A Twin Robot Approach for UT Inspection and Porosity Evaluation of Complex Shaped Helicopter Components

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1. Introduction

In the production of aircraft the use of carbon fibre reinforced plastics (CFRP) is constantly increasing. This is because of their outstanding mechanical properties with regard to e. g. specific weight and strength, as well as the possible flexibility in design, such as joining numerous different metallic parts into one single CFRP component. However, the possibility of designing very streamlined and highly integrated parts comes along with structures that are more and more complicated in function and shape, as a single CFRP component covers tens or even hundreds of metallic parts in conventional aircraft design.

This complexity in shape poses ever increasing difficulties for the non destructive verification of the integrity of the structure. This holds especially true for components of helicopters, as they usually consist of a variety of sharply bended, very complex, multi-axially shaped parts (see Fig. 1).

Increasing attention is paid nowadays also to the porosity content, due to its high impact on the strength of the component and consequently on the weight of the structure. A key issue is here to find appropriate material property indicators that describe the material properties on one hand, and can easily be measured on the other.

2. The Machine

In close conjunction between the customer, Eurocopter Deutschland GmbH, Munich, Germany, and the system supplier, intelligeNDT Systems & Services GmbH & Co. KG, Erlangen, Germany, a system for the above mentioned requirements was designed and delivered, that is in operation since March 2004. Key features include:

- *Through transmission technique and multi channel Pulse Echo inspection for porosity evaluation*
- *NC-Programming via CATIA, with an optional teach mode included*
- *Scanning, presentation and evaluation in full 3D dedicated software*
- *Evaluation of defect echoes, BWE shadowing, thicknesses, depths*
- *Fully automated scanning including fully automated change between the techniques for manless ghost shifts*

Those features are described in detail below.

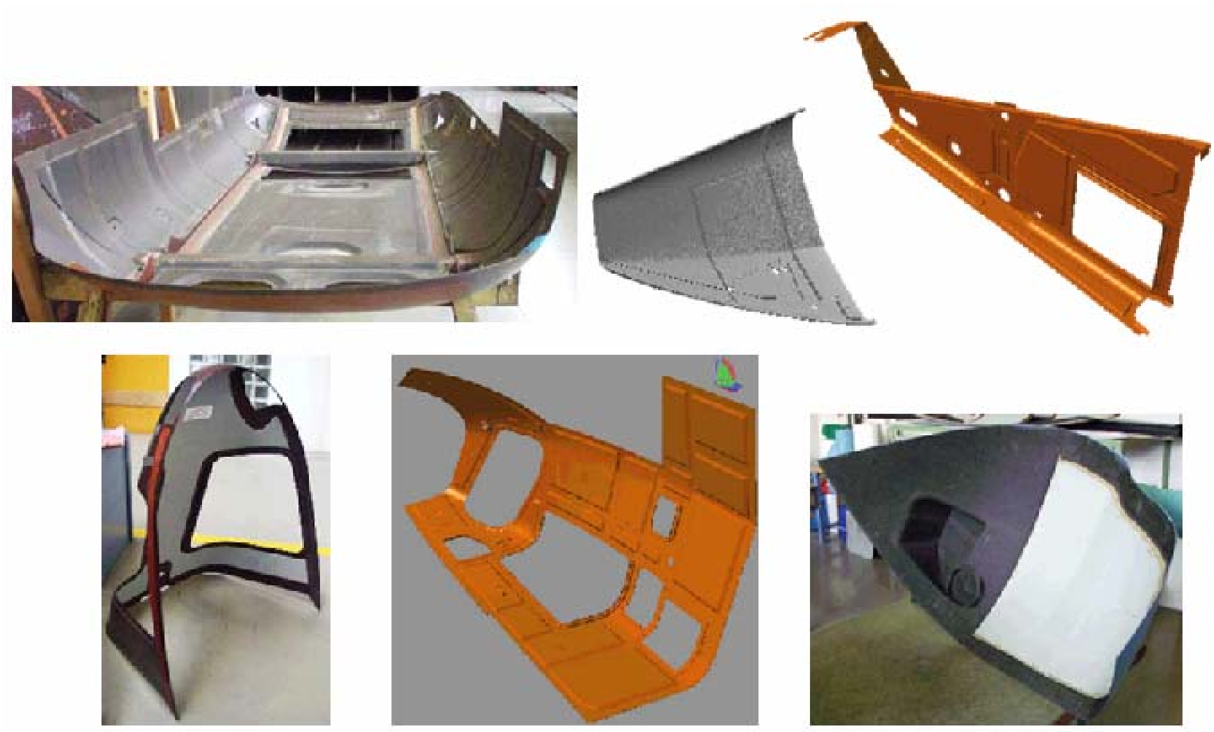

Fig 1: Complex Geometries belong to the part spectrum of the inspection machine

3. Inspection Techniques

Depending on the material setup and properties different techniques for inspection and coupling are applied.

