Comparison PA and TOFD vs. Radiography: New technologies lead to a more efficient approach

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Abstract. The application of NDT techniques, Phased Array (PA) and Time of Flight Diffraction (TOFD) can be more efficient than the use of traditional radiography. When applying TOFD- and PA techniques to detect more critical errors, welding quality can go up. Less unnecessary repairs have to be carried out and costs can be reduced.

The replacing of pipes in a refinery was chosen as an example, with the following additional requirements:

- More safety through fewer or no radiation;
- The lowest possible risk of failure by detecting as many as possible critical mistakes;
- The quickest possible turnaround and no delay for the other activities because of radiography;
- No unscheduled maintenance after completion of the project.

These requirements could best be met through the use of NDT techniques TOFD and PA. Many contractors, however, maintain control of the welding radiography. A common argument is that the more errors are detected and thus more welds are rejected in PA and TOFD. In this article the strengths and weaknesses of TOFD and PA have been compared to Radiography. In addition to the fact that no single technique gives 100% detection, the acceptance criteria of TOFD, PA and radiography are different. That's because the good workmanship assesses the strengths of each technique. All this is reflected in an expert opinion tabel, established over a period of 3 years and involve a large number of NDT experts.

The number of repairs while applying TOFD amounted to 4.9% of the 659 welds; for Radiography this was 6.3% of the 508 surveyed welds (TOFD proof project). The ultimately lower amount of TOFD is explained by the fact that welders were accurate and immediate feedback on their work. Because the type of error can be precisely determined, the number of false calls decreases and there are fewer unnecessary repairs. Acceptance criteria for PA according to the ISO standard will be needed in the near future.

Final conclusion:
- TOFD and PA versus RT: equal or less rejects. Through better detection of critical errors more integrity is obtained
- Safer (no radiation)
- Reduced risk of failure
- Reduce turnaround time
- Greater flexibility within a project
- Reduced unscheduled maintenance
- Lower costs

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1. Introduction

Non-Destructive Testing (NDT), using (semi-) automated Ultrasonic Phased Array (PA) and Time of Flight Diffraction (TOFD) can be more efficient than the use of traditional Radiography. When applying (semi-) automated TOFD- and PA techniques, critical defects can be detected more easily, which can improve welding quality. Fewer unnecessary repairs have to be carried out and costs can be reduced. These are, on a short note, the findings from the study (2014) by Jos de Visser, Norbert Trimborn and André Elling.

2. Research

The question ‘TOFD and PA versus Radiography - higher welding quality and disapproval higher rejection rate?’ was key for this study.

The replacement of piping in a refinery was chosen as a test case. Research focused on the turnaround time required and on weld quality.

Jos de Visser on behalf of the owner of the installation, Andre Elling on behalf of the plant manufacturer and Norbert Trimborn as NDT- expert worked closely together in this project.

3. Owner goal: minimise interference

The objectives of the owner of the installation are primarily focused on safe construction and operation of the installation. In addition, the impact on people and the environment needs to be minimised, as well as the probability of failure.

Second and equally important objective is to maximise the efficiency of the installation, in a way that:

• reduces the risk of unplanned downtime;
• maximises the time between maintenance shutdowns and
• minimises the time needed for maintenance shutdowns.

The requirements above can be realised by the execution of the welding operations within a minimum turnaround time. This can be achieved through effective planning and implementation and by minimising disruption of other shutdown work. The appropriate approach is that welding is carried out in accordance with approved welding procedures and welding qualifications and with the right equipment in good conditions. The welding is then subsequently checked with NDT. This method can be characterised as an approach in accordance with the applicable standards.

For this project, the replacement of pipes in the refinery, the owner suggested as additional requirements:

• More safety by minimising radiation.
• The lowest possible Probability of Failure by optimised detection of potential critical defects.
• The shortest possible turnaround time, made possible by absence of delay caused to other activities by Radiography.
• After completion of the project, the probability of unplanned maintenance shutdowns should be significantly reduced.

When replacing conventional Radiography with advanced Ultrasonic NDT techniques, i.e. TOFD and PA, it is most likely that these requirements are met.
Radiation does not occur during the application of TOFD, other activities do not have to be interrupted due to safety reasons. In addition, these techniques perform better than the traditional techniques concerning the detection of critical defects.

Many contractors, however, prefer to continue NDT on welding by Radiography; a common argument for this is that more defects are detected by PA or TOFD and thus more welds are rejected. The authors of this article have therefore made a detailed comparison of strengths and weaknesses of TOFD and PA versus Radiography.

4. NDT specialist goal: to improve weld inspection

It is important to establish that no NDT technique is capable of detecting 100 percent of the existing defects. Therefore, the NDT standards are based on the principle of Good Workmanship (GWS) and not on Fitness For Purpose (FFP). Good engineering practice is based on the measurement of the welding quality delivered by the welder and not on the measurement of the weld integrity (the POF) after examination. During construction and repair activities GWS is used worldwide as a starting point and has been proven to pose an accepted risk.

When applying good engineering practice, the Acceptance Criteria (AC) used depend on the strengths and weaknesses of the NDT techniques applied.

