Improved Inspection of CRA-Clad Pipe Welds with Accessible Advanced Ultrasonic Phased-Array Technology

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Abstract. CRA-clad pipes are increasingly used for the transport of hot and corrosive materials, as cladding provides a higher resistance to degradation caused by corrosion. Because of the nature of the corrosion resistant alloys (CRA) used for clad pipes, the inspection of the resulting dissimilar girth weld poses a particular challenge, to which the petrochemical industry has been searching for a simple and reliable solution. Olympus has developed tools to increase the capacity for detection and sizing of flaws located at the root, in the volume, and on the surface of the dissimilar weld. These tools include dual matrix and dual linear array probes combined with off-the-shelf ultrasonic phased array instruments and software, all packaged in a friendly and accessible manner. This paper presents how accessible advanced ultrasonic phased array technology contributes to the improved integrity of CRA-clad pipes used in infrastructures as pipelines, LNG and refineries.

Introduction

CRA-clad pipelines are increasingly used for the transport of hot and corrosive materials because of the higher resistance to corrosion provided by the corrosion resistant alloys (CRA). However, the layer of protection that these alloys provide also impedes effective ultrasonic inspection of dissimilar girth welds of pipes.

The quality of the weld between two sections of pipe is critical to ensuring the integrity of a pipeline. For years, radiography was the method of choice to verify the integrity of structures such as pipelines. More recently, the development of advanced ultrasonic testing techniques, including phased array and time-of-flight diffraction (TOFD), has extensively improved the efficiency of ultrasonic inspection, advantageously replacing RT for many applications.

Unfortunately, when applied to CRA-clad welds, the advanced ultrasonic techniques have presented certain limitations and more advanced tools have had to be developed.

CRA-Clad pipe inspection issues

Corrosion resistant alloys (CRA) are very effective, but they are costly. To limit the cost of pipeline construction, only the inside wall of the pipes are lined with a layer of CRA material with enhanced properties. Depending on the environmental conditions, various combinations of materials and thicknesses can be used; for example, a layer of Inconel clad on a carbon steel pipe. The CRA can be bonded to the inside of the pipe using a metallurgical (clad) or a mechanical (lined) process. The same CRA material is also used in the weld that joins pipes together to construct the line. Because velocity, grain structure, and other properties of the CRA material differ from the parent material, these types of manufacturing and assembly processes raise new challenges in the inspection strategies of pipeline girth welds.

Ultrasonic inspection of dissimilar girth welds in CRA-clad piping poses a particular challenge. As the material of the clad layer (Inconel, stainless steel, etc.) differs from that of the parent material (carbon steel), the characteristics of the interface between these materials makes the rebound on the internal wall (ID) of the pipe unpredictable or even impossible. In addition, the anisotropic structure of the cladding and the weld creates ultrasonic mode conversion and erratic beam orientations. Consequently, high-precision techniques such as zone discrimination cannot be used. Pulse-echo using the second leg of the ultrasonic beam is impossible, which makes inspection of the cap and its subsurface extremely challenging.

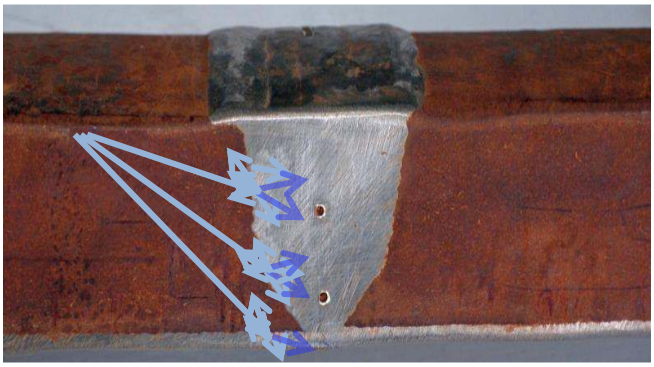

Figure 1: Effect of the anisotropic structures of the weld and cladding on shear wave ultrasonic beams

Olympus solutions for CRA-Clad girth weld inspection

The Olympus solution for CRA-Clad girth weld inspection is based on the use of dual linear arrays (DLA) and dual matrix arrays (DMA). The inspection is done with the first leg as skipping on the ID of the pipe if out of question. The use of low-frequencies probes (1 to 4 MHz) with compression waves (LW) favours the penetration of the weld with sufficient energy. Coverage of the full volume and surface of the weld can be obtained by performing a sectorial scan with theses probes The solution is easy to set-up and perform with off-the-shelf instrumentations like the OmniScan MX2 and the PipeWizard.

