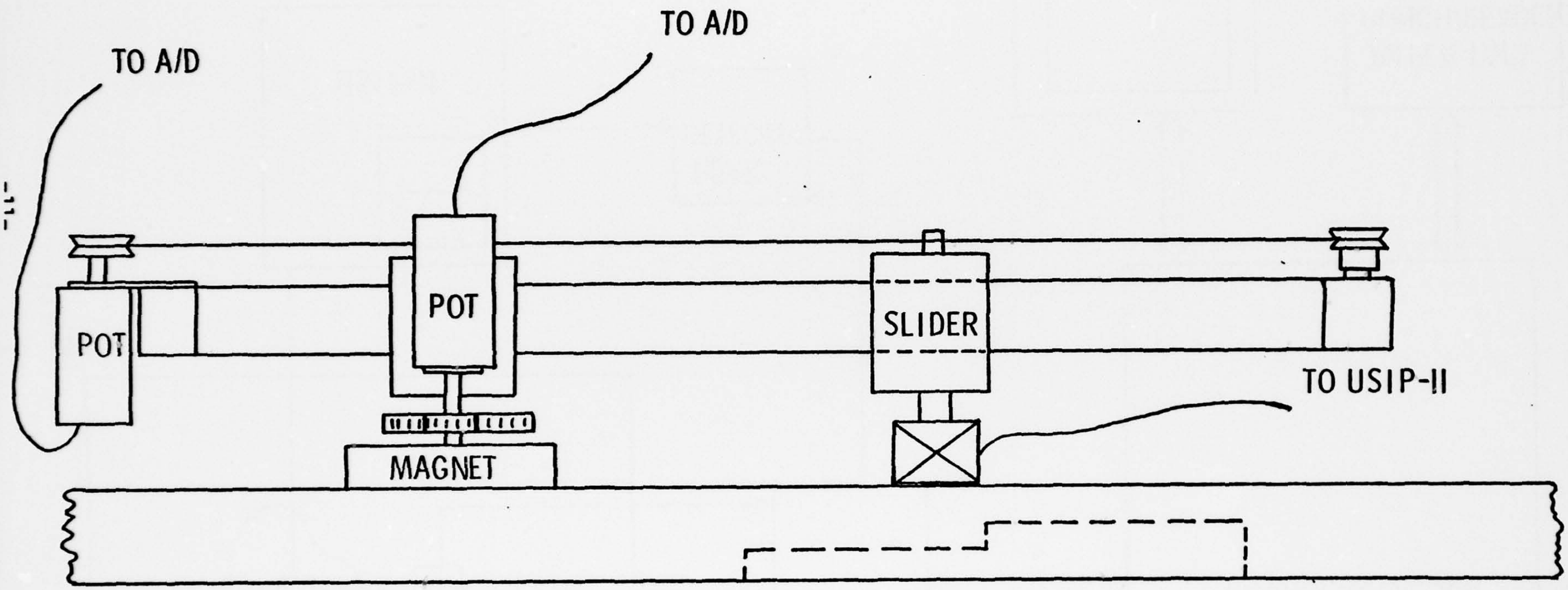



Fig. 2 - SHIP HULL PLATE SCANNER

