In-situ Weld Quality Inspection with Matrix Phased Array (MPA) Ultrasonic Technology

Sean Gleeson[a], Gavin Dao[b], and Jeong K. Na[a]

[a]*Edison Welding Institute, 1250 Arthur E. Adams Drive, Columbus, OH 43221*
[b]*Advanced OEM Solutions, Cincinnati, OH 45236*

Abstract. In the Oil and Gas industry, it is very common to make welds on pipes in the field. For straight pipes, most of the time, welds are inspected with an automated ultrasonic testing (AUT) system. However, pipes having non-traditional geometric constraints such as a slanted corrugation feature prohibit the use of an AUT method. As an effort to develop a field deployable in-situ weld inspection system, a high-speed MPA circuit board (purchased from Advanced OEM Solutions) has been used to drive a 32-element MPA probe operating at 3 MHz. The goal of the most recent phase of this development was to achieve a minimum of 200 inches per minute real-time inspection speed to match a welding process developed simultaneously at EWI. In order to meet the speed requirement, it was necessary to maximize the data acquisition rate as close as possible to the data transfer rate the MPA circuit board could support. A customized ultrasonic imaging algorithm developed using the Python programming language proved to be effective enough to achieve a maximum of 220 inches per minute inspection speed. In this paper, detailed discussions on the development of imaging algorithm and the results of real-time imaging inspection performed on a test specimen are presented.

Keywords: Automated Ultrasonic Testing (AUT), Matrix Phased Array (MPA), Python

INTRODUCTION

Principles of In-situ Ultrasonic Matrix Array Testing

The technique of using a matrix of ultrasonic transducer elements differs in principle from linear phased array or single crystal ultrasonic inspection methods (Fig. 1) because the arrangement of the piezoelectric elements in a matrix array inherently produces two dimensional position data. Because position information is always available with reference to the array itself, data collected can always be presented as a C-scan image. This differs from single crystal or linear phased array ultrasonics where both techniques require a mechanical rastering mechanism to index and scan when a c-scan image is to be produced.

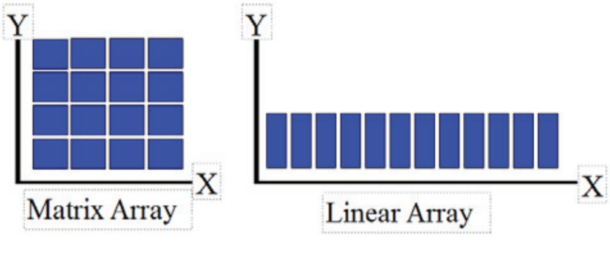

FIGURE 1. Transducer element configurations for matrix and linear arrays.

Because a c-scan provides a top down view, it is arguably the most intuitive way to display ultrasonic data. Having ultrasonic data continuously displayed in a c-scan format has the advantage of simplifying the interpretation of the information which enables defect detection to be automated or allows operators with general knowledge of ultrasonic inspection techniques to assess. Because the size, shape, element size and element pitch of the 2-D array is known, the size of features detected in the c-scan image can estimated using well established feature detection software. Once a feature is detected, calculations on the feature can be quickly performed allowing area, length, width etc. to be

40th Annual Review of Progress in Quantitative Nondestructive Evaluation
AIP Conf. Proc. 1581, 95-99 (2014); doi: 10.1063/1.4864807

available in real time. This technique is designed to free the end user from complicated analysis of non-destructive testing information by presenting this data in a form which is intuitive quantitative in nature.

The ability to use the concept of matrix phased array in in-situ process monitoring (Fig. 2) of welded pipe comes when the MPA transducer and in process pipe are allowed to move relative to each other. This is accomplished by either keeping to MPA transducer stationary and moving the pipe or fitting the MPA transducer on a mechanical positioning system. Moving the pipe and MPA transducer relative to each other allows the area of examination to be continually updated, thereby providing a real time, continuous inspection of the weld area.

Execution

To implement this technique for an eventual practical application, the following factors need to be considered.

- Ability to run autonomously or by an operator with minimal UT knowledge.
- Ability to operate at inspection speeds greater than 200 inches per minute.
- Software and hardware optimized for stability and reliability.
- Ability to detect features and calculate area and diameter information in real time.

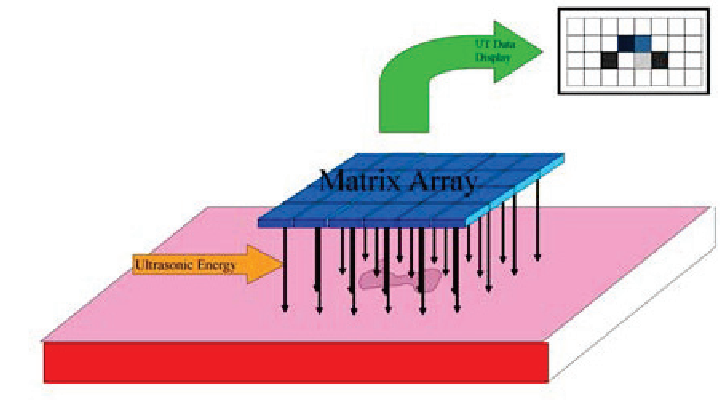

FIGURE 2. Matrix array C-scan concept.

After a brief search, it was determined that there was no off the shelf combination of software and hardware that could be configured to deliver the requirements needed. The project was broken down into three components, transducer, hardware and software. Because the project deliverable was to prove feasibility, it was decided to re-purpose a 32 element MPA transducer. This transducer, fabricated by Imasonic (Fig. 3), has an operating frequency of 3MHz with a 5.05 by 4.2mm pitch giving a coverage area of 6.7 cm^2. Normally, when designing inspection, the transducer requirements would be identified and optimized using modeling software. Once the design is complete, the specifications of the transducer would be provided to a manufacturer for fabrication. In this case, it was decided to use a transducer that was not optimized so that the majority of the budget could be focused on the hardware and software development.