Trough transmission

In areas with sandwich setup free water jet through transmission is usually applied. This is fast and simple and usually yields enough signal to noise ratio. Information on defect depths and material thicknesses is not supplied.

The requirements regarding the mechanical positioning accuracy are normally relatively high, as the two squirter nozzles on the two sides of the component need to be kept in perfect alignment during the scan.

The porosity evaluation is very limited with this technique and presently not state of the art.

Pulse Echo

In monolithic laminates pulse echo inspection is possible. The coupling is performed here in contact technique. This yields a much better signal to noise ratio and gives defect depths and wall thickness mapping in addition to defect detection and in the same go.

Automated pulse echo scanning equals manual scanning with regard to sensitivity and detection capability. Defect detection above a threshold of DSR3 is easily possible, as well as porosity assessment according to the current rules for manual UT.

In order to achieve a high productivity the system scans with 1, 2, 4, or 8 channels in parallel.

4. Robots

Conventional scanning systems are normally set up with linear cartesian axes and one or two rotational axes. Apart from the fact that only a limited range of configurations can be met (it would need 6 degrees of freedom for full flexibility), it is generally difficult or impossible to gain sufficient access to both sides of a complex bent surface with linear mechanics, especially when strong curvatures are involved.

The use of commercially available multi purpose 6 axis robots was chosen, as these systems feature fast and reproducible positioning together with a maximum of flexibility and dynamic stiffness at a very competitive price.

The high level of positioning accuracy in dynamic motion of two robots synchronised was proven using a non contact 3 dimensional Laser positioning equipment as shown in Fig. 2