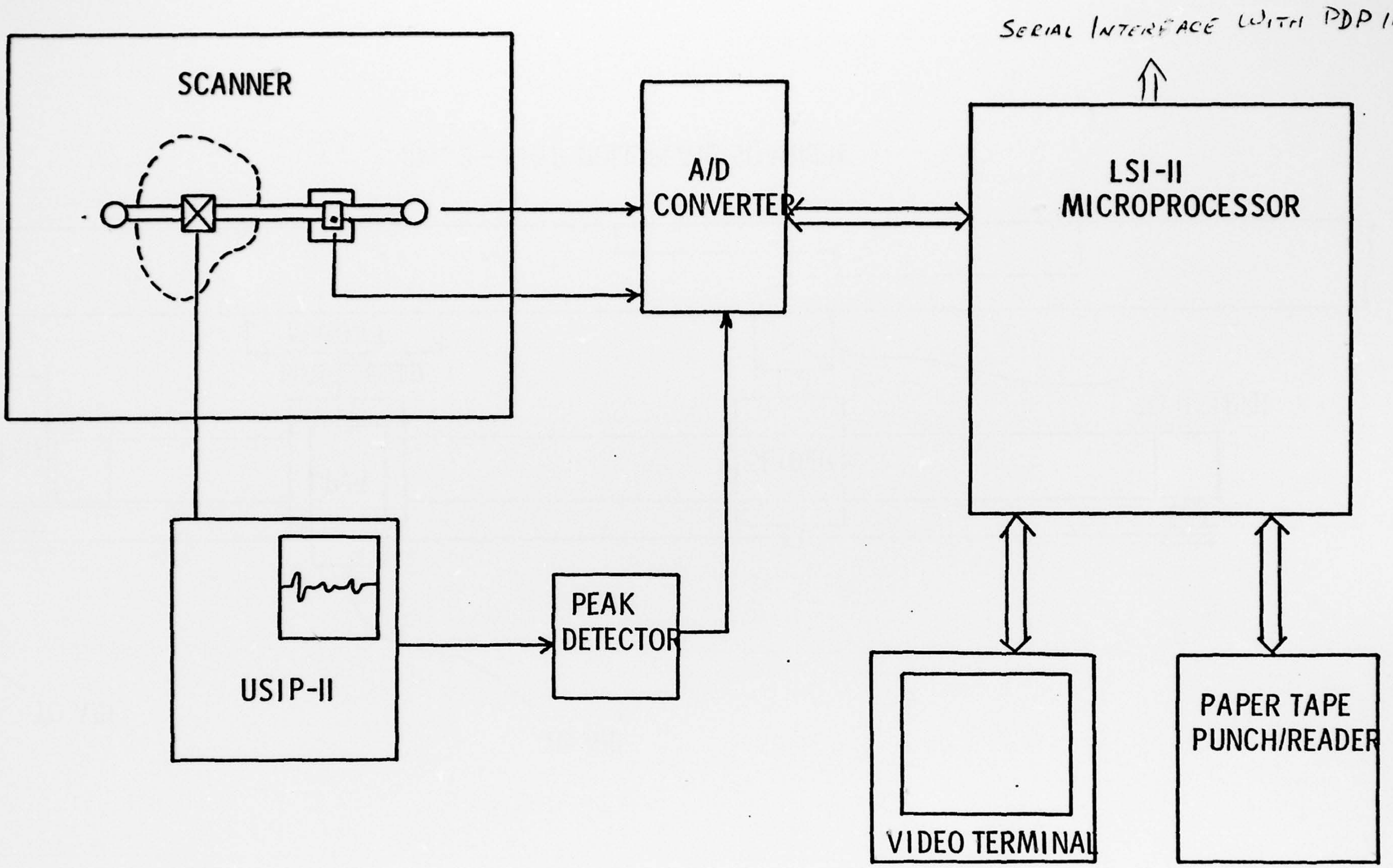



Fig. 3 - SHIP HULL INSPECTION SYSTEM

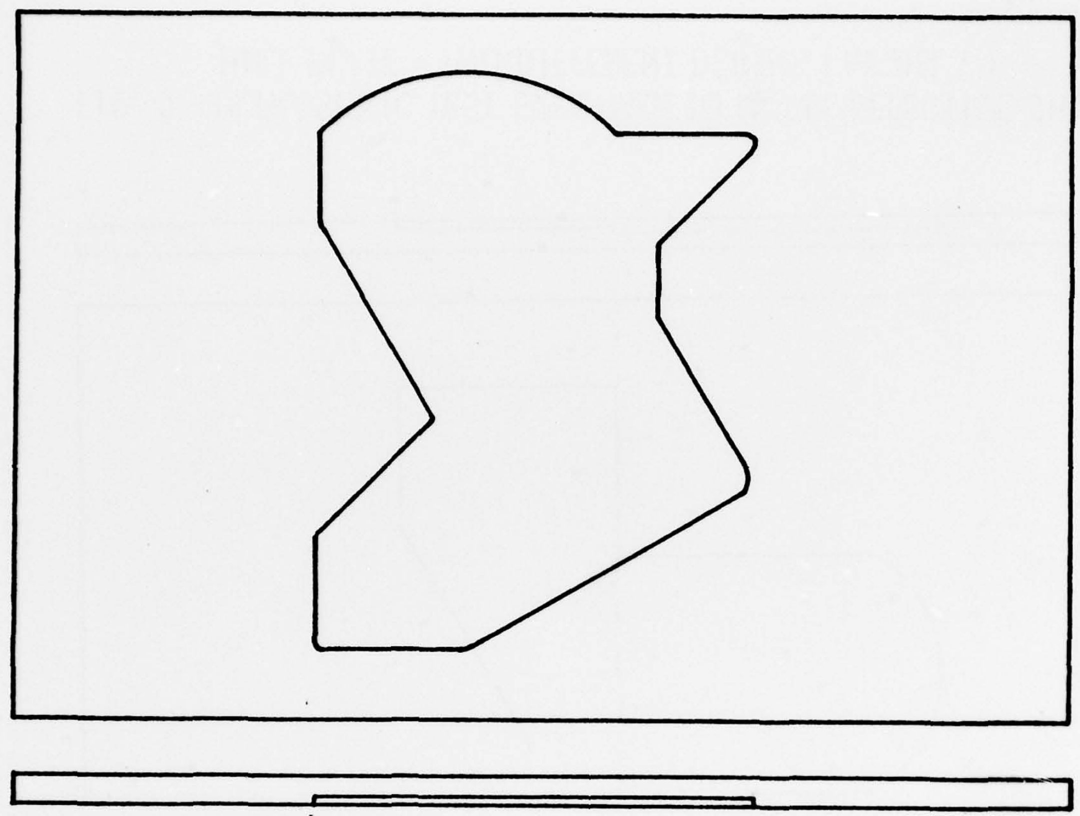


FIG. 4 - ULTRASONIC TEST SPECIMEN TO MODEL DEFECTIVE SHIP HULL PLATE ( MODEL 1 )

