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PRESENT TRENDS IN QUALITY ASSURANCE OF WELDED COMPONENTS THROUGH NDE METHODS

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ABSTRACT

Welding plays the most important role in the fabrication of equipment for the pressurized process plants & its maintenance throughout the life cycle. To ensure reliability, a comprehensive health assessment program for the welded components using various Non Destructive Examinations (NDEs) is ensured during fabrication as well as in-service maintenance.

The two best-established NDE methods used for volumetric inspection of welds are Radiography Testing (RT) and Ultrasonic Testing (UT). Historically, Radiographic Testing has been the Non Destructive Examination (NDE) method of choice for inspection of critical welds in a variety of applications. However, with the advent of Automated Ultrasonic Testing (AUT) methods like Phased Array Ultrasonic Testing (PAUT) & Time of Flight Diffraction (TOFD), the code has allowed ultrasonic in place of radiography when certain laid down conditions are met. Although in thinner wall vessels, the Radiography Testing is still the most widely adopted technique for detecting both volumetric and planar indications, the PAUT & TOFD technologies have made rapid changes in inspection and reliability in various industries and are rapidly replacing the conventional radiography. A major advantage in replacing RT with PAUT & TOFD is reducing the radiation risks apart from increased production rate and better sizing of the discontinuities.

The paper deals with the industrial experience of NDEs used for quality assurance of welded components during fabrication as well as in detection of the effects of damage mechanisms during in-service inspection. The paper also incorporates case studies where PAUT and TOFD were used in lieu of RT.

Keywords: Non Destructive Examination, volumetric inspection, Radiography Testing, Ultrasonic Testing, Phased Array Ultrasonic Testing, Time of Flight Diffraction

INTRODUCTION

The two best-established NDE methods used for volumetric inspection of welds are Radiography Testing (RT) and Ultrasonic Testing (UT). Historically, Radiographic Testing has been the Non Destructive Examination (NDE) method of choice for inspection of critical welds in a variety of applications. By providing a pictorial, volumetric record of areas of interest, it was, and for some purposes still is, the best choice for many applications. The manufacturing codes like ASME Section VIII Divisions I & II specifies the type of welds which are to be mandatorily tested by RT. However, with the advent of Automated Ultrasonic Testing (AUT) methods like Phased Array Ultrasonic Testing (PAUT) & Time of Flight Diffraction (TOFD), the code has allowed ultrasonics in place of radiography for the examination of heavy wall pressure vessel welds & nozzles vide Code Case 2235 when certain laid down conditions are met. Although in thinner wall vessels, the Radiography Testing is still the most widely adopted technique for detecting both volumetric and planar indications, the PAUT & TOFD technologies have made rapid changes in inspection and reliability in various industries and are rapidly replacing the conventional radiography. A major advantage in replacing RT with PAUT & TOFD is reducing the radiation risks apart from increased production rate and better sizing of the discontinuities. Before the application of computerized data acquisition to the Ultrasonic Testing equipment, almost all the international codes and standards have traditionally specified RT rather than UT for the detection of flaws since RT provides a permanent record of the examination conducted, unlike manual UT. Also, RT is more effective than conventional UT in detection of planer defects aligned to the radiographic beam which is considered to be more ‘at-risk’ defects to propagate and cause failure in operation. With the development of the automated UT systems like PAUT and TOFD which overcomes the limitations of conventional ultrasonic systems, the detection of critical defects have become more reliable and repeatable and in most cases, in shorter time. The utilization of PAUT in quality assurance of welds also means that the time lost earlier due to stoppage of jobs in adjacent area during a shutdown is saved. Furthermore, time for processing & retaking of radiographic films due to process marks & other issues also get reduced in addition to the relief to overwhelming repulsion of people on such application wrongly considered to be terribly dangerous for lifelong impact on health & time consuming exercise.

DISCUSSIONS

Ultrasonic waves are mechanical vibrations induced in an elastic medium (the test piece) by the piezocrystal probe excited by an electrical voltage. Typical frequencies of ultrasonic waves are in the range of 0.1 MHz to 50 MHz. Most of the industrial applications require frequencies between 0.5 MHz to 15 MHz. Most conventional ultrasonic inspections use monocrystal probes with divergent beams. The ultrasonic field propagates along an acoustic axis with a single refracted angle. The divergence of this beam is the only "additional" angle, which might contribute to detection and sizing of miss-oriented small cracks.

