High-temperature TOFD inspection of carbon steel weld

Time-of-flight diffraction on carbon steel welded plate up to 240 °C

1. Scope of the Technical Note

Ultrasonic time-of-flight diffraction (TOFD) is a popular method widely used in petrochemical, energy and other industries for the in-service detection and characterisation of welds defects such as root corrosion, porosity, inclusions, and cracks. However, with increasing demand for on-stream measurements, conventional TOFD is limited due to the temperature at which these probes can operate, often causing failure of the transducer, or causing noise in the wedges to mask the ultrasound signal.

Ionix high-temperature TOFD transducers, with integrated wedges, are suitable for weld inspection at elevated temperatures up to 350 °C. Here, the transducers with integrated wedges are mounted on to a modified EddyFi Lyncs scanner for high-temperature encoding, with high-temperature couplant, connected to commercially available Mantis UT set, and a carbon steel plate inspected at 240 °C for lack of side wall fusion and notches in the weld.

Highlights:

- All noted indications are identifiable through the temperature range 15 to 240 °C
- Acceptable sensitivity to defect detection maintained
- Suitable resolution was achieved for signal separation at elevated temperature

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2. Methodology

A carbon steel test block with manufactured defects from Sonaspection, summarised in Table 1 (see Appendix A for more information) was used.

Table 1: Summary of the test blocks used for evaluation

Test block i.d.	Material	Thickness	Weld cap	Weld defects
002	Carbon steel	28 mm	32 mm wide	• 1.5 mm root EDM notch • 3.7 mm mid-wall lack of sidewall fusion • 3.7 mm weld cap lack of sidewall fusion • 1.5 mm weld cap surface breaking EDM notch

An EddyFi Lyncs scanner was modified with magnetic wheels, compatible tool posts and encoder for high-temperature operation (up to 350 °C) and connected to an EddyFi Mantis U..

A pair of Ionix HotSense, 5 MHz, 6mm diameter crystal HT TOFD probes with integrated 60 degree (at 200 °C) non-profiled (flat) wedges were fitted with compatible pins for the Lyncs HT scanner, and coupled with Echo Ultrasonics Echo 6HT pumpable couplant (with an auto-ignition temperature of 421 °C) through the couplant channels on a continuous drip feed from a pump.

The probes were connected to the UT set via 5 m, dual lemo 00 to lemo 00 high-temperature cables.

The test block was heated, with the surface temperature monitored by a K-type thermocouple, and each temperature step, allowed to stabilise for 30 mins.

Figure 1: Photograph of the modified Lyncs scanner for high-temperature use on the test block.

A-scan range was set capturing the lateral wave, backwall reflection and mode converted wave on the test block on a section without flaws, from a PCS calculated for the wedge used, at ambient temperature. No compensation was made for elevated temperature on the PCS (due to the angle change) or velocity.

The pulser voltage used was the default 200 V with a 100 ns pulse length. Receiver filters used were low pass 10 MHz. B-scans were produced for test block 002, scanning a 300 mm length of the weld, capturing data in 1 mm steps at surface temperature setpoints of ambient (~15), 200 and 250 °C.