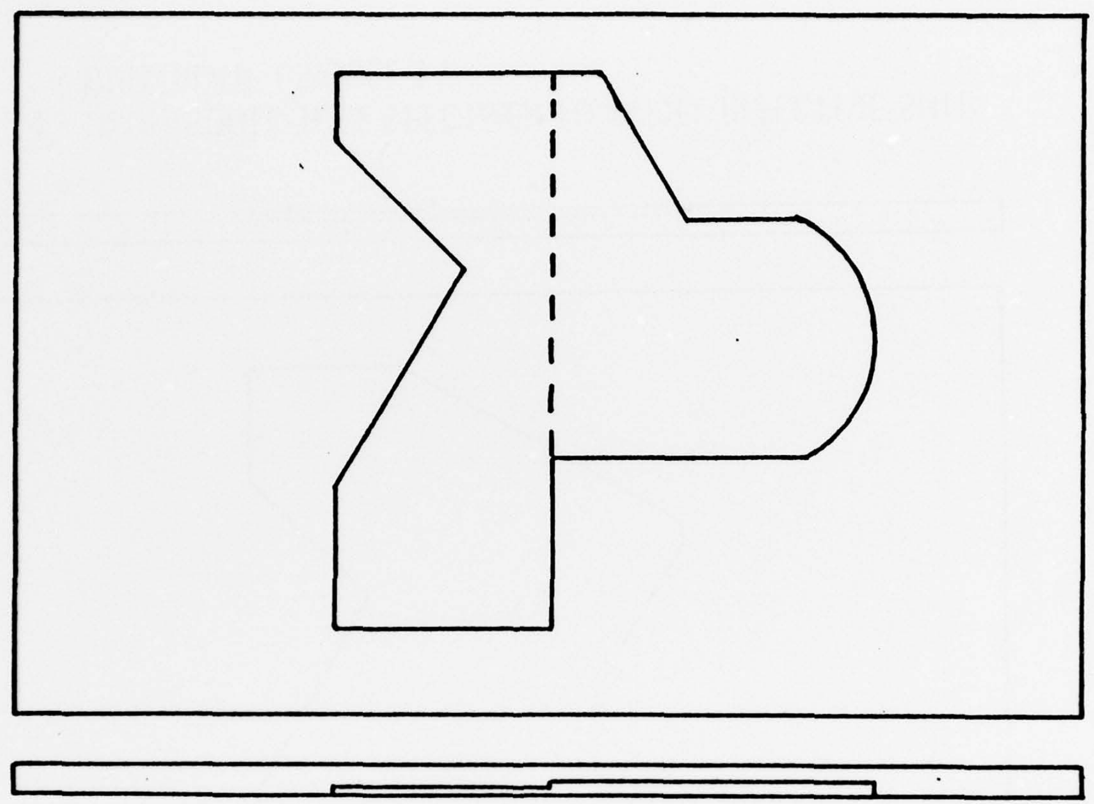


FIG. 5 - ULTRASONIC TEST SPECIMEN TO MODEL DEFECTIVE SHIP HULL PLATE - TWO DIFFERENT DEPTHS ( MODEL 2 )

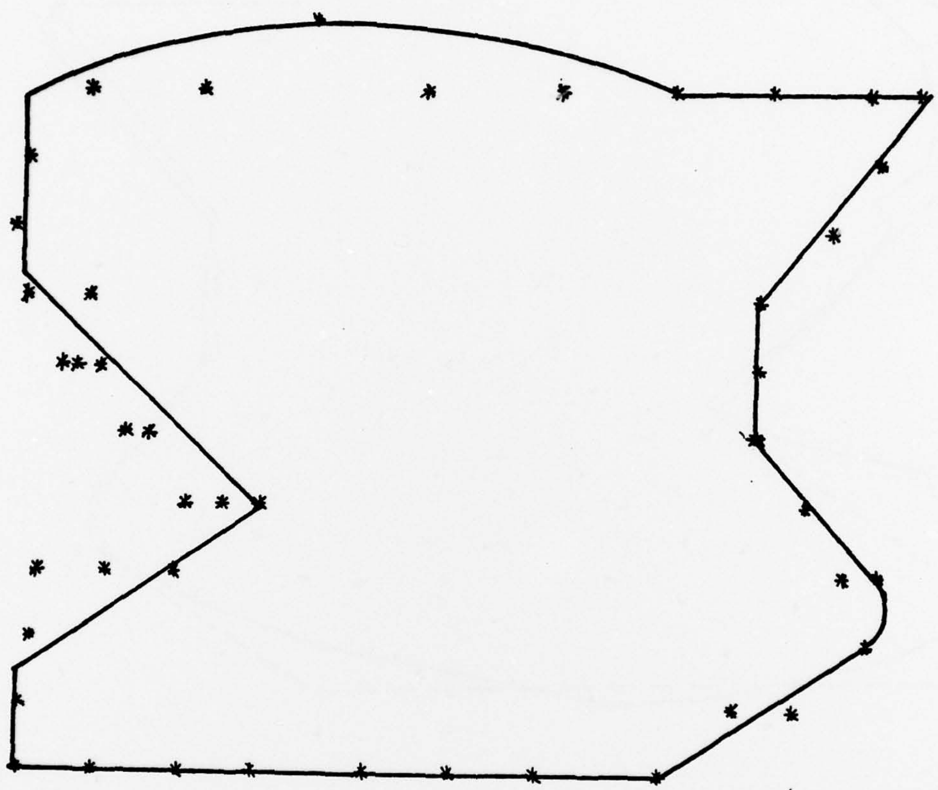


FIG. 6 - TYPICAL EXAMPLE OF THE GRAPHICS DISPLAY SHOWING A FLAW MAPPED BY THE C-SCAN SHIP HULL INSPECTION SYSTEM (MODEL I)

