NOZZLE INSPECTION USING PHASED-ARRAY TECHNOLOGY

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Abstract: Nozzles have been a challenge for the ultrasonic inspections due to their geometry and high inspection requirements. The phased array technique applied by Tecnatom to the inspection of these components has allowed quality to be improved in the detection, the sizing and the positioning of the defects that may occur in these components. This ultrasonic technique has been used to generate new inspection procedures replacing others based on traditional techniques.
In order to achieve this objective, the following has been necessary:

- Design and manufacturing of new array probes.
- Design and manufacturing of new mechanical equipment.
- Manufacturing of mock-ups.

The procedures generated have been developed and validated on mock-ups and their operability has been verified during inspections performed at a Nuclear Power Plant, making it possible to simplify the examination of these components and at the same time reduce the dose and the time given over to the acquisition of ultrasonic data.

Introduction: Ultrasonic Inspection of nozzles from their outside surface has always been a challenge. The particular geometry of the nozzles, in addition to the position of the postulated defects, has led to develop inspection techniques, scanners and analysis tools, which have been able to be used later in other applications. This paper explains how Tecnatom is using the Phased Array Technique in the inspection of nozzles from the outside surface.

Tecnatom has developed procedures to inspect nozzles for a long time, trying to improve them continually. In year 2003 it was decided to carry out the automatic inspection of two groups of nozzles, whose dimensions were slightly smaller than other nozzles located in the same Nuclear Power Plant, although they had a similar shape. Before this development, the ultrasonic inspection of those nozzles had been carried out manually.

Therefore, the purpose of the project was to prepare a trustworthy inspection method and, once this procedure was developed, extending the achievements to inspect the other nozzles in the next outages.

The new inspection procedures, in addition to securing that the detection and sizing of defects was at least equal than with the former procedures, ought to reduce significantly the dose during the inspection.

Results: General geometry of the nozzles is represented in figure 1. Areas required to be inspected are the nozzle-to-shell weld and inner radius. The postulated defects are thermal fatigue-induced cracks.

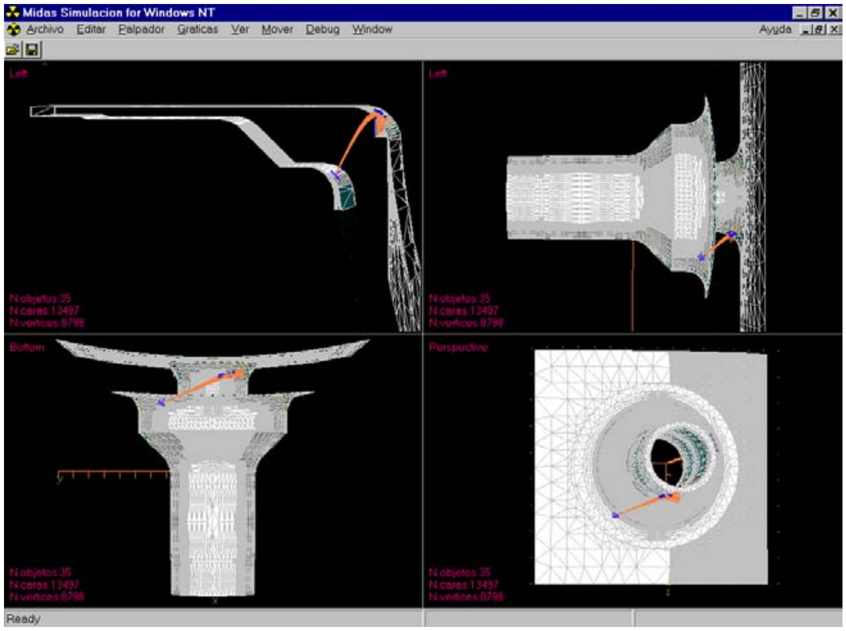

Figure 1. General geometry of the nozzles

With the purpose of reducing dose, inspection was designed with only one assembly process of the scanner on the nozzle. The scanner was modified for this purpose, so that its installation in the nozzle was easy and fast. Also in order to improve the simplicity and reducing dose, the inspection was designed with only one probe, which was located on the wall of the vessel. The angle refracted by this probe was controlled from the electronic device, while the skew of the probe was controlled mechanically.
A lineal phased array probe of 32 elements and 2 MHz was used for all the inspections (see figure 2).

