In-process weld repair of ammonia converter with HotSense TOFD

Real-time evaluation of weld fills during repair of an ammonia converter, using high-temperature TOFD examination.

Overview

During a scheduled turnaround at a 4 year interval, multiple, major cracks were detected within the extremities of a shell to shell circumferential weld of an ammonia converter using ultrasonic methods - manual UT, TOFD and Phased Array (see Figure 1). The cracking was ID connected and propagating up to 50% of the through wall thickness. A subsequent repair campaign was launched, with SonoInspec, a global NDT service company specialising in non-intrusive inspections whilst plant is operational, undertaking TOFD examination at 66% partial, and 100% fill whilst at pre-heat temperatures of ~200 °C (400 °F) through the 120 mm (4.7") thick steel wall to verify integrity of the repair in-situ.

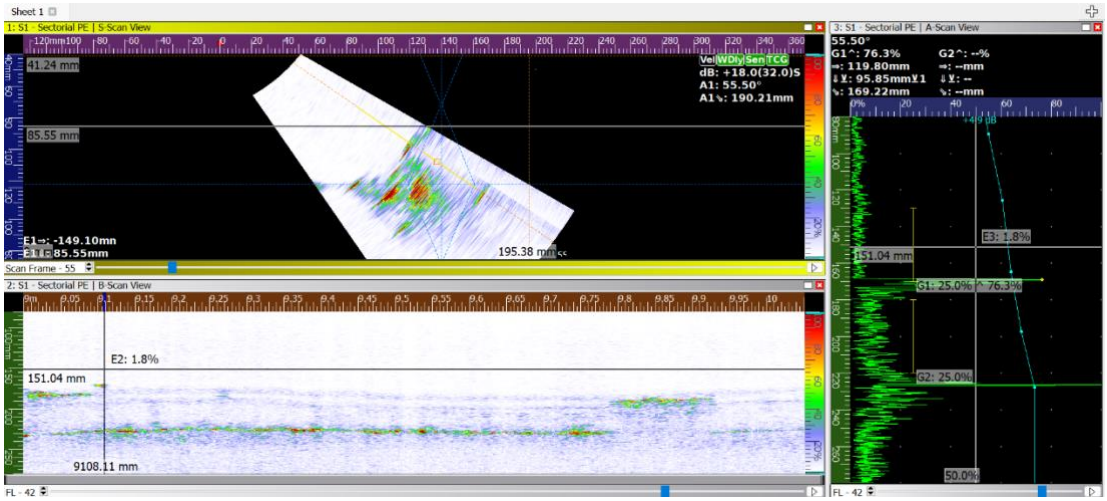

Figure 1: Sectorial PE Phased Array UT scan with S-scan (top), B-scan (bottom) and A-scan (right) of the circumferential weld, showing indications of cracking damage

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The Challenge

Ammonia converters operate at high-temperatures (200 - 400 °C / 390 - 750 °F) and pressures in the presence of hydrogen gas and catalyst, which can lead to damage mechanisms such as High-Temperature Hydrogen Attack (HTHA), nitriding and stress cracking in high load areas such as around the basket.

Inspection and repairs are often preferred to be undertaken non-intrusively, from the outside shell to prevent the catalyst from being exposed to atmosphere and replaced.

In this example, the repairs were executed to a custom weld design as shown in Figure 2, with a requirement for high-temperature Time Of Flight Diffraction (HT TOFD) examinations at both 66% and 100% weld fill, whilst at elevated temperatures, before the final post-weld heat treatment examination at ambient.

Before this could be accepted, validation blocks were produced to aid the partial fill weld inspection at 200 °C, and verify the procedure. The blocks were manufactured with 33%, 66% and 100% weld fill and included 6 side-drilled hole (SDH), 3 mm ID surface EDM notch and artificial defects for validation. HT TOFD was required to be undertaken whilst hot.