The main feature of phased array ultrasonic technology and phased array ultrasonic testing is the computer controlled excitation (amplitude and delay) of individual elements in a multi element probe. The excitation of piezo-composite elements can generate an ultrasonic focused beam with the possibility of modifying the beam parameters such as angle, focal distance and focal spot size through software.

TOFD employs two longitudinal wave (L-wave) angle beam transducers arranged symmetrically opposite to each other and facing each other, straddling the weld or base material under test. One probe acts like a transmitter of ultrasonic energy while the other probe receives the ultrasonic energy. The transducer, pulsar, and amplifier characteristics are selected to generate as broad distribution of energy as possible over the material under test providing full weld coverage.

PAUT is good technique at detecting and sizing volumetric indications. Typically the sizing is less accurate than TOFD unless the indication is large or a cluster and at a optimum orientation such that the round nature of volumetric indications does not deflection the UT wave. Excellent at detecting and sizing planer indications such as cracks, lack of fusion, incomplete penetration. TOFD is excellent at detecting and sizing volumetric type indications (i.e. slag, porosity, etc) Good at detecting and sizing planer indications but is not always good at detecting and worst at sizing close to the surfaces.

There are advantages and disadvantages to each inspection method. The method needs to be selected based on what type of indications are expected and targeted in the acceptance criteria. Usually both TOFD and PAUT are used together and both signals are analyzed to determine the type and size of the indications.

Specifically, this combination was proven that this is more suitable for thick structures (above 13mm). Today, the PAUT & TOFD procedure is used for operational inspections or quality control of structures during production instead of routine radiography and conventional ultrasonic shear wave procedures. Although TOFD is more often utilized for inspecting welds with simple geometry and fine grain steels, such as welds with thicknesses from 13 mm to 300 mm, it is useful in inspecting more complex geometries. Defects like cracks, lack of penetration, lack of fusion, porosity, and slag in welds of pressure vessels could be diagnosed via this technique very precisely. Major components in the vessels are nozzles which are difficult to do Radiography. Nozzles are also pressure retaining parts of the reactors. Nozzles in vessel can be inspected by PAUT for defect detection.

CASE STUDIES

Some applications of PAUT and TOFD in oil refineries, where this technique proved useful in lieu of conventional radiography are presented below as case studies;

Case-I

PAUT was carried out at Diesel Hydro-treating Unit (DHDT) of one of Indian Oil Refineries for defect identification of weld joints during fabrication in NB 6”, 8”and 10” pipeline. PAUT was done by using Omni Scan MX- 2 and interpretation was done by level III UT expert. PAUT was carried out instead of conventional radiography technique, this lead to huge saving in production loss due to stoppage of work during shutdown of refinery and radiation hazard was eliminated. However in some cases the defect was identified in PAUT, the same was verified by carrying out radiography of the same weld joint to ascertain the defect.

Figure 1: PAUT Omni scan MX2 **Figure 2: TOFD weld inspection set up**

Case-II

PAUT was used in refinery for detection of thermal fatigue cracks at the hydrogen quench location at OHCU Reactor Effluent line. PAUT showed reduction in scanning time and data which can be stored for trending, reporting and comparison purposes.

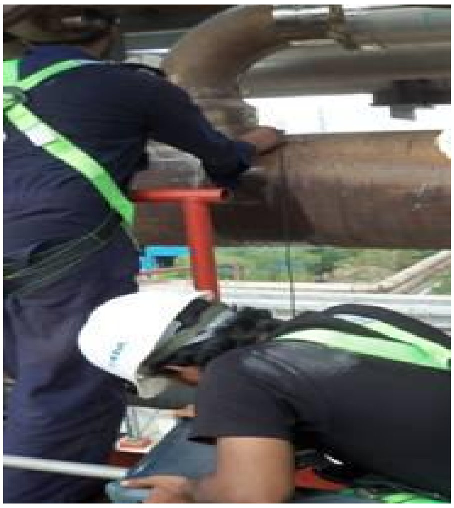

Figure 3: PAUT for detection of thermal fatigue crack at hydrogen quench line Of OHCU Reactor effluent line

Case-III

PAUT was for detection of wet H2S cracking at vessel in OHCU unit of refinery. Scanning of in-service vessel was carried out for detection of crack due to wet H2S corrosion cracking.

Figure 4: PAUT for detection wet H2S cracking

Case-IV

PAUT techniques used in circumferential crack detection and sizing of heavy walled Category "D" nozzles and nozzle welds. Nozzle welds represent several heavy wall pressure vessels ranging in thickness from 50.8mm to 110mm. PAUT showed significant reductions in scanning times and crack imaging proved to be a valuable asset for complex geometries.