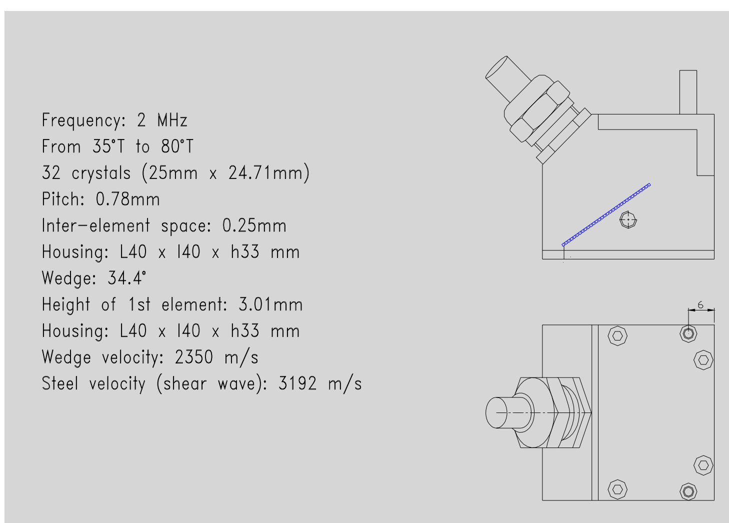

Figure 2. Phased array probe.

Discussion: Below, the three main aspects of this development are going to be described:
Nozzle-to-shell weld: Circumferential and radial defects were postulated in the nozzle-to-shell welds, which imply perpendicular and parallel scans to the weld.
In the nozzle-to-shell weld perpendicular scans (for circumferential defects) shear waves with refracted angles of 45º, 55º and 70º were used. The purpose of the refracted angle of 70º is to

detect near surface defects, which implies that the array probe works as a dual probe in this situation, with 16 elements working as emitters and the other 16 elements working as receivers.
In the nozzle-to-shell weld parallel scans (for radial defects), which are performed clockwise and counterclockwise, shear waves with refracted angles of 35º, 45º, 55º, 65º, 75º y 80º were used. For near surface defects a refracted angle of 70º was used (working in dual mode). The reason for using more incident angles in the parallel scans is the particular geometry of the nozzle, which implies that the inspection of the totality of the weld is performed by combining the position of the probe and the skew, with different incidence angles depending on thickness.
Inner radius area: In the inner radius scans (for radial defects), which are performed clockwise and counterclockwise, shear waves with incident angles of 55º, 60º, 65º, 70º, 75º, 80º and 85º were used, combined with programmed trajectories of the scanner. These trajectories are calculated taking into account the positions and skews of the probe which give a better incidence on the defects.
Calculation of the scan trajectories: Simulation software was used to calculate the optimum trajectory and skew of the probe. This software simulates the geometry of the component, the position of the defects and the probe, and the beam emitted by the probe. This beam is represented as a group of straight rays, which rebound on the defects and the surfaces of the component (see figure 3).

