Development of a procedure for the ultrasonic examination of 9% nickel LNG storage tank welds using phased array technology

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Abstract. During construction of 9% nickel LNG tanks, weld examination is often done by conventional radiography. This paper presents the development of a procedure for the semi-automated ultrasonic examination using phased array technology in lieu of radiography.

Introduction

The growing interest of natural gas as a source of energy led to an increase in transportation and storage systems. LNG storage tanks are build using materials with specific mechanical properties at low temperatures. One of these steels is 9% nickel steel (9Ni) providing a combination of mechanical properties at a reasonable price. 9Ni material is welded using consumables with a high nickel contents (typically 60-70%).

According to most applicable codes, the examination of storage tank welds requires a volumetric method, often done by conventional radiography. Eliminating the radiation during construction of LNG tanks is beneficial to all parties, provided an alternative solution could be developed and demonstrated. Several codes allow for the use of ultrasonic examination in lieu of radiography.

The Advanced NDT division of Vinçotte looked into the possibilities to examine these welds using ultrasonic phased array systems. The four step approach consisted of collection of welded samples and having reference reflectors made, development of UT techniques using phased array equipment, open trials on reference blocks for procedure development and blind trials for demonstration/qualification of complete acquisition system.

Reference samples

Two reference samples were provided with respective thickness of 25 mm (T25) and 12 mm (T12), the first being a X-shape weld, the second a V-shape weld on strip. Side drilled holes (SDH) Ø 2 mm as well as electro discharge manufactured (EDM) notches were made. EDM notches were put both at OD and ID for the T25 sample with heights of 2 and 6 mm, both with a length of 20 mm.

UT technique development

The cryogenic nickel steels are usually quenched and tempered in a very narrow temperature range to optimise the microstructure and thereby its properties. This is one of the reasons that 9Ni base material is ultrasonically relatively transparent what cannot be said about the weld material. The use of high nickel (60-70%) content filler metals makes these welds more difficult for ultrasonic examination.

The first lab work consisted to define the wave type, frequency and probe type, which would give acceptable ultrasonic responses on the reference reflectors. To have the examination as single acquisition scans, the choice was made of using phased array probes, allowing multiple angles. The basic configuration for the ultrasonic examination is shown in figure 1.

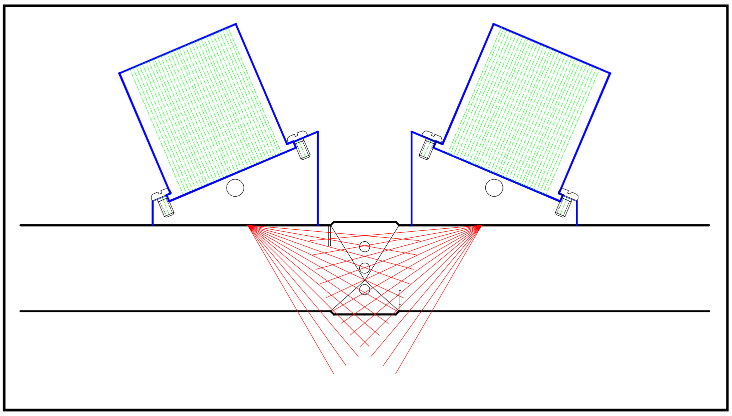
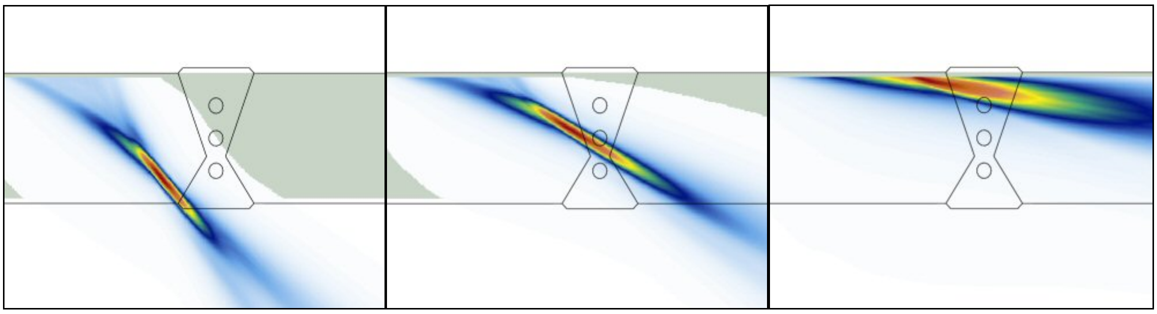


Figure 1: Basic configuration

To determine the parameters for wedges and probes, beam simulations were performed. The resulting beams were plotted against sample layouts showing the ultrasonic coverage of the examination. This is shown if figures 2a, b and c for a phased array probe on one side of the weld.



Figures 2a, b and c: Beam simulations

Results on reference blocks

The use of S-scan representation from both sides of the weld was chosen for the ease of interpretation of UT data. The screen layout of the data analysis software makes it easier for identifying, measure and positioning flaw data in three dimensions.