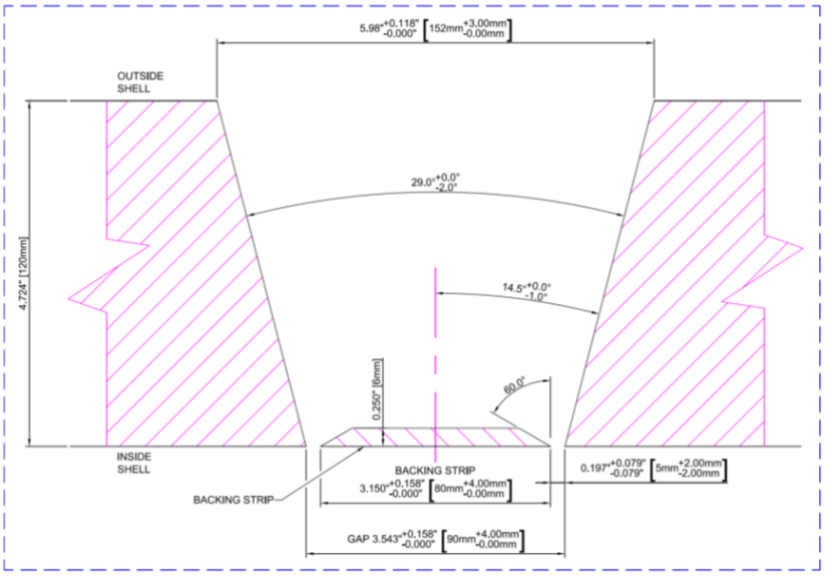

Figure 2: Weld design

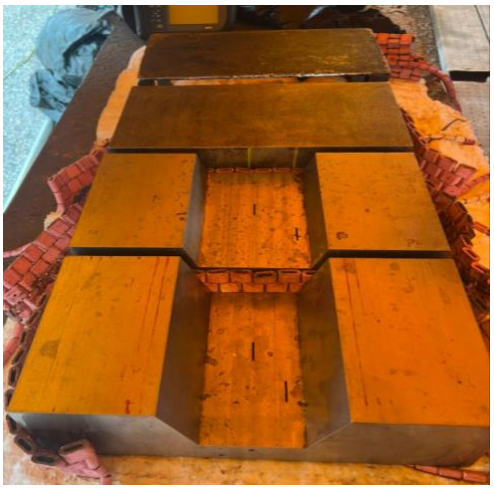

Figure 3: Validation blocks at varying weld fill levels

The Solution

To complete the TOFD examination at across the wide range of temperature with accuracy and reliability, SonoInspec used HotSense TOFD due to:

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- The HotSense TOFD transducers operate over a wide temperature range -55 to +350 °C (-67 to +662 °F).
- Increased wear resistance and robust construction to offer longer probe life.
- Increased sensitivity to make reliable and accurate wall measurements even through the thick walled components at elevated temperatures.
- Manufactured in compliance with international standards to easily fit directly into existing inspection procedures
- Quick to deploy, calibrate and begin taking measurements.

> *"We picked up a 3 mm EDM notch at the far service crystal clear with HotSense TOFD, and with our regular probes we did not pick it up at all with the same setup [sic].*
> *Actually, we can cover the full ASME block with HotSense TOFD and this setup at once.... unbelievably good."*
> **Advanced UT Inspector, SonoInspec**

Execution

By deploying HotSense™ HT TOFD, SonoInspec were able to valid the procedure with scans at 33%, 66% and 100% weld fill level, initially at ambient temperatures, and then at elevated temperature (~190 °C / 374 °F). TOFD transducers, 5 MHz, 6 mm with an integrated 50 deg refracted angle wedge were used and were successfully able to:

- At 66% fill, due to the wide weld width, it was possible to detect all indications within the first 40 mm from the ID in the validation blocks (see Figure 4).
- At 100% fill, accurately detect and size both bevel notches, the ID surface notch and all 6 SDH defects in one setup at both ambient temperature and at 185 °C in the validation blocks (see Figure 5).
- When the repairs were executed, the high-temperature TOFD was effective in detecting defects without the need to cool down and bring back up to preheat temperature.

Key Deliverables

- SonoInspec were able to conduct **high-temperature TOFD whilst a weld was being repaired** at elevated temperatures, and at various fill levels.
- **Accurate**, **repeatable** weld defect detection and sizing was enabled whilst repairing of the weld was conducted.
- **Reduced maintenance time** by undertaking inspection with no requirement to cool and reheat to preheat temperatures.
- **Increased productivity** by completing welding repair and inspection together,