A DLA (dual linear arrays) probe is basically a transmit-receive probe where one linear array is used as the transmitter and anther one is used as the receiver, separated by acoustic insulation. This dual configuration eliminates interface echoes, as well as dead zones resulting from wedge echo, and it generates more energy and less noise in the inspection data. Capable to sweep the ultrasonic beams from 30 LW up to 80 LW and more, this optimized configuration inspects the surface and volume with the same probe and wedge, ensuring full weld coverage. When mounted on a fully automated scanner like PipeWizard, two DLA probes (one positioned on each side of the weld) are capable of performing the inspection in only one pass.

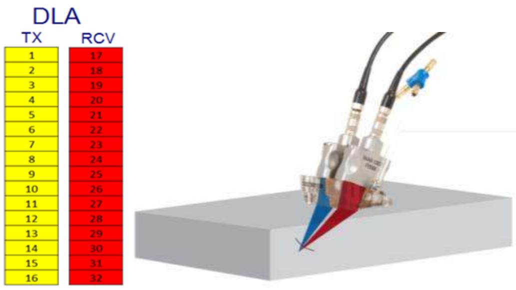

Figure 2: Left: DLA(Dual Linear Array) probe configuration; Right: DLA probe operation mode

A DMA (dual matrix arrays) probe is similar to a DLA except that the emitters and the receivers are matrix arrays instead of linear arrays. While it has the same advantages of the DLA probe, it also brings the capability to electronically focus at different depths and also to perform skew angles looking for oblique flaws. The operator can easily adapt the set-up of DMA probes to different pipe configurations. Such DMA probes can be mounted on an automated scanner but they are mainly use in a manual or semi-automated modes with the OmniScan MX2.

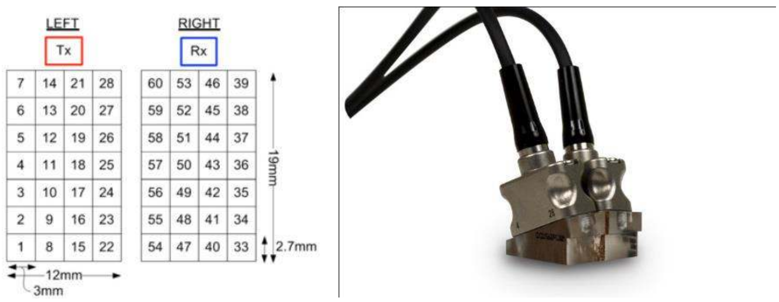

Figure 3: Left: DMA(Dual Matrix Array) probe configuration; Right: DMA probe picture

Basically, the weld is separated into different zones: the root, the volume, and the upper area (including the cap). The DLA/DMA probe inspects the volume with longitudinal waves that penetrate the weld, interrogating the opposite portion of the weld, to identify lack of fusion at the weld bevel. High angle LW and surface waves interrogate the upper part of the weld, including the surface, while the root is inspected with lower LW angles. All these angles are grouped together into one easy-to-read view called a sector scan.

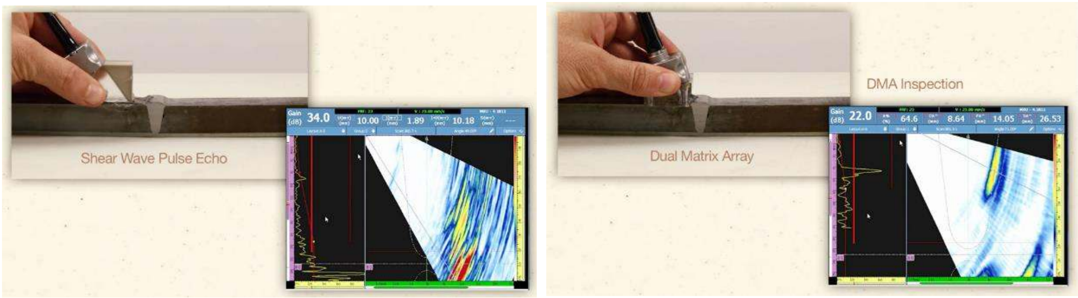

Figure 4: Illustration of the efficiency of the DMA solution for CRA-Clad weld inspection. Left: SW phased-array probe; Right: DMA probe