A first interest was the response on SDH, representative for volumetric flaws. Figure 3 shows an image of the ultrasonic data obtained on T25. Observed from both sides giving proof of weld volume coverage.

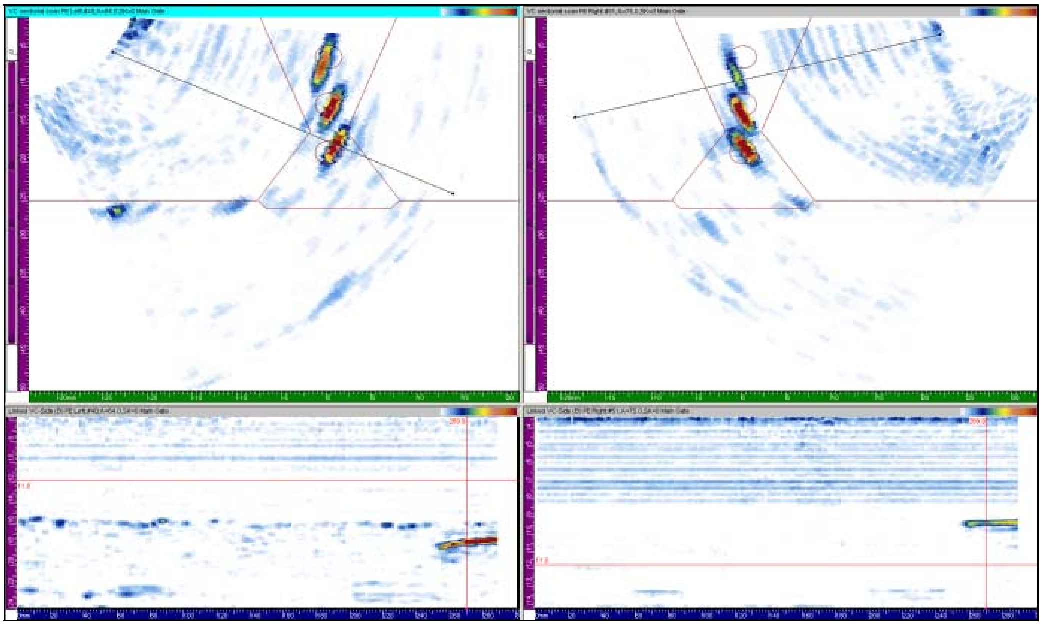


Figure 3: UT image of SDH Ø 2 mm in T25 sample

The second interest was the response on the EDM notches. It was observed that no reliable detection of these notches could be achieved through the weld material with the given configuration. Nevertheless the obtained results were promising. Figure 4 shows an image of the ultrasonic data obtained on T25. The zoomed area shows the response on a 2 mm EDM notch. The tip signal can easily be differentiated from the corner trap echo allowing an accurate height sizing.

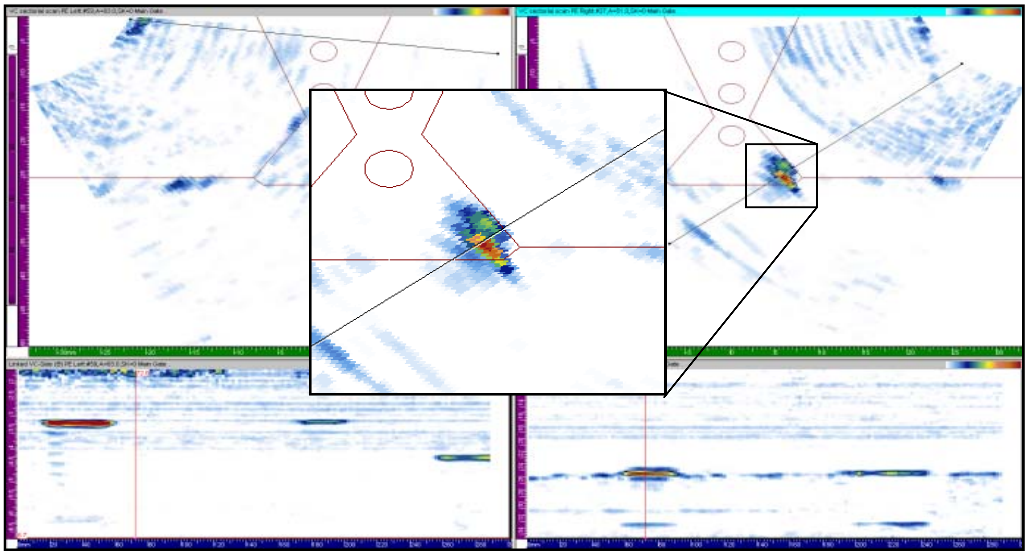


Figure 4: UT image of ID EDM notch h = 2 mm in T25 sample

Another interesting result was the response of the notches located at the scanning surface (OD). These are detected with the higher angles of the UT system. Figure 5 shows an image of the ultrasonic data obtained on OD EDM notch h = 2 mm.