See below for an overview of the strengths and limitations of the NDT methods:

4.1 Time of Flight Diffraction

TOFD- strengths are especially the short setup times, immediate results and excellent reproducibility. Defect heights can be accurately determined. High POD of the defects listed in the expert table (Table 1). TOFD causes little or no delays to other shutdown activities.

TOFD limitations are the limited characterisation (see Table 1), no information of the transverse position of the weld defects, not suitable for austenitic materials, suitable for wall thicknesses from 6 mm. The interpretation of the images is different compared to Radiography.

The GWS acceptance criteria for TOFD are based on detection of planar (fusion defects and cracks) and volumetric defects, where the height of the defect can be measured extremely accurately. The result is a percentage of rejection which is equal to that of Radiography.

4.2 Phased Array

PA- strengths are reproducibility, a high-POD (see Table 1), an immediate result, good characterisation and position information, the ability to examine single sided access welds and a good measurement of defect height (but less accurate than TOFD). PA gives a similar result compared to RT and is suitable for wall thicknesses of 3.5 mm and above.

PA limitations concern the long set-up times and the fact that there no accepted ISO-standard is available yet. The use of ad-hoc devised acceptance criteria for pulse echo can lead to ineffective acceptance and rejectance of defects, or potentially reduced welding integrity.

GWS acceptance criteria of PA are based on the length and height, amplitude and characterization or a combination thereof.
4.3 Radiography

is based on empirical experience and is a long-accepted NDT method.

Radiography strengths are the suitability for austenitic materials, the suitability for complex geometries, good characterisation, correct information about the lateral position of defects and a high POD for the detection of volumetric defects (see Table 1.)

Radiography limitations concern the use of ionising radiation. No other activities in the immediate vicinity can be carried out during Radiographic Testing. Due to space limitations for the radiation source, 100% weld inspection will not always be possible (accessibility can be limited by obstacles such as other piping). Height measurement of defects is not possible and the POD for planar defects such as cracks and fusion defects is low, (see Table 1).

Acceptance Criteria for Radiography allow no planar defects and cracks because of the limited POD for these defects and inability to determine the extent of such defects. Volumetric defects such as slag can be acceptable up to a certain length. To assess GWS, the length and width of volumetric defects are determined. These then serve as the main measure for acceptance or rejection.

In summary: No single NDT-technique is capable of detecting 100 percent of the defects present. The Acceptance Criteria of TOFD, PA and Radiography are different. The reason for this is that the strengths of each technique are used to assess Good Workmanship.

These findings are reflected in the following expert opinion table (Table 1), established over a period of three years with the cooperation of large number of NDT experts.

Table 1.
PA and TOFD are compared with Radiography in the table. The left column shows the most common weld defects; the most critical (root weld crack) above, decreasing in severity to excess penetration below.

What is particularly striking here is:

- TOFD performs well for the detection of most defects. Critical defects are detected more frequently than when using Radiography
- PA performs well for the detection and characterisation of defects. Particularly, the detection of critical defects is better detected than Radiography
- Radiography performs poorly regarding the detection of critical defects.
- Previous NIL/KINT research projects (NDT 1 and 2 and Non Destructive Testing of Thin Plate (6-15mm)) for TOFD and Radiography support these results.

5. Contractor’s goal: more flexibility and shorter project time to completion

The use of ultrasonic techniques in lieu of Radiography will offer the contractor the option to gain flexibility. The absence of ionising radiation when using TOFD and PA offers the advantage of performing the necessary NDT inspections during day shift. Other workers can continue their tasks and the results of NDT are instantly available so that any repairs needed can be carried out immediately.

TOFD and PA both offer the above advantages, but these are often seen as less important by the contractors. They are convinced that the number of repairs as a result of applying these techniques will increase. However, studies in the past, such as the KINT project TOFD acceptance criteria, that took place in the context of the development of NEN 1822, the forerunner of the current international TOFD standards (ISO 10 863 and 15 262) and TOFDPROOF (EPERC project, 2002-2005) show that this is definitely not the case (graph 1 and graph 2.).

In the near future, a comparable validation project will be developed for PA.
The number of necessary repairs needed when applying TOFD is 4.9% out of 659 welds inspected. When applying Radiography the percentage is 6.3% out of 508 welds inspected.

Interestingly, the application of TOFD, shows more rejected welds at the start of the process. This amount decreased rapidly to a lower ultimate rejection rate at the end of the project. This can be explained by the fact that welders received immediate and accurate feedback on their work. Welders are able to oversee quickly what has gone wrong and adapt very fast to avoid these defects, which result in fewer rejected welds. Because of the
accuracy of the feedback on defects, the number of false calls and hence the number of unnecessary repairs declines sharply.

6. Future

The expectation is that the rejection rate in the start-up phase of a project can go down by using the same NDT technique during welder qualification and during the project. Acceptance criteria for PA according to the ISO standard need to become available.

7. Joint final conclusion of the three parties:

- TOFD and PA versus RT: Rejection rate equal or less. Improved detection of critical defects leads to higher weld integrity.
- Safer (no radiation)
- Reduced risk of failure
- Reduced turnaround time
- More project flexibility
- Reduced unscheduled maintenance
- Lower overall costs

References

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