NON-DESTRUCTIVE INSPECTION OF GIRTH WELDS BY PHASED ARRAY AND TOFD METHODS

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ABSTRACT

In pipeline steels, which are generally made of low-carbon and low alloy high strength steels to meet the requirements, girth welds are used to join the pipes. Submerged arc welding (SAW), semi-automatic or fully automatic welding system, is used to obtain better welding quality. The parameters and used equipment changes with regards to the desired properties, i.e. pipe diameter and wall thickness. Ultrasonic phased array and combined inspection systems, i.e. TOFD, have many significant advantages over conventional methods for pipeline inspection. The advantages can be better interpretation, higher detection rates, no chemical wastes, no safety hazards and no requirement the specific area for inspection. Trend in the inspection system is decreasing the inspection time and increasing the detection sensitivity. Automatic systems, i.e. PipeWizard, become popular with increasing demands.

Keywords: PipeWIZARD, Phased Array UT, TOFD, Girth Welds, NDT

INTRODUCTION

Welding is the primary connecting process in pipeline construction. In the world, approximately 7000 miles pipeline construction is done in every year. Several different welding processes can be deployed during the construction phase of the pipeline. Each process has its advantages and limitations when being implemented in girth welding activities. The specific welding process used must be considered based on its overall ease of implementation in the particular welding activity, criticality of the service environment and techno-economic impact. Welding of pipelines and related components comprise of mainline welds (i.e. line pipe-to-line pipe connections), tie-in welds (i.e. line pipe-to-line pipe connections for specific locations), repair welding of girth welds and fabrication welding [1]. The schematic view of girth weld is provided in Fig.1 below.

Since pipelines operate at a high percentage of yield strength, these welds must be constructed to a high standard. The inspection requirements increases in each day due to the advent of higher strength steels, greater environmental concerns, thinner pipe walls, high demand for pipelines and improved technology. Increasing quality can be tested by AUT equipment in faster and easily ways. One of the examples of AUT systems, PipeWIZARD, can be seen in Fig.2.

Figure 1. Schematic view of girth welds (Figure adapted from [2]).

Figure 2. PipeWIZARD girth welds inspection systems.

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Advantages of AUT systems are listed below [3]:

- Better control of welding process, also giving lower rejection rate
- No radiation hazard, no chemicals, no licensing
- Use of Engineering Critical Assessment (ECA) acceptence criteria with measurement of vertical height and depth of indications, reducing rejection rate
- Data and inspection reports on electronic support
- Real-time analysis from smart output display
- Very short inspection cycle time for high production rate
- Better detection and sizing accuracy, leading to lower rejection rate.

Generally, more than one inspection system is used in AUT systems. One of the most popular one is phased array method, which use electronic beamforming to generate and receive ultrasound using included elements. Each element in the array is individually pulsed and delayed to create a wide range of beam angles and focal distances. Major advantages of phased array systems are

- A phased array scanner is significantly smaller and lighter than conventional multi-probe scanner. It is then easier to manipulate and requires less coating cutback on each side of the weld
- Phased array setups are performed by loading a file, not by adjusting each individual transducer position
- Phased array systems are used to inspect almost any type of weld configuration, while conventional multi-probe systems are limited in wall-thickness and pipe diameter
- Phased array beams are optimized (angle, focus, UT path, beam width) by setting appropriate parameters in the software, leading to better sizing accuracy
- Phased array system has about 80% fewer moving parts than equivalent conventional multi-probe system, giving steady inspection reliability scan after scan
- Phased array electronic scanning allows customized weld inspections, including multi-angle TOFD, advanced imaging, and detailed inspections

The other popular inspection system used in AUT is time-of-flight-diffraction. The TOFD technique is based on diffraction of ultrasonic energy from tips of discontinuities, instead of geometrical reflection on the interface of the discontinuities. The working principle of TOFD is based on four different types of waves:

- the lateral wave that propagates near the surface between the two transducers
- longitudinal wave generated by the transmitter and partially transformed in spherical wave when the beam crosses the tip of a defect
- the shear waves generated by the mode conversion L/T on the interface of discontinuities
- the longitudinal wave reflected by the backwall
not multi-probe. However, time efficiency and better detection sensitivity is also true for TOFD method.