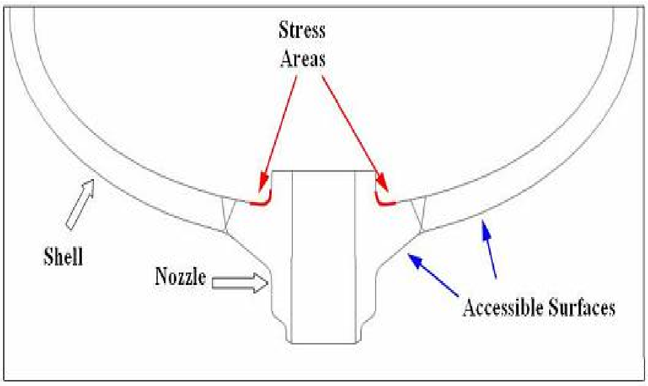

Figure 5: Cross sectional view of forged nozzle

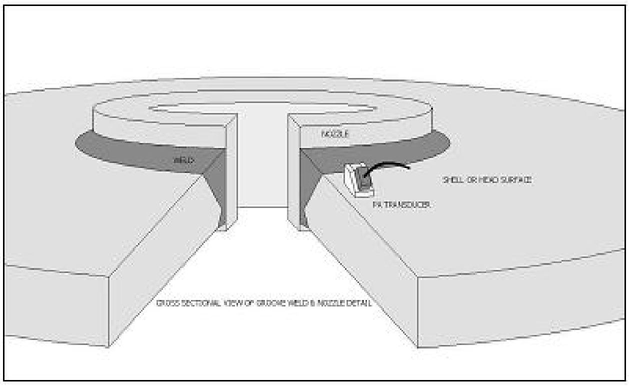

Figure 6: Probe placement overview

Figure 7 & 8: Above images show scanner and probe placement for PAUT examination

RESULTS

PAUT was carried out on a large number of weld joints 6” wash water line, 10” rich amine line & 8” RLNG line and the scanning results are shown below from Figure-9 to Figure-13. Different numbers of weld defect were found which are shown in Table-1.