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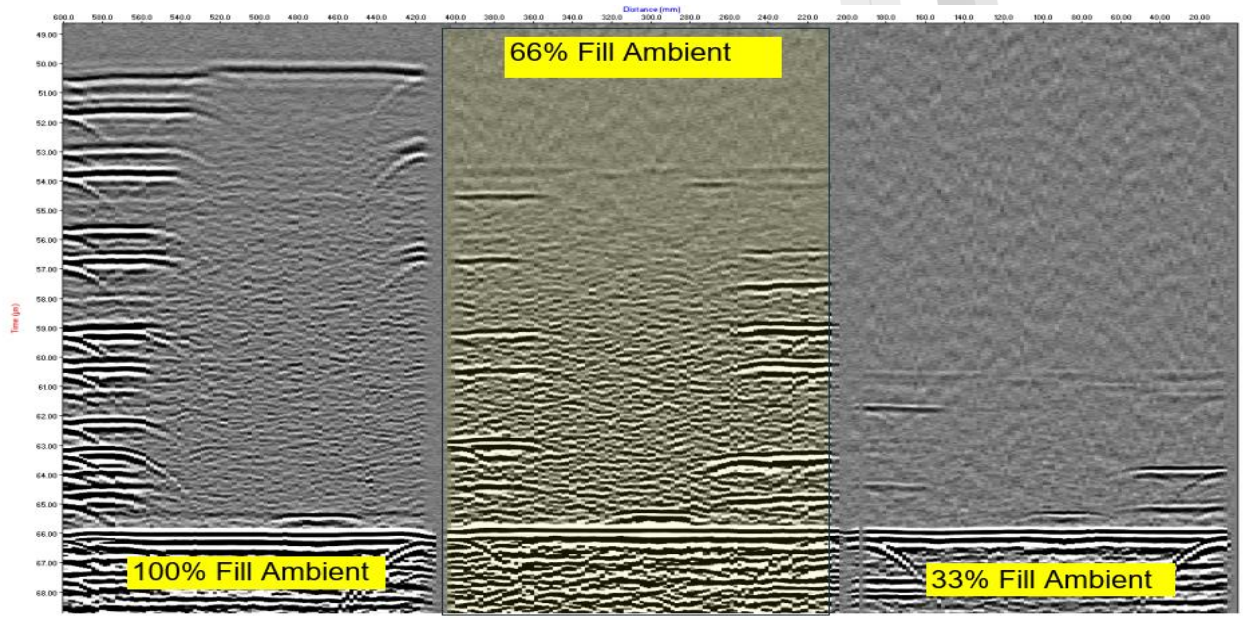

Figure 4: 5 MHz, 50 deg wedge combination scans of 3 validation blocks at each welded fill level at ambient temperature

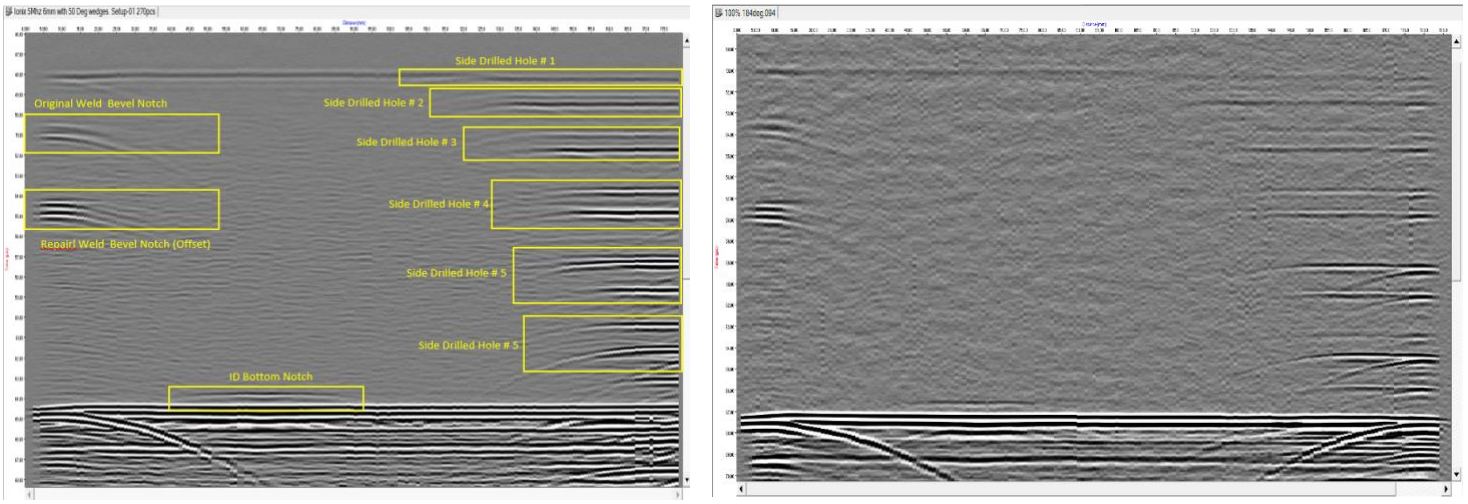

Figure 5: 5 MHz, 50 deg wedge B-scans of validation block at 100% fill level at (left) ambient temperature and (right) 185 °C, with all the artificial defects identified (yellow box).

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