**EXPERIMENTAL PROCEDURE**

Olympus PipeWIZARD girth weld inspection system is used to test x70m grade pipeline steel. Firstly, one part of the pipeline is located perpendicularly to its longitudinal axis. The pipe section is cleaned and then the visual inspection of girth weld, both inside and outside, is done by using magnification lens. It is found that there is no defect at surface and teeth of the weld joint by visual inspection. Secondly, the automatic ultrasonic inspection testing system (AUT) – PipeWIZARD is used to detect the defects inside the pipe steel and on the weld joint surface. This PipeWIZARD system includes phased array probe (32 elements) and TOFD probes at the same time. These probes are located left and right hand side of the girth weld at outer surface of the pipe. AUT system is placed on the controlling band, which has a magnetic field in order to move the AUT system. After completing the setup, system is started and calibration of the systems, UT & TOFD, is done by using pre-existing calibration weld joint.

Thirdly, the system is placed on the side where investigation of weld joint will be done. AUT is processed and the data, which contains phased array scans (A-B-C-S) and TOFD scans, is collected. After that, the collected data is investigated by using software and the found defects are reported by using same software again. Moreover, all of the collected data can be used for reporting. For instance, one of the defects is reported by using ABS-scan and other one can be reported by using CS-scan results. Manipulation of collected data can be seen in figures below.

**RESULTS AND DISCUSSION**

Non-destructive inspection tests are done on the girth weld by PipeWIZARD system in a short time, 1.5-2 min/cycle. Test results are provided in Figs. 7 and 8. The scan results are provided according to their colour codes. The colour codes are used due to the data collection processes and for easy reporting. The red regions show that the defect is too large with respect to the allowable standards. In white regions, there is no defect which is larger than the size limitation.
The detected defects are examined in detail, by using different views and changing the gain setup of the test equipment, in a short time when compared with conventional UT or radiography methods. The comparison between radiography and AUT results are provided in Fig.9 below.

Additional defects are located at weld root and weld wall of girth weld. These are lack of penetration and lack of fusion problems respectively. They can be prevented by using proper welding method and doing surface preparation before welding effectively. TOFD is an effective method for identifying cracks and lack of fusion located along the vertical axis of the weld or with any other orientations, because defect detection is not affected by unfavourable orientation to the primary sound energy angle. So, TOFD method shows the smaller defects easily. The detection results also provide the above statement.

Figure 8. Phased array and TOFD test result of girth weld. Grey regions shows the TOFD scan results.

Figure 9. Comparison of the results of PipeWIZARD and radiographic tests.

It can be seen that the accuracy of PipeWIZARD system is higher than that of the radiographic tests. Additionally, defect labelling and reporting are easily done by using AUT systems as it can be seen in Fig.10.

CONCLUSION

In conclusion, girth weld inspection should be done in a shorter time and more precisely because of their importance for pipeline joining. It becomes possible by only integrating the AUT systems, i.e. PipeWIZARD, in the field application. AUT systems contain some of the non-destructive inspection systems at the same time, i.e. PA and TOFD, and this makes the system work faster and more accurately. Phased array UT method allows obtaining data from desired sections inside the weld and TOFD method allows detecting welding problems without locating the probe according to defect orientation. Furthermore, it is possible to detect and report the internal defects, i.e. lack of fusion and lamination problems, in detail.

REFERENCES


AUTHOR INFORMATION

Mehmet Çağırıcı is a senior undergraduate student at Middle East Technical University, TURKEY majoring in metallurgical and materials engineering. His advisor in this project is Prof. C. Hakan Gür, Chair of METU Metallurgical and Materials Engineering Department. His academic interests non-destructive testing methods, welding of metals, mechanic properties of metals and composite materials. He studied “Investigation of critical parts of nuclear power plants by NDT methods” in previous research topic. In his free times, he likes to go trekking, take landscape and portrait photographs, make model airplanes, drive a RC cars and helicopters.