DMA probes for manual inspection validation study

The method using the DMA probes and the OmniScan MX2 was validated with a carbon steel pipe with an Inconel 625 cladding and weld. The sample was 30in of diameter and 40 mm thick with 3 mm of cladding on the ID. Side-drilled holes (SDH) of 2.5 mm diameter and 2 mm deep notches were located at different positions within the cross-section of the weld.

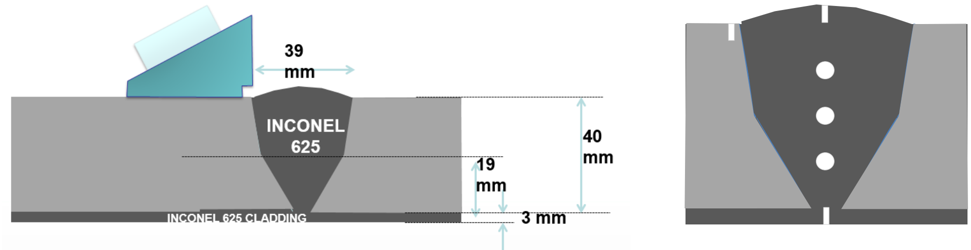

Figure 5: Schematic of the validation sample

A 2.25MHz DMA probe with 7 x 4 elements configuration utilizing 28 elements for the transmitter and 28 elements for the receiver with an aperture of 19 x 12 mm was used with the OmniScan MX2 32-128PR. A sector scan from 30 to 80 LW was used.

Figure 6: Olympus equipment for DMA inspection. Left: OmniScan MX2; Center: 32-128 PR module, Right: DMA probe

The inspection was done manually without the use of an encoder or a scanner and the following results were obtained.

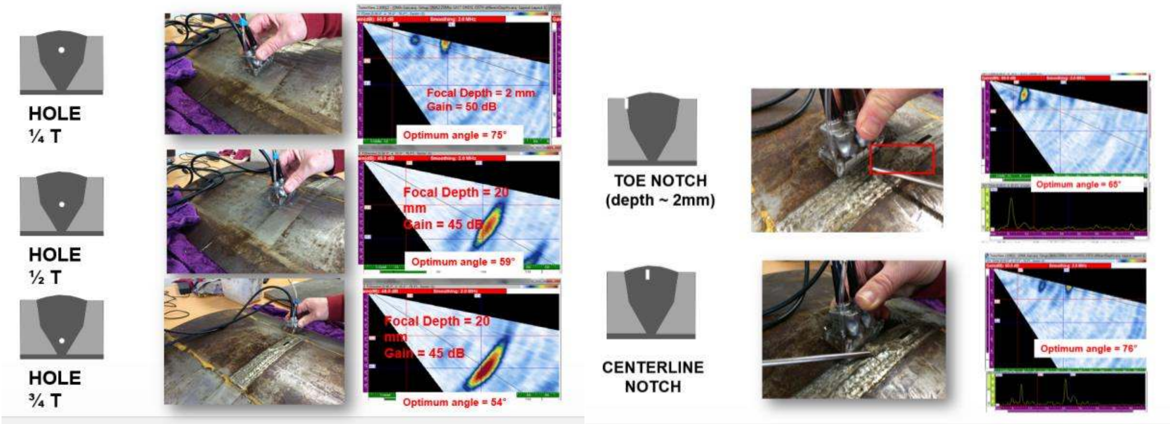

Figure 7: Results obtained for volumetric reflectors (left) and surface notches (right)

All volume reflectors (SDH) were detected with an excellent SNR while the surface notches were also clearly detected.