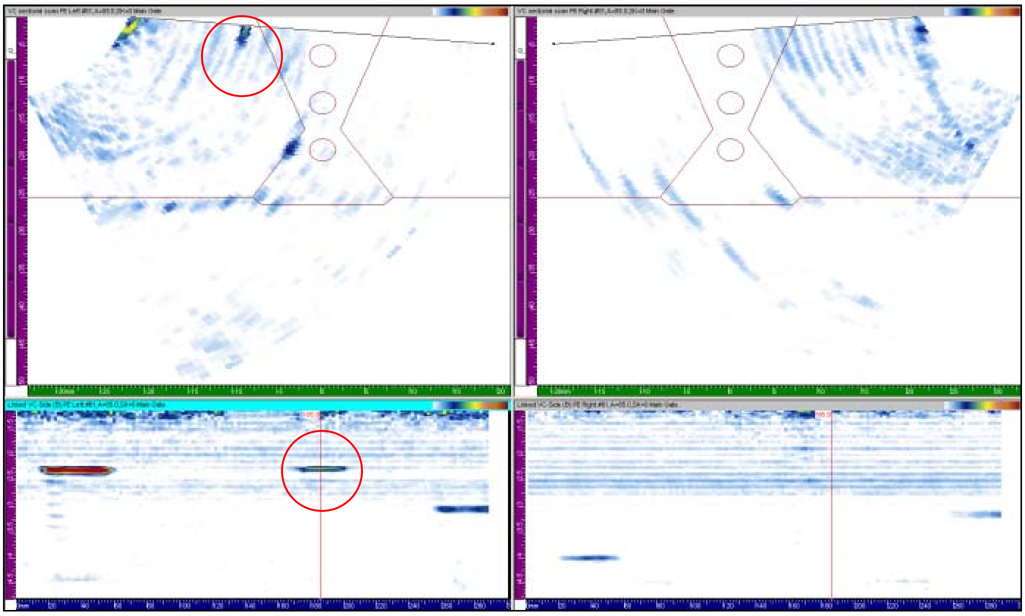


Figure 5: UT image of OD EDM notch h = 2 mm in T25 sample

The use of S-scans and the non-detection of EDM notches through the weld material make the ultrasonic systems detection capability more dependent of flaw orientation. Therefore additional shear wave angles were added, generated by the same phased array probes to run simultaneous, working after skip, to cover the weld bevel area.

The ultrasonic system proofed to work properly in terms of detection and sizing of flaws in the volume to examine. The examination could be performed from one side of the tank and the procedures outcome could easily be compared with the applicable acceptance criteria (f.e. API 620 appendix U). However a special case required a dedicated approach.

The bottom ring to bottom plate weld is being examined using a single phased array probe running on the ring side. To ensure detection of the complete weld volume and adjacent base material, an extra scan from the other side of the tank wall is required. A specific block with reference reflectors was used to demonstrate the procedures capability to detect volumetric and planar flaws. The effect of the weld material after repair was also verified for the procedure validity on a repaired area. Figure 6 shows an image of this weld configuration with a repaired zone.

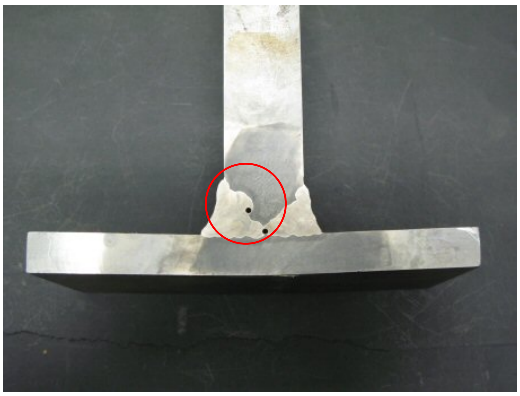


Figure 6: Image of bottom ring to bottom plate weld with repaired zone

Blind trials and site applications

The final procedure was demonstrated on various blind blocks. The result was that all flaws were detected and could be sized with acceptable accuracy. The use of multiple angles and wave types resulted in a higher detection rate compared to conventional RT. This was also confirmed during the first use of this procedure, which ran parallel with RT examination.

Benefits

There are many benefits in the use of semi-automated ultrasonic examination in lieu of radiography:

- ✓ Fast and reliable examination
- ✓ Digital recordings, for later analysis and archive purposes
- ✓ Direct results, immediate feedback to welding operations
- ✓ No radiation during examination, other activities can continue
- ✓ No use of chemicals (development products)
- ✓ No waste of film packing, lead screens

Conclusions

A procedure was developed for the semi-automated ultrasonic examination of 9% nickel LNG storage tanks. This procedure has been demonstrated during demonstration and qualification trials. This procedure has already been applied during construction of LNG tanks (Zeebrugge LNG terminal Belgium, Canaport LNG terminal, Canada).