Hardware: AOS provided an OEMPA 32/32 Phased Array instrument (Fig. 3) that was capable of firing the 32 element matrix phased array probe. The OEMPA 32/32 has 32 individual channels with 32 independent parallel data channels. In addition, this box has:

- 5ns Delay Resolution, 40us Delay Range
- Up to 20kHz PRF
- 140V Negative Square Pulse (width 30-1000ns)

- 100 MHz A-scan Sampling
- Data Throughput: 5MB/s or 10MB/s
- LAN Connection
- Olympus PAUT connector

AOS is an OEM supplier of advanced ultrasonic phased array instruments marketed to users with the capability to develop custom software solutions. They provide system drivers, an API and several working examples of utilities that can visualize data, create and load setup files from a PC based software application to the OEMPA box. The source code is also provided with these applications and can be used as a template to writing a custom application.

FIGURE 3. Matrix array probe and OEMPA UT electronics.

Software

Due the requirements of the project, a custom software solution was developed (Fig. 4). To provide the programming, Eehscience LLC was hired to create the application. AOS driver and application development is written in C++. Due to the experiential nature and the aggressive schedule of this project, it was determined that programming in the Python language would decrease development time. A link or "hook" was available due to the open source nature of the Python language. This "hook" allowed the Python software to directly call the OEMPA dynamic link library (DLL). Between the coding skill of Eehscience LLC, the provided AOS OEMPA software and the well supported open source nature of the Python programming language an application was able to be developed that demonstrated feasibility of In-situ Weld Quality Inspection with Matrix Phased Array (MPA) Ultrasonic Technology.

RESULTS

The results of the system demonstrated the ability to detect holes in panels in excess of 200imp (Fig. 5).

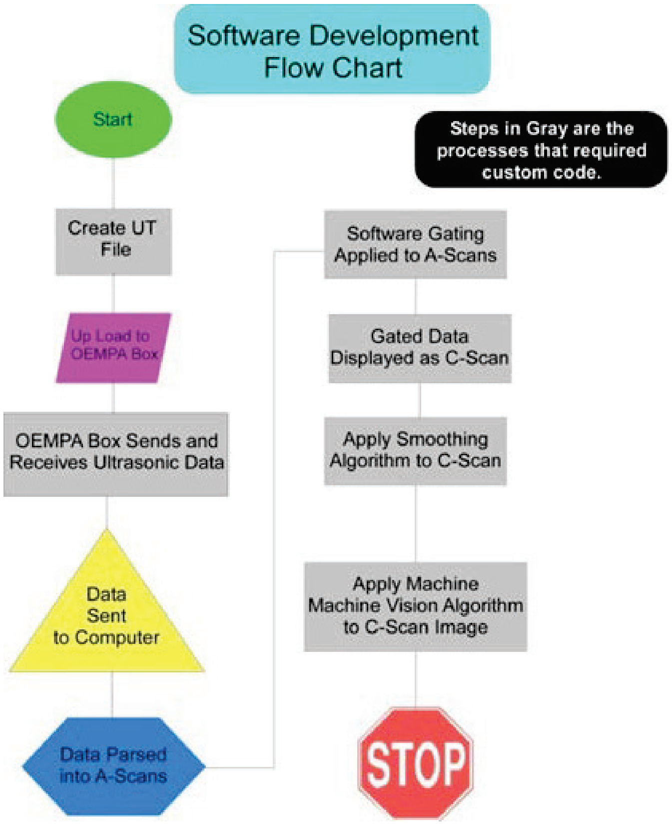

FIGURE 4. Software development flow chart.

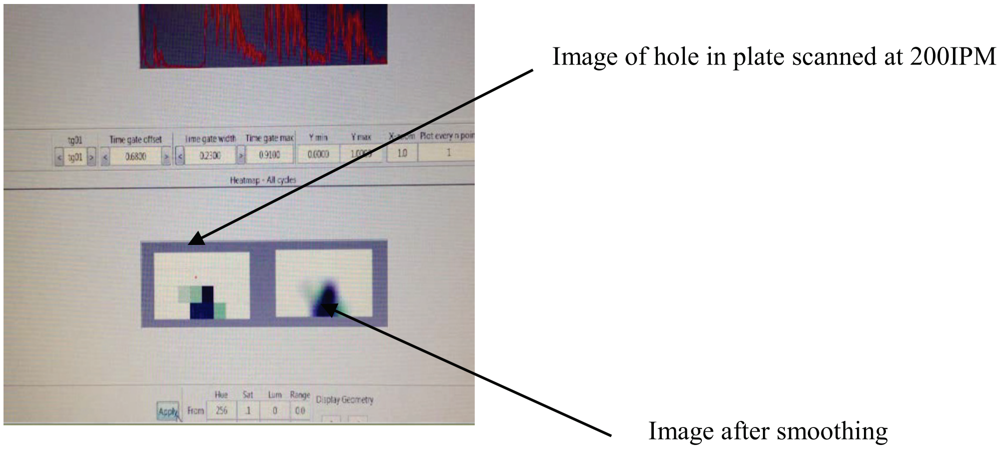

FIGURE 5. Image of In-situ inspection.

FUTURE WORK

In order to take full advantage of this technique, the system would be optimized to support 128 element arranged in an 8 by 16 matrix. In addition, the elements would be reduced in size and the frequency would be increased based on the optimization results from a modeling effort. On the software side, adding the ability to focus and steer a beam would also increase the sensitivity of the system.

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