DEVELOPMENT AND QUALIFICATION OF A PROCEDURE FOR THE MECHANIZED ULTRASONIC EXAMINATION OF FULL STRUCTURAL DISSIMILAR METAL WELD OVERLAYS.

V. Chardome, M. Plateau, J. Cermak Vinçotte, Brussels, Belgium, May 2012

ABSTRACT
For the project of applying full structural dissimilar weld overlays on the pressurizer surge lines in the Belgian nuclear power plants, Vinçotte was requested the development and qualification of a procedure for the mechanized ultrasonic examination of such welds. The overlay and the upper portion of the underlying dissimilar metal weld were to be ultrasonically examined. Dedicated phased array probes were developed to provide the required detection and sizing capabilities. A specific procedure was developed, tested and qualified on various welded mock-ups. This paper details the work and the results during the development and qualification phases of this project.

INTRODUCTION
The ultrasonic examination of dissimilar metal welds is already a challenge. Adding a full structural weld overlay (SWOL) increases the challenge considerably. It is commonly known that the ultrasonic examination of austenitic and dissimilar metal welds requires specific ultrasonic probes designed. Due to the coarse grain structure of the base and weld material, the frequency of the transducers to use is typically found between 0.3 and 2MHz. Among others, typical characteristics are wave type, high damping and high sensitivity piezocomposite elements. Based on the experience with such welds a procedure was developed for the examination of a SWOL (figure 1).

VOLUME TO EXAMINE
A full scale welded mockup was provided for the development of the entire acquisition system. The thickness is 50 mm (DM weld) plus ca 25 mm of weld overlay. The examination volume is given by the Code Case N-740-2 as SWOL acceptance volume and PSI / IS volume illustrated by figures 2a and 2b.

Figure 1: typical pipe to pressurizer configuration with SWOL
Based on the Vinciottes experience with this kind of materials, the use of dual matrix phased array (TRL PA) probes was obvious. A transmitter / receiver configuration was to be defined and tested for this specific weld configuration.

SURFACE CONDITIONS
The proposed footprints of the TRLPA probes are 30x30 mm and 60x60 mm and thus the surface conditions were to be evaluated. This was done by scanning the entire mockup with a 3D laser scanning system. The digitised surface could then easily be compared with the theoretical surface (figure 3). Surface condition studies performed in the past showed clearly that the surface conditions (waviness) may affect the forming of the ultrasonic beam seriously.
During lab test it became clear that a 3D laser scanning of the SWOL surface on site would be very difficult or even impossible (dose consuming and geometrical restrictions). Therefore a simple device was made, allowing a quick evaluation of the surface condition necessary for the ultrasonic examination (figure 4).

![Figure 4: waviness evaluation tool](image)

**Figure 4: waviness evaluation tool**

**PROBE DEVELOPMENT**

Dual matrix phased array probes of 1 and 2 MHz in a transmitter/receiver layout were selected as base for the examination of the SWOL. These TRLPA probes were first tested by simulation. This allowed to define wedge angles, UT examination angles, focal depths and other parameters typical for these TRLPA probes (figures 5a & 5b).

![Figure 5a: beam forming](image)

![Figure 5b: beam simulation](image)

**Figure 5a: beam forming**  **Figure 5b: beam simulation**

Pre-selected angles and focal laws were tested on side drilled holes (SDH) in the mockup. Each angle/focal law was characterized to determine angle, probe delay and exit point. For each selected angle a DAC was established on the SDH in the mockup (figure 6).
QUALIFICATION
The procedure qualification was based on a performance demonstration (ASME based) with a technical justification (ENIQ based). The qualification flaws are sharp edge notches with their respective tips at various depths with different orientations, parallel and transverse to the weld center line (figure 7). Additionally, some flat bottom holes (FBH) were added with orientation such to simulate vertical and horizontal oriented lack of fusion.

The detection phase demonstrated that the applied ultrasonic techniques showed that the observed signals on the qualification reflectors (flaw tips) had an average signal to noise ratio exceeding 11 dB (i.e. all reflectors were clearly detected).

THROUGH WALL SIZING
The through wall capability was evaluated by two different methods: simulation (figure 8) and practical demonstration.
Figure 8: TWS simulation

For the practical demonstration, a portion of the mockup was used to insert subsurface planar flaws at a specific depth (SWOL thickness). To enable the smallest possible width of the subsurface flaws, a pilot hole needed to be made (dia. 0.6 mm). This made possible to insert a small EDM wire for the manufacturing of the subsurface flaws (figure 9). Flaw height sizes are 2.0, 2.5, 3.0, 4.0, 5.0, 6.0 and 7.0 mm.

Figure 9: zoom on subsurface planar flaw h = 2.0 mm

The result of the simulation and the practical demonstrations (figure 10) showed consistency about the sizing by tip diffraction (ability to resolve tip and bottom signal). This was demonstrated to be \( h \geq 2.5 \) mm.
ACQUISITION SYSTEM
Running two TRL phased array matrix probes required a phased array system capable of handling 4 x 32 elements in a pulser/receiver configuration on a 128 channel system. An Omniscan 32/128 PR system was chosen to control the proposed phased array probes with dedicated wiring. The UT acquisitions are performed by a PC through a network cable (up to 100 m distance to the weld). The mechanical system is based on Vinçottes PIMMS2000 scanning system (figure 11).
PROCEDURE DEVELOPMENT
Based on all the above, a procedure was written, describing the probes (angles, focal depths), the acquisition system and the evaluation and analysis rules. For flaws that could not be sized in height by tip diffraction, an amplitude evaluation was foreseen based on the DAC established on the SDH in the mockup.

CONCLUSION
A procedure was developed for the mechanized ultrasonic examination of full structural dissimilar metal weld overlays. This procedure was demonstrated on a real as welded mockup with artificial flaws. This procedure has already successfully been applied on the SWOL at the Tihange 2 and 3 nuclear power plants.