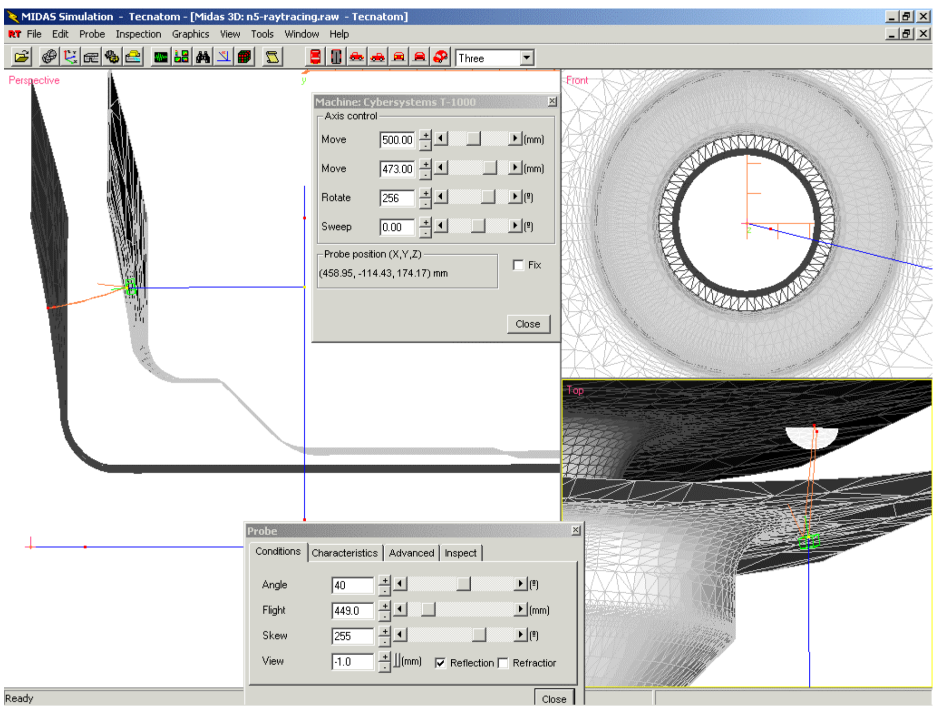

Figure 3. Simulation software image.

The following methodology to perform the calculations was used: a computer model of a nozzle was simulated. This nozzle is also available in a full-scale mock up, which has implanted and mechanized defects. These defects represent the ones that can be found in the component. The incidence angles, the trajectory and the skew of the probe were optimized on this computer model, and an ultrasonic inspection procedure was prepared on the basis of the results. Once the procedure was validated in the full-scale mock up, the calculation was extended to the totality of the nozzles. Figure 4 represents one of the inspections performed.

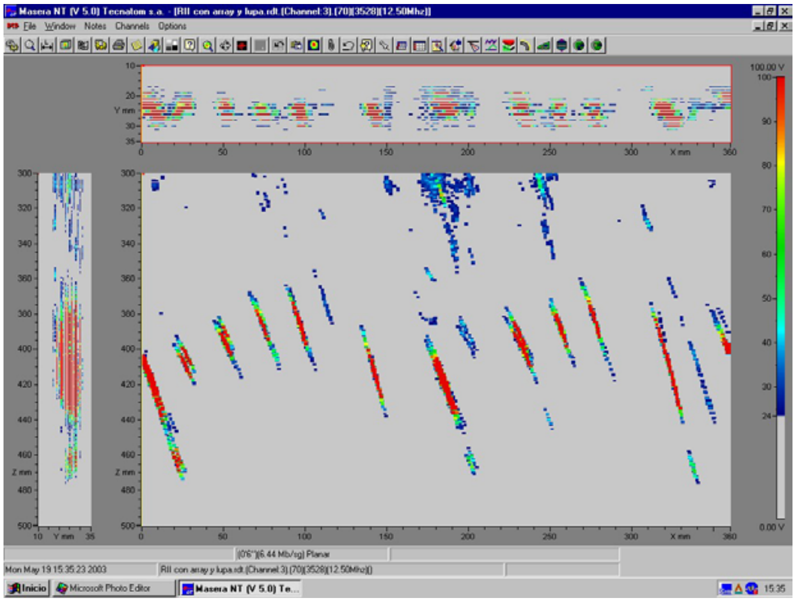

Figure 4. Image of MASERA.

Conclusions: As a conclusion, the final procedure used during the inspection gives a reliable ultrasonic technique for both the nozzle-to-shell welds and inner radius areas. This procedure has also minimized the dose. After analyzing the decrease in the dose and the inspection time, decision of using this procedure during the next inspections of this kind of nozzles has been taken.

The procedure has been successfully used in a Nuclear Power Plant in 2003.

References:

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