Phase Array Ultrasonic Testing (PAUT) & Time of Flight Diffraction (TOFD) of DSS Piping of very high thickness (70 mm)

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Abstract. In one of high temperature high pressure process fabrication in India, L&T encountered DSS piping of very high thickness (i.e. 70mm).
Radiography Testing was required to carry out for all groove joints.
Radiography Testing was not feasible for hookup joints because of considering nearby surrounding ongoing brown field job.

Hence PAUT/TOFD was envisaged in lieu of Radiography Testing. It was a great challenge to perform PAUT on such a high thickness DSS material considering the course grain weld structure.

L&T has demonstrated & performed successfully the PAUT/TOFD of said high thickness DSS material weld joints.

This paper explains the technical details such as scan plan, procedure requirements and block preparation, calibration, scanning of weld, data interpretation and comparison with RT including challenges overcome.

Introduction

In one of project L&T – MFF has taken the challenge to utilize the PAUT + TOFD in lieu of RT for DSS piping weld joint. Requirement of project specification was to radiograph the joint for volumetric inspection.

Duplex stainless steels have a mixed microstructure of austenite and ferrite, the aim usually being to produce a 50/50 mix, although in commercial alloys the ratio may be 40/60. Duplex stainless steels have roughly twice the strength compared to austenitic stainless steels (hence it was used for high stress piping) and also improved resistance to localized corrosion (that’s why selected for saline environment), particularly pitting, crevice corrosion and stress corrosion cracking. To take all these benefits we have used DSS material of grade 2205(UNS NO.31803). The material is characterized by high chromium (21–23%), molybdenum (up to 3.5%), nickel (4.5-6.5%) and nitrogen content (0.08-0.20%) introduced with improved welding properties mainly through nitrogen alloying. On the other part due to coarse gain structure. The capabilities of ultrasonic for the examination of welds in such materials are restricted compared to the ferrite steel because of the presence of large elongated anisotropic grains (dendrites). This type of grain structure can lead to anisotropic ultrasonic behaviour contrasting with the isotropic behaviour of homogenous.
welds made in carbon or low alloy steels. The size, the arrangement, and the elastic anisotropy of the different grains result in high scattering associated with mode conversion effects, beam distortion, and a variation of ultrasound velocity with direction and position in the weld. The scattering of energy is observed as a relatively high noise level (grass) and high attenuation.

In recent years, with advancement in technologies in every field of life, NDT has also been shaped in a unique way. Now NDT has become safer and played a vital role in design and hence becoming a part of safer world. Radiography Test (RT) is a method which has a major concern related to safety as compare to other methods. Though technology has developed, document has created & many research and trial has been performed, still concept of UT in lieu of RT is not so easily accepted, we need more demonstration/establishment of procedures/comparison of procedure to replace RT by UT. In recent years many researchers/NDT experts have done work to replace the RT with UT including overcoming the limitations of UT.

Considering above there are many challenges came up which were discussed in coming section of this paper.

Challenges

1. The project specification requirement was to perform RT for volumetric examination.
2. Offshore joints radiography cannot be performed as a RIG was working round the clock and hence permit for RT work could not be provided. Whereas to perform RT of 75 mm thick weld joint either a Co 60 source (which is not permitted at INDIAN offshore) or high curie Ir 192 source could be utilized. If RT to be done the cost of stopping RIG cannot be imagine hence alternate become requirement. This contradictory situation has become instrumental to take this challenge as opportunity.
3. Property of DSS material itself, the property of DSS material (which enhance strength, corrosion resistance etc.) has become limitation for UT.
4. No PTR of DSS material for such high thickness

Methodology

To overcome the challenge, meeting the codes and specification requirement the following methodology was adopted:

a. Pipe manufacturing process: to minimize the effect of grain, a unique piping manufacturing process was selected. DSS forged bars were machined to make the piping.

b. Welding process: All the weld edge preparation was done with laser profile cutting machine to maintain the dimension as per below Figure 1.

![Figure 1](image-url)
c. Use of PAUT + TOFD in lieu of RT:

i. Preparation of procedure and approval from client and TWI (called as expert to authenticate the demonstration) as PTR was not available.

ii. Preparation of demonstration block: One flawed sample for demonstration was prepared. The block was having dimension of diameter 16” and thickness = 75mm. The artificial flaws were introduced intentionally at outer & inner surface and at mid-wall of weld. Radiography was taken and results were preserved for comparison with PAUT + TOFD. The drawing of flaw location of block is attached as Figure 2.

![Figure 2](image2.png)

iii. Preparation of calibration block: For time base and sensitivity calibration separate blocks were prepared as per ASME B 31.3.

![Figure 3](image3.png)

iv. Preparation of scan plan to ensure the weld: Detailed scan plan was made to cover entire weld volume including Heat Affected Zone +6 mm. Scan includes the coverage for side wall with four different indexes, refer Figure No.3.
To avoid indications from surface irregularity of welding bead, excess reinforcement of entire weld was removed further it was help us to cover volumetric indications which are just below the surface (4-6mm).

Procedure establishment through demonstration: Once the demonstration block & calibration block prepared, procedure was approved by approving authorities; a demonstration was performed in presence of approving authorities and data were stored for interpretation and evaluation, refer Figure No. 4
The results of both test were compared and presented in a tabulated format as per attached Figure No. 5.
The results of both test were compared and presented in a tabulated format as per attached v. Comparison of result of RT and PAUT+TOFD.

vi. Acceptance by Client approving authorities: The test was performed by 3 different technicians separately and their result was found matching with RT. Hence based on witness, repetition of result, meeting the result of both method i.e. PAUT+ TOFD and RT, the use of UT in lieu of RT was accepted and approved for use in offshore hook-up weld joints.
Application on site

Implementation at site: after successful approval PAUT + TOFD was utilize at offshore for all the hook-up joints and the same was witnessed by client’s designated representative.

Benefits and Effects on existing Products/Processes/People:

1. By utilizing PAUT in lieu of RT at offshore can save time, save money, stoppage of work at site and also reducing the radiation hazard to mankind as well as for sea lives.
2. L&T has got first time approval in the world to perform PAUT in 75 mm high thick DSS pipe line which can be used as PTR.
3. It has put the feather on cap of L&T as one of the most innovative and action oriented company.
4. Though approval target was of 75 mm thickness but at offshore it could be used for less thickness too.

Conclusion

After successful demonstration of test at onshore, we had performed the test at offshore efficiently with maximum reliability which in turn saved huge amount of money, time and endanger to human life as well as the sea creatures.

Though there may many challenges but if dedicated efforts shall be made and one uses the new advance technology the result can be fruitful. L&T – MFF has invested a huge amount for only few joints but the end result was fruitful in terms of financial and safety. New technology should be promoted and adopted for safer world. Since PAUT+ TOFD results are matching with RT an result (which was specification requirement) for DSS pipe having thickness up to 75 mm thickness. So considering successful demonstration, it is concluded that PA UT+ TOFD can be performed in lieu of RT for Duplex Stainless Steel for thickness range up to 75 mm.

References

[1] ASME- Section V- Non-Destructive Examination.