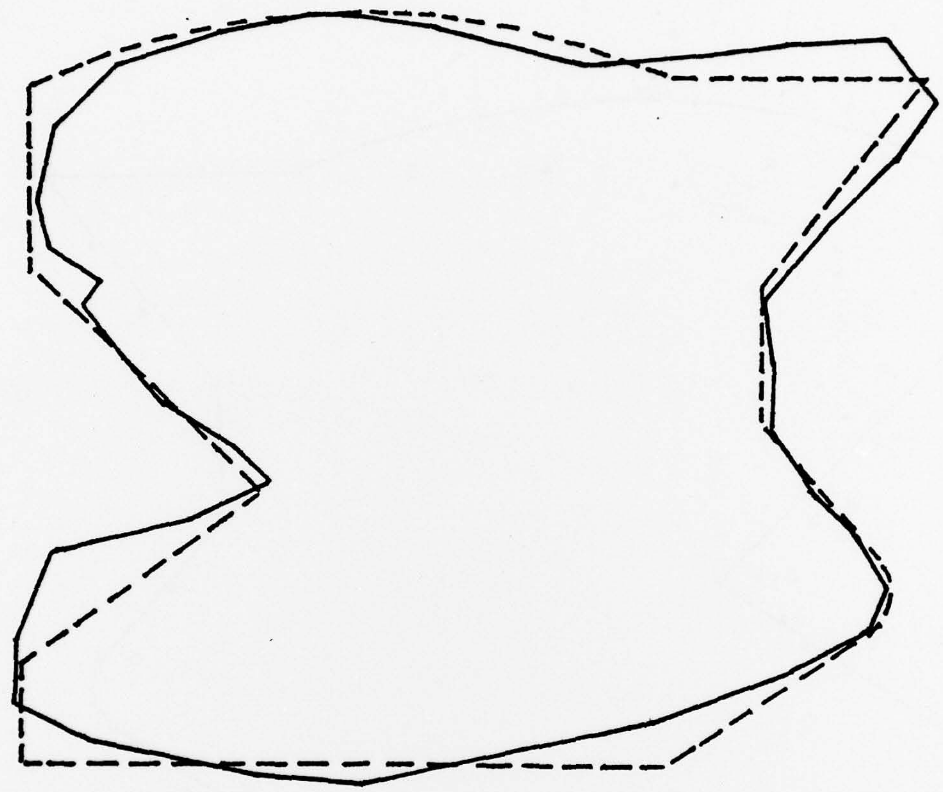


Fig. 7 - PLOT OF FLAW FROM PDPII TERMINAL USING C-SCAN COORDINATES (MODEL I)

