ADVANCES IN INDUSTRIAL TESTING MACHINES FOR THE AUTOMATED INSPECTION OF AEROSPACE COMPONENTS

New challenges, new approaches

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SUMMARY
AREVA NDE-Solutions specializes in mechanized non-destructive testing (NDT) systems and services and has succeeded in transferring our nuclear inspection technology and know-how to the aerospace carbon composite inspection industry.

The aerospace industry needs absolute reliability and safety. New designs and demands to inspect 100% of these new components pose new challenges. The parts to be inspected are becoming larger, with more complex shapes, high curvatures, multilayered and often combine monolithic and sandwich structures. Stringers, radii, chamfers and edges must be inspected as well as untrimmed components and components drilled with holes.

In addition, the new NDT machines must be reliable, inspection time and system costs must be minimized, and the systems should be flexible enough to anticipate future inspection needs. This represents a true industrial challenge.

The combination of intelligeNDT’s flexible testing platform with state-of-the-art mechanics and complete control of the entire NDT chain of supplies and expertise (Design, Sensors, Hardware, Software, Project Management, Commissioning, Training and After-Sale Services) has resulted in a series of inspection systems that combine very high level of defect detection with a truly optimized industrial process.

We show innovative systems based on trough-transmission squirters or contact methods with multi-element phased array techniques using robots or gantries.

INTRODUCTION
intelligeNDT systems & Services, the German component of AREVA NDE Solutions, specializes in mechanized non-destructive testing systems and services and have succeeded in transferring our nuclear inspection technology and know-how to the aerospace carbon composite inspection industry. There are many similarities between the nuclear and aeronautical non-destructive testing (NDT) business including the demand for zero defects and zero failures.

This article shows specific sample innovative systems that have been manufactured to inspect high-tech composite components of all shapes and thicknesses made from numerous materials and using various manufacturing process. Trough-transmission and multi-element phased array techniques have been deployed using contact methods, squirters, local or complete immersion mechanisms. Delivery configurations include water tanks, water squirters, gantry mounts, single or twin five or six axis robots. Solutions to sample problems such as inspection of chamfers, stringers, small-radii parts, and evaluation of porosity are discussed as well as the solution implementation on fully automated industrial machines.
The main principles underlying manufacture of aerospace structures are the need for absolute reliability and safety combined with practical optimization of the manufacturing process and particularly focusing on quality control and quality improvement. Non-destructive inspection techniques and systems at the manufacturers’ site are an important part of this constant quality control process. New designs and demands to inspect more and more regions of these new parts pose new challenges to NDT specialists, some of which are addressed in more detail below. The parts to be inspected are becoming larger, with more complex shapes, high curvatures, multilayered and often combine monolithic and sandwich structures. Several sub-components are also now produced in large volumes despite their complex geometries (e.g. beams with various cross section shapes: U, H, L, Z etc.).

Stringers, radii, chamfers and edges must be inspected as well as untrimmed components and components drilled with holes. All these geometrical, structural, and manufacturing process variations pose challenges for new NDT systems. In addition, the new NDT machines must be reliable, they must include part-traceability functions, inspection time and system costs must be minimized, and the systems should be flexible enough to accommodate today’s standard and advanced test techniques as well as anticipated future inspection approaches. This represents not only a technical and scientific, but also a true industrial challenge.

Size
In recent history, each new generation of aircraft has increased the extent of carbon fibre reinforced plastics (CFRP) (see graphic to right for material distribution in one current aircraft design). In the past, CFRP was mainly used for non-structural covering purposes (i.e. as cover sheets for metallic frame structures). Manufacturing and design improvements has allowed use both for covering and load bearing purposes. Many parts that were joined by rivets, are now being integrated into single complex CFRP structures, most often utilizing mixed curing and bonding processes.

Due to this evolution, the parts have reached huge dimensions, compared to the state of the art just 15 Years ago. Consequently, the scanning volumes of our most recent machines reach sizes up to 30 m in length, and scanning heights as much as 7 m!

In these giant scanning volumes, still all requirements with regard to defect resolution and recognition, as well as positioning accuracies among others must be at least as good as in
the passed "good old times", and in many respects even better. Machines grow in dimension with the parts to inspect as shown below.

**Machine for NDT of wing cover in an early state of manufacture (Scanning Volume: 30 m long, 7 m high)**

**Complexity and Shape**

CFRP parts are no longer simply isolated coverings. Rather they are integrated "final" parts including the load bearing structure, with mounting reinforcements, corners, tapered ends, stringers, radii, pad up's, edges, and all varieties of holes and cut outs requiring a dramatic increase for scanning accommodations. This has led to more sophisticated scan-plans and associated programming (see below).