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3. Results

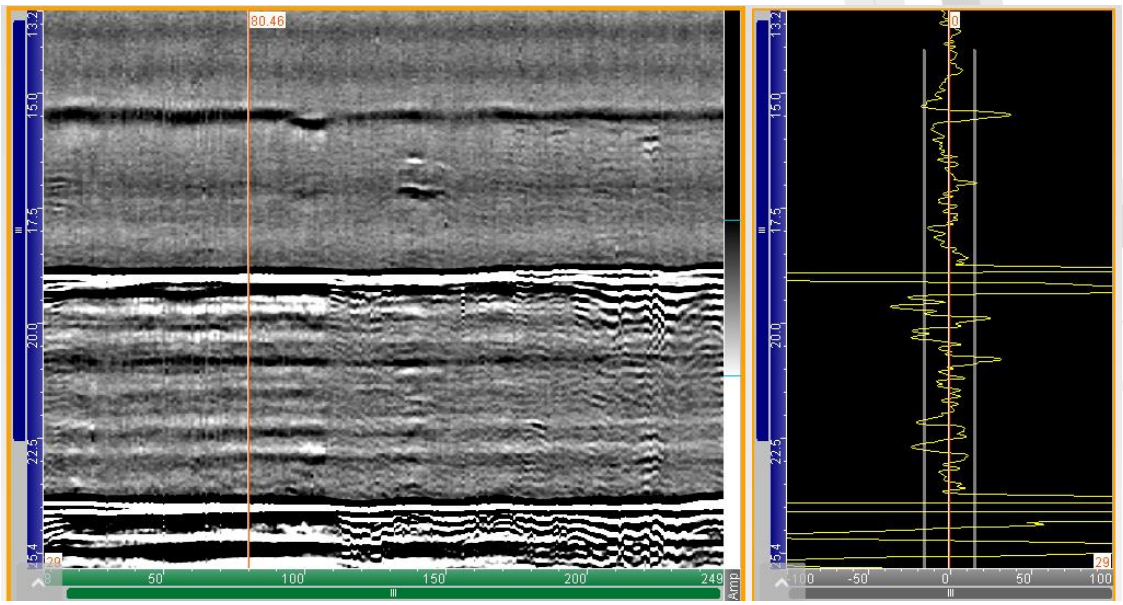

Figure 1: *Mantis B-scan (left) and A-scan (right) representation collected with 5 MHz, 6 mm dia. transducers with 60-degree integrated wedge from a test block 002, at a surface temperature of ~15 °C with Echo6HT couplant. on heating. Reference gain of 40 dB.*