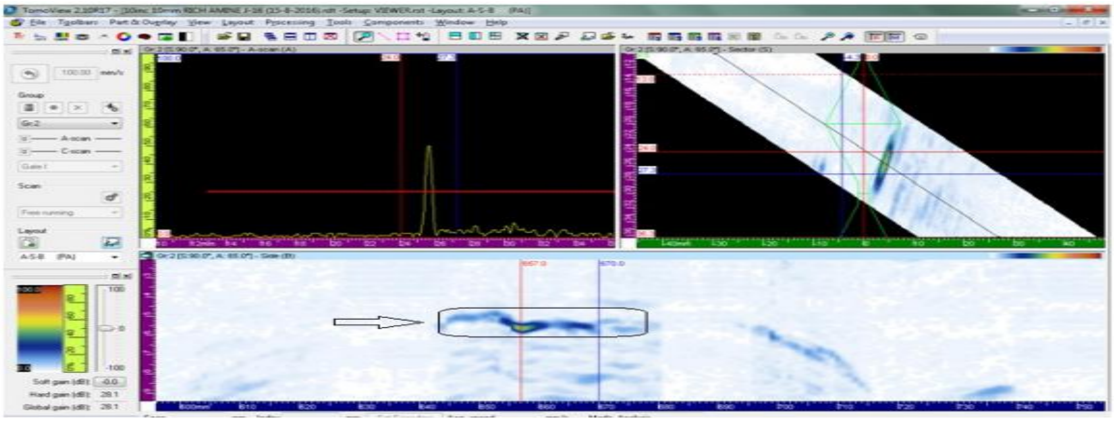

Figure 9: Defect observed in NB 10” rich amine line

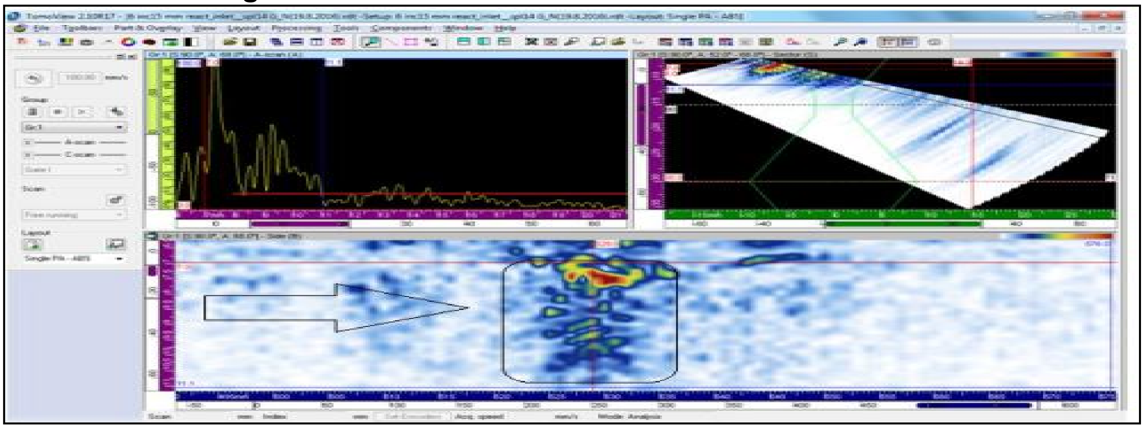

Figure 10: Defect observed in NB 6” wash water line

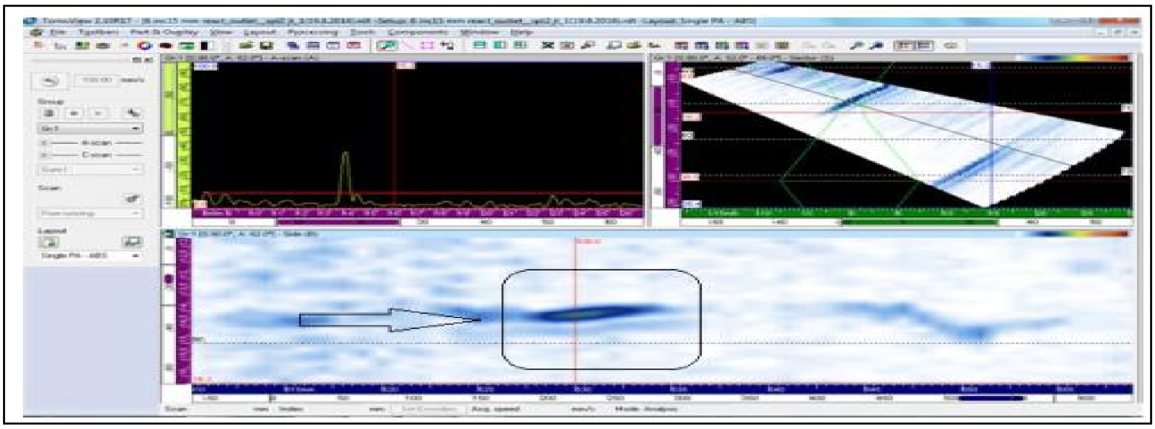

Figure 11: Defect observed in NB 6” wash water line

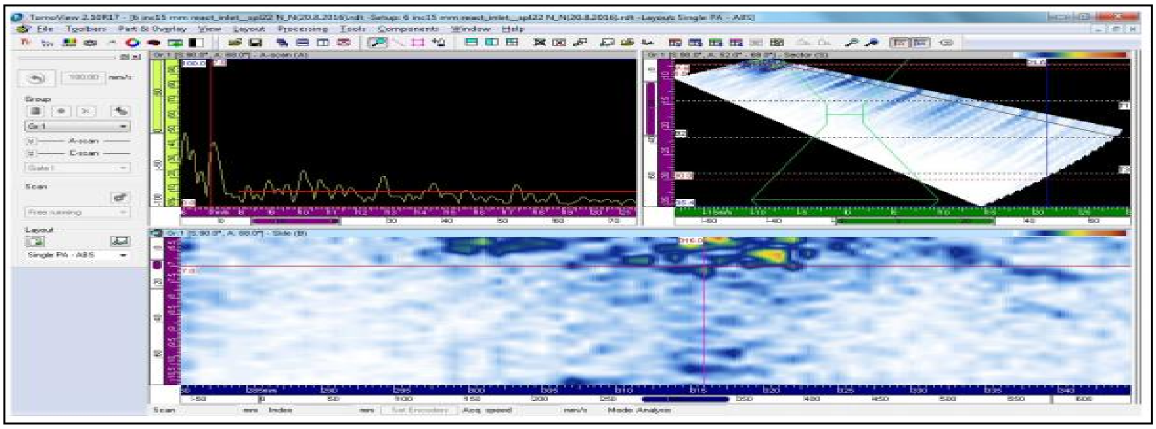

Figure 12: Defect observed in NB 6” wash water line

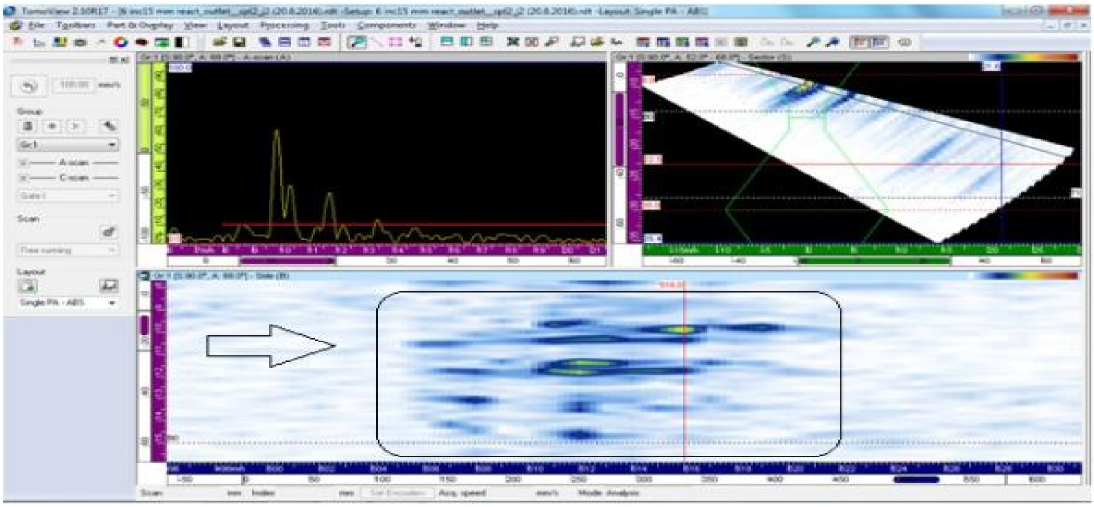

Figure 13: Defect observed in NB 6” wash water line

Figure 14: Weld joint scanned by PAUT

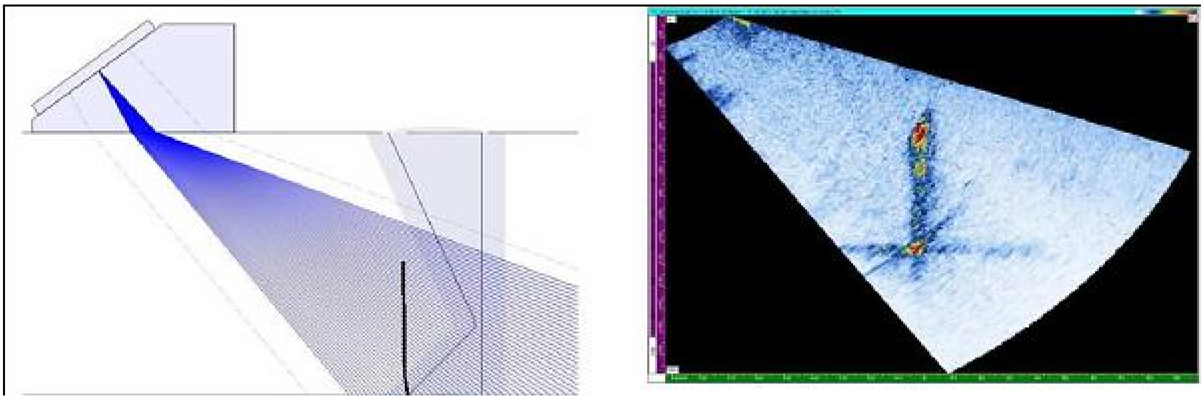

Figure 15: Phased array image of crack indication in nozzle of reactor.

CONCLUSIONS

PAUT is efficient in giving real time interpretation of defects present in the materials and thus give advantage of time savings thereby giving more production output combined with better and precise defect measurements. The data of PAUT can stored for trending, reporting, auditing, peer review and comparison purposes. Also it is safe from radiations unlike that happen in radiography testing of materials. However, considering the fact it is a very new method to conventional NDT technicians, proper training and care should be taken before assigning any PAUT job. Also result interpretation and analysis should be done by highly skilled NDT technician. If at any point of time PAUT interpretation is doubted due to lack of skill or technician is not confident, the PAUT technique can be combined with other NDT technique like radiography for ascertaining the defects.

ACKNOWLEDGMENTS

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