These demands strongly push towards 6 axis manipulation devices, as the old fashioned 5 Axis kinematic no longer appropriately serve many contour following requirements. This also includes the capability to follow arbitrarily shaped complex 3D scan paths on surfaces that are locally semi-spherical or even stronger bow (more than 180° of curvature). These features may also include very low-radius curvatures as well.

Machines grow in complexity with the parts they are to inspect as shown below.
Dual Robot Machine for NDT of Helicopter parts (Through Transmission and Pulse Echo Modes)

Material Layup and Defect types

Due to a broadened scope of application, new CFRP structures frequently conform to requirements for lightning protection and foreign material impact protection. Therefore the outer surfaces of the parts are made up of one or more sheets of copper mesh and glass fibre material which impedes the ultrasonic penetration and poses additional challenges to the sensors and probes. In addition, recently evolving demands to characterise porosity, i.e. the indirect assessment of a physical quantity, have increased the NDT demands compared to past requirements focusing primarily on defects.

Efficiency

The ever increasing demand with regard to scan speed, accuracy, productivity, etc. could dictate that the scanners have proportionally increased system prices. But the opposite is true. Responding to strong cost control pressure, all routes for efficiency increases are exploited including innovations and advanced technology to reduce NDE system costs.

One way to control cost is to extend test system amortization time to one or two decades (you even can find some 30 years old machines that are the back bone of ultrasonic NDT in some manufacturing sites). Today’s designs must anticipate evolving technologies (not only inspection, but also programming, evaluation, and plant integration and monitoring) in order to secure the customer’s investments.

CURRENT SOLUTIONS

In order to cope with the challenges described above, AREVA has chosen a multifold design approach:

With regard to scanner mechanics, we have complemented the traditional linear gantry or bridge designs with single or dual off-the shelf articulated robots.

Both designs have their individual weaknesses and strengths. Linear systems are often custom-built, as sufficiently precise and water resistant do just not readily exist. Also, accuracy and stiffness are sometimes an issue. For the robots, limiting factor for their
application include limited reach and more complex kinematic positioning calculations. Benefits include short delivery times, unmatched stiffness, accuracy and speed at reasonable cost (due to mass production), plus advanced control and correction algorithms.

A large variety of sensoric equipment has been developed for specific inspection tasks such as stringer webs, inner and outer radii, corners, edges, etc. All of these apply phased array technology with curved or flat transducers, solid state delay lines, and local immersion solutions. Those systems sometimes combine with manually operated or automated tool change devices in order to allow one machine to fulfil the full scope of required inspections.

The control and programming software nowadays allows offline programming using proprietary or commercially available software. This reduces the machine down time required for teaching and adaptation to a minimum and makes programming more reliable predictable, e.g. by simulation of the scan process. All these measures help increase the return on invest for the machine. Nonetheless, several NDT specific details need to be considered by the software, such as passing over holes or not (depending on type of sensor and size of hole), automatic overlapping sub-areas, or scan boundaries outside the part surface.

*Offline Programming (OLP) becomes more and more crucial due to increased complexity and dimensions of parts and the required positioning accuracies*

Last but not least, all the lots of acquired data need to be visualised and evaluated. To this end, intelligenNDT offers a wide range of software tools to make evaluation faster, such as automated or semi-automated defect detection, sizing, and classification, tracking of evaluation progress and its results, comprehensive defect lists etc.

Software support for systematic and unbiased evaluation routines and their automated and objective reporting and tracking make the full process safer and well documented.

Evaluation comprises not only C-Scan imaging, but also documentation and reporting features, such as automatic labeling, documentation of evaluated areas, automated defect sizing and free definition of referencing elements (e.g. stringers), as shown below.
C-Scan view of a component with reporting indications

SUMMARY

The combination of AREVA’s flexible testing platform with state-of-the-art mechanics and complete control of the entire NDT chain of supplies and expertise (Design, Sensors, Hardware, Software, Project Management, Commissioning, Training and After-Sale Services) has resulted in a series of inspection systems that combine 5 key advantages:

- Integration into the manufacturing process chain including consideration for time and cost effectiveness,
- tailored design to meet customer requirements,
- automation of the NDT inspection process
- machine assisted indication evaluation and sizing
- part and location traceability
Recent mechanic designs employing articulated robots and linear mechanics complement the latest ultrasonic sensor designs in Phased Array technique to achieve these targets. This combines with advanced software structures particularly designed for efficient programming, e.g. offline, and advanced evaluation, such as automated defect detection, sizing, and classification.