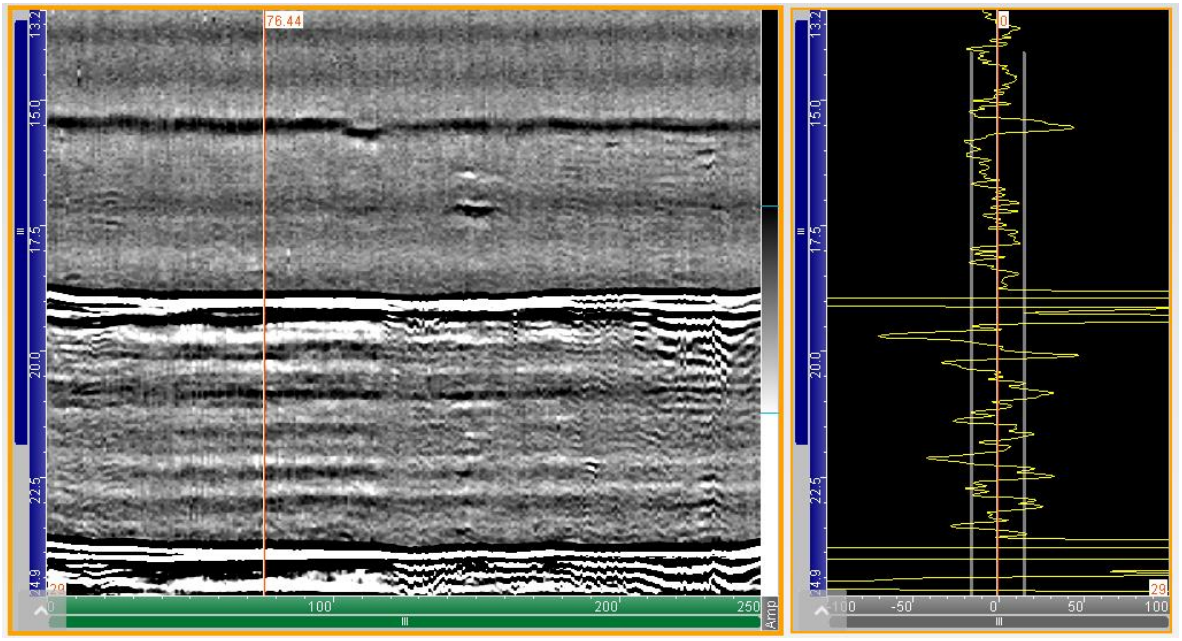

Figure 2: *Mantis B-scan (left) and A-scan (right) representation collected with 5 MHz, 6 mm dia. transducers with 60-degree integrated wedge from a test block 002, at a surface temperature of 200 °C with Echo6HT couplant. Reference gain of 54 dB.*

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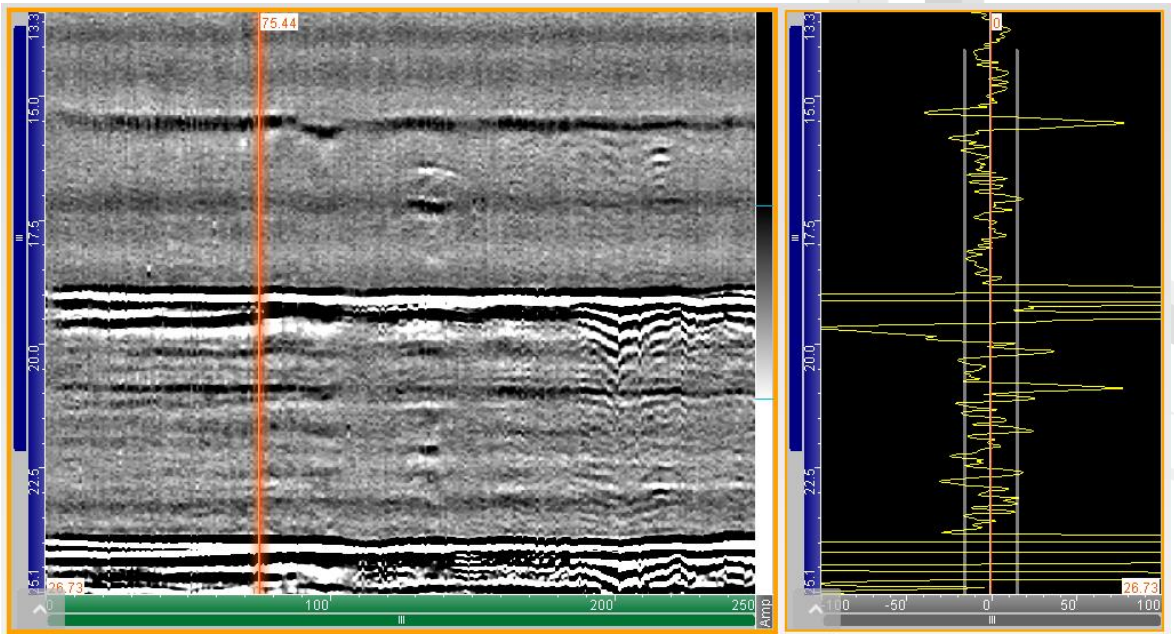

Figure 3: *Mantis B-scan (left) and A-scan (right) representation collected with 5 MHz, 6 mm dia. transducers with 60-degree integrated wedge from a test block 002, at a surface temperature of 240 °C with Echo6HT couplant. Reference gain of 54 dB.*

All four defects in test block 002 are identified by indications with acceptable sensitivity to each defect for detection. Suitable resolution is maintained through the temperature range for signal separation.

A reasonable increase in gain to offset the attenuation of the steel is required, but without the need for additional pre-amplification.

4. Conclusions

Throughout the temperature range, 15 to 240 °C;

- All noted indications are identifiable
- Acceptable sensitivity to defect detection
- Suitable resolution was achieved for signal separation

HotSense Technical Note	
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