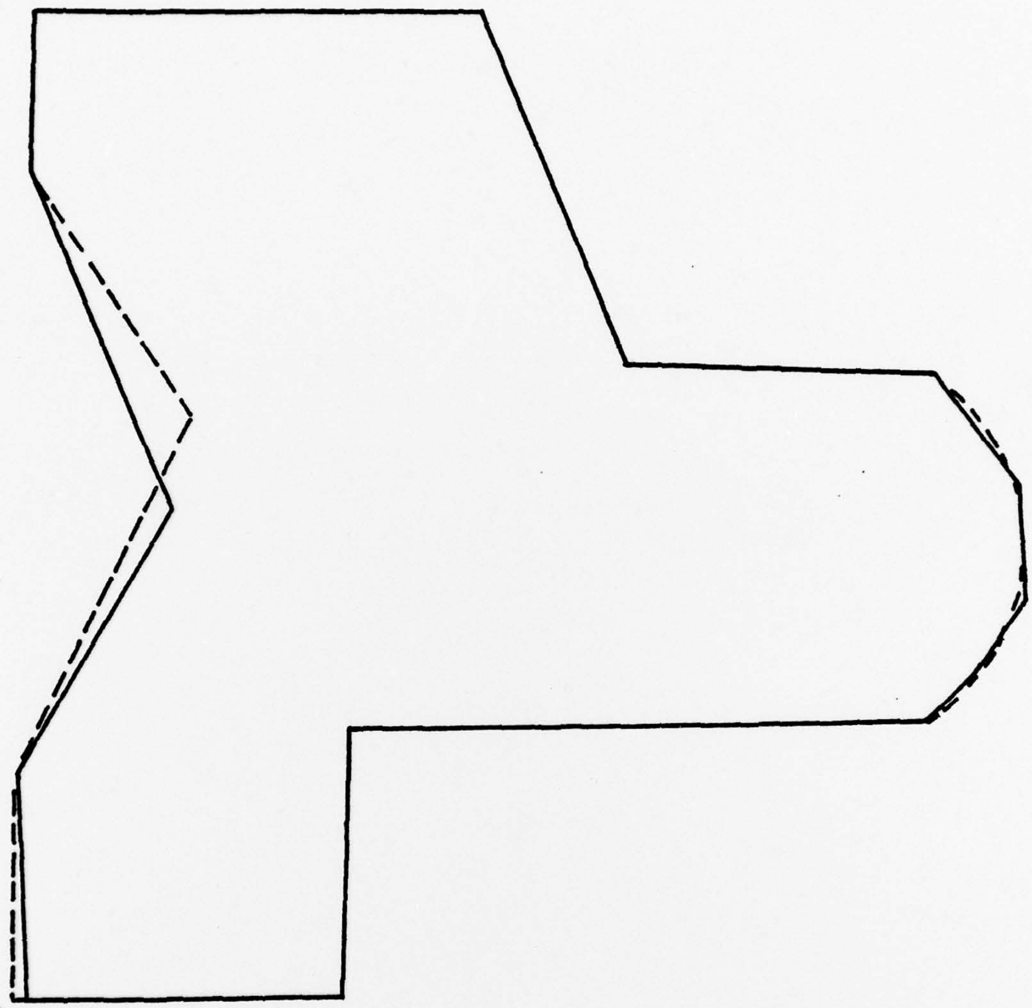


Fig 8 - PLOT OF FLAW FROM PDPII TERMINAL USING C-SCAN COORDINATES
(MODEL 2)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

## REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | | |
|---|---|---|
| 1. REPORT NUMBER<br>N00014-77-C-0607 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>Microprocessor Utilization In Ultrasonic Inspection Flaw Growth Classification Studies | | 5. TYPE OF REPORT & PERIOD COVERED<br>1st Annual Report<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>Joseph L. Rose<br>Graham H. Thomas | | 8. CONTRACT OR GRANT NUMBER(s)<br>N00014-77-C-0607 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Drexel University<br>32nd & Chestnut Sts.<br>Phila., PA 19104 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>NR 064-583 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Department of Navy, Office of Naval Research<br>Structural Mechanics Program<br>Arlington, VA 22217 | | 12. REPORT DATE<br>August 1978<br>13. NUMBER OF PAGES<br>21 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>Unclassified<br>15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release, Distrubution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Microprocessor
C-Scan
Ultrasonics
Minicomputer
Nondestructive Testing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Computers are extremely vital to the work that is being performed in many research and development areas in ultrasonic inspection. The underlying purpose of this study was to demonstrate the applicability of microprocessors to the ultrasonic inspection field. The importance of using microprocessors to perform ultrasonic data acquisition and signal analysis is to allow the large, laboratory based computers used for traditional signal processing to be replaced by smaller, inexpensive, and portable processing

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) units. Thus the computing power now limited to the laboratory could be transported into the field. The emphasis of microprocessor implementation was directed initially towards ultrasonic inspection problems of interest to the U.S. Navy, in particular that problem of inspecting ship hull plates.

A second task is also included as part of this microprocessor feasibility study. An advanced ultrasonic inspection problem, that of fatigue crack growth determination, was developed as a possible implimentation test for the microprocessor.