In summary, a 2.25 MHz DMA probe paired with the OmniScan MX2 32:128 PR can be advantageous for the inspection of CRA-clad pipelines with large diameters. The full coverage of the dissimilar weld was ensured as SDH located in the volume and the notches located on the ID and OD can be detected with one single sector scan.

DLA probes for automated inspection validation study

During automated inspection of pipeline girth welds, it makes sense to use DLA probes with appropriate wedges as the same set-up is used for a long period of time so, adjustment to different configurations is not necessary.

The technique using DLA probes with an automated scanner like the PipeWizard was validated on a segment of CRA-Clad pipeline. The sample is 219 mm diameter carbon steel pipe, 14.1 mm thick with 3mm Inconel overlay and with an Inconel weld. The weld has J-bevel configuration and reflectors are located at the OD surface, at the root and in the volume.

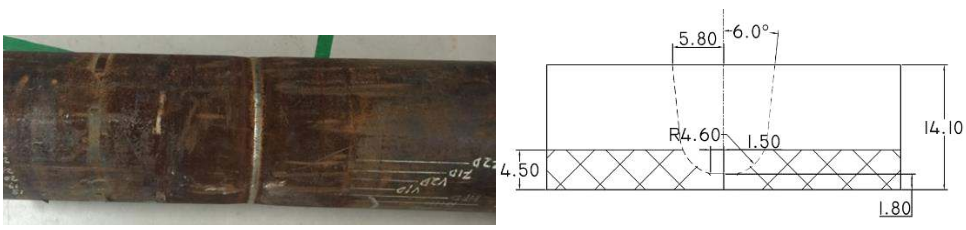

Figure 8: Picture of pipeline segment and J-Weld cross section schematic

Two 4 MHz DLA probes (one on each side of the weld) mounted on LW wedges connected to the PipeWizard system were used to perform the weld inspection in one line scan around the pipe.

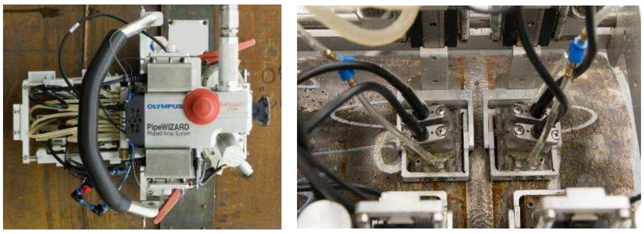

Figure 9: Olympus equipment for DLA inspection. Left: PipeWizard scanner; Right: DLA probes mounted on the scanner

Each DLA probe performs a Sector Scan from 30 to 80 LW covering the entire volume of the weld as well as the OD and ID with ultrasonic configuration working in the first leg only. The advanced functions of the PipeWizard software (Sscan, merged views) were used and no zone discrimination was performed. The results are shown below attest that one single DLA probe configuration can perform full coverage of the dissimilar weld detecting volume, hot pass root and surface targets with high SNR.

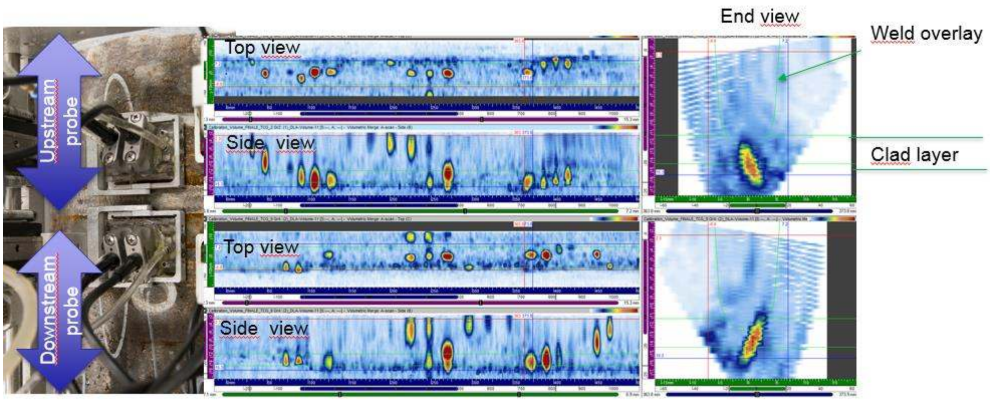

Figure 10: PipeWizard imaging of the pipeline segment illustrating root flaws detection

