Application of the PA technology to the automatic inspection of elements with complex geometry by robotized trajectory tracking.

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Abstract

In the manufacturing processes of the aeronautical sector, the use of composite materials is common practice allowing great advances which is rapidly spreading to other fields. The high-quality standards required for this type of material requires a 100% quality control of the structural elements before these parts are assembled and subsequently used.

The increasing use of composite materials in more industries implies finding a suitable way for testing and evaluation. Non-destructive testing using ultrasonics is an appropriate method to detect defects in these types of materials. However, because of their complex structure the most applicable and accurate process for detecting flaws and anomalies has to be found.

For conventional ultrasonic testing, single-element probes are used to generate an ultrasonic signal into the material to inspect it. However, when inspections are done on composite materials, phased array probes (PA) are now being used to detect component failures and thereby determine their quality more rapidly.

The objective of this work is to apply the PA technique in the development of a new automated system that inspects, not only flat parts, but also for curved geometries following the contour of the part without loss of signal, removing the necessity to delimit different zones of inspection, optimizing the representation of results and reducing the time of evaluation and errors in interpretation.

This system has robotized trajectory tracking, applying Pulse-Echo, and Double Transmission techniques with Phased Array technology, as well as TT transmission, with water coupling, so that it is possible to inspect one hundred percent of monolithic structures of solid laminates and sandwich structures.

During the last years, great efforts have been made to improve different parts of the inspection systems. The results have been satisfactory for simple inspections, but not for inspections of elements with complex shapes is still proving a major challenge.

Keywords: Phased Array (PAUT); Ultrasonic Testing; Complex geometry; Robotized trajectory tracking.
1. Introduction

Until now Tecnitest has developed a wide range of immersion tanks characterized by:
- Flexibility and individual nature of bespoke design, providing customers with a cost-effective exact match for their requirements and creating a tailor made automated solution to inspection needs
- Bespoke individual design
- Robust aluminium frame
- Available lengths ranging from 1m to 15m and widths ranging from 0.3m to 3m
- Guaranteed compliance with EU standards
- “Visualscan” Software
- A, B and C Scan result presentation available

With the possibility of using the following techniques:
- Conventional UT and Phased Array options
- Ultrasonic Inspection modes in planar scans
  - Pulse-Echo (P-E)
  - Through Transmission (TT)
  - TT with local immersion (squirters)
  - TT with in full immersion
  - Double Transmission/Reflecting plate (DT)

![Figure 1. Immersion tank and Visualscan™ Software](image)

However, in sectors as strict as the aeronautical industry, it is often required to have more productive inspection systems even integrated into the airplane's own manufacturing process.

2. Development

In this way, Tecnitest has worked on the development of a robotic inspection system that allows the inspection of the pieces with a complex geometry. The TRITON10 system is a device designed to perform inspections, using ultrasound, in pieces made of composite materials.

To be able to track this type of trajectories in a robotized way, the system consists of:
• An immersion tank
• An ultrasound system SITAU "Phased Array" designed to operate in automatic systems which require multiple "phased array" probes to cover 100% of the area to be inspected. The connection of up to 7 "phased array" probes with 128 elements, each of them is allowed and offers the necessary flexibility to set the most appropriate configuration depending on the geometry of the component to be inspected.
• An articulated industrial robot with programmable manipulator in its 6 controlled axes, automatically controlled and programmable to work in a linked and independent way in 3 areas of movement simultaneously, applying the Pulse-Eco techniques with Phased Array, double transmission with plate reflective, and transmission for sandwich structures, so that the inspection of one hundred percent of the surface of the piece is possible.
• A robot guidance system with linear guides
• A set of quick change tools equipped with several slots
• An inspection Station
• A Security system, composed by: physical barriers, optical barriers, security stop buttons, control cabinet.

![Immersion tank with robotized trajectory tracking](image)

Figure 2. Immersion tank with robotized trajectory tracking

Thus, after the correct configuration of the ultrasonic equipment and using the appropriate tool, the system allows the inspection of different types of pieces according to the different inspection standards used in aeronautic field.

3. Results

This system allows working in three operating modes
• Operation mode 1: the immersion tank and the robot are used together and the displacement is done following a linear guide. The use of positioners and a gimbal allows the inspection of surfaces with certain curvature and a trajectory tracking according to a plane that is not necessarily horizontal. The available inspection techniques are: PE and DT, with PA technology, for inspection of solid laminates
with a flat or slightly curved shape. In this mode of operation, the pieces are placed in immersion in the bottom of the tank and the scan is performed according to a plane that can be vertical or horizontal.

- Operation mode 2: the tank is used and the pieces with complex geometry (e.g. omegas type) are placed on an ad-hoc tool (previously designed for this use) immersed in the tank. The robot, with the previous information corresponding to the CAD design, is responsible for carrying out the inspection completely automatically using a custom-made probe head that allows to absorb deviations in the geometry. The inspection technique available is PE, with PA probes. Inspection trajectories are programmed, based on the information of the coordinates of the piece to be inspected, so that the robot together with the head can follow the defined geometry.

- Operation mode 3: Based on the use of TT inspection mode with water. It allows to inspect sandwich components, both flat and with complex geometry using a transmission tool.