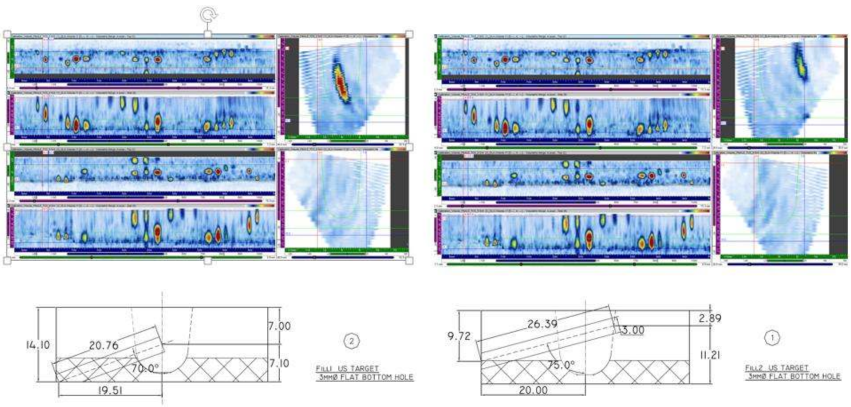

Figure 11: PipeWizard imaging of the pipeline segment illustrating volumetric flaws detection

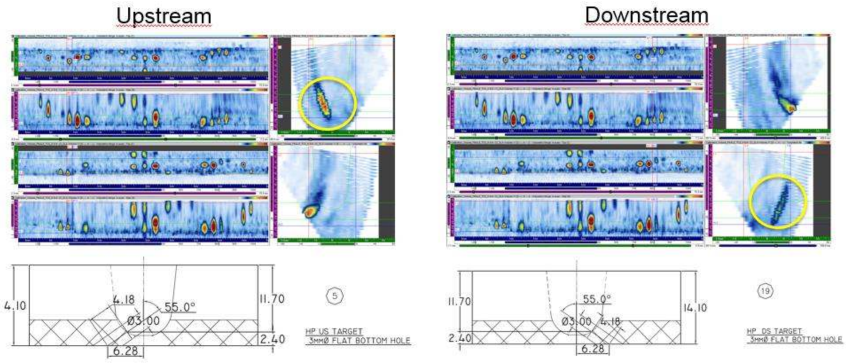

Figure 12: PipeWizard imaging of the pipeline segment illustrating hot passes flaws detection

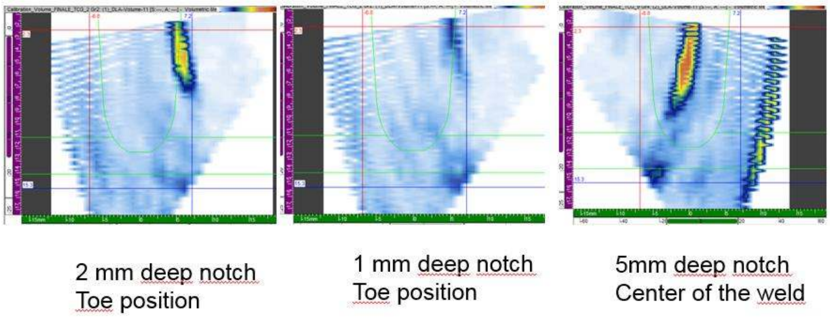

Figure 13: Detection of different surface notches

In summary, the use of one pair of DLA probes mounted on an automated scanner like the PipeWizard scanner can successfully inspect CRA-Clad pipeline in only one pass. Only one single DLA probe configuration can perform full coverage of the dissimilar weld detecting volume, hot pass root and surface targets with high SNR. The DLA probe is capable to perform with very high angle LW angles allowing detection of surface breaking targets.

Conclusion

Olympus has developed tools to increase the capacity for detection and sizing of flaws located at the root, in the volume, and on the surface of the CRA-Clad dissimilar weld. These tools include dual matrix array and dual linear array probes combined with off-the-shelf ultrasonic phased array instruments and software, all packaged in a friendly and accessible manner. Major players of the industry have already adopted these solutions to assure integrity of the infrastructures.