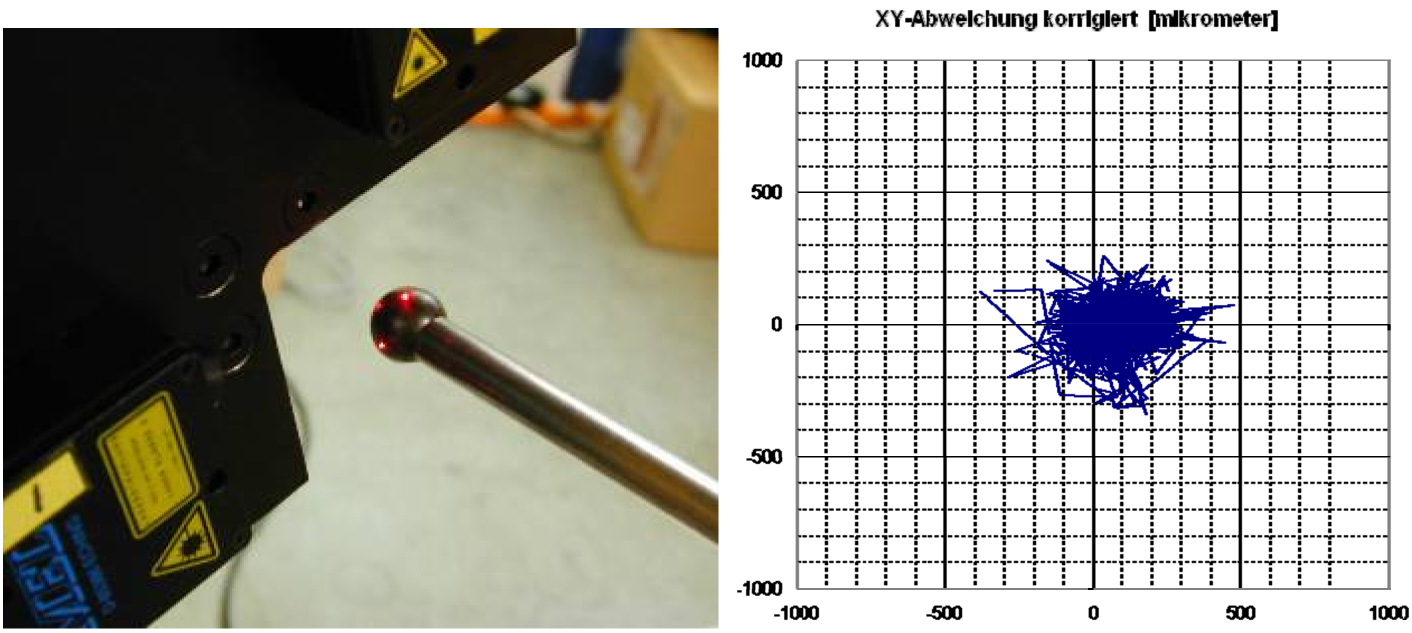

Fig 2: Synchronisation – measured with 3D-Laser positioning system

One of the big advantages of commercial robots rather than a dedicated special machine is that numerous software tools are available that can be applied to almost any possible industrial motion application, yielding very high productivity.

5. CATIA Interface

Due to the complexity of the part spectrum and the need for true and undistorted presentation of the UT results, operating the system in conventional tech mode was unacceptable.

Therefore, a data interface was created that allows to program the scan paths, scan area sizes and shapes, UT setup's etc. directly from the manufacturer's CAD data.

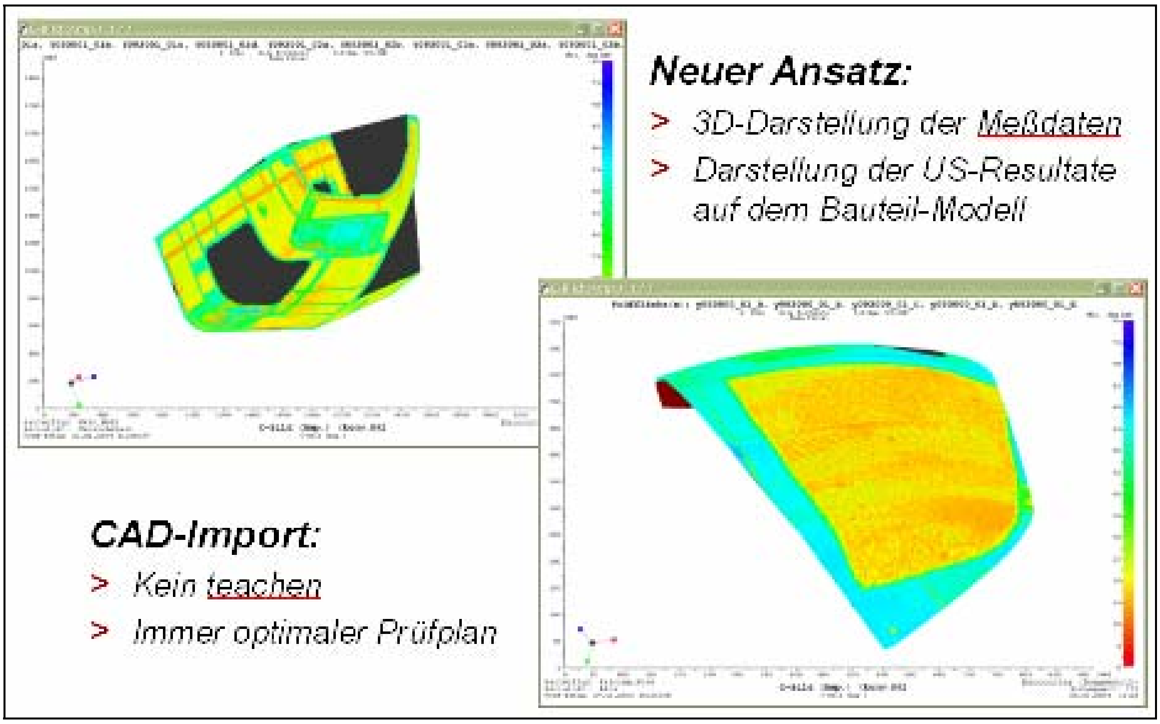

Fig 3: CAD based inspection and presentation

6. Automated Tool Change

The system was designed to inspect a large variety of complex shaped parts with different techniques:

- large flat areas of full CFRP full laminate in multi channel Pulser Echo,
- Strongly curved geometries with an appropriately reduced number of PE probes, and
- Sandwich areas in Through Transmission

In order to incorporate all these requirements, a fully automated tool changer was designed, that allows the fully automated change between 1, 2, 4, 8 channel PE , and Squirter inspection with no user intervention.

7. 3D Evaluation

In view of the very complex geometry of the scanned parts, it was obvious that the normal way of evaluation using 2 dimensional presentation software would lead to unacceptable distortion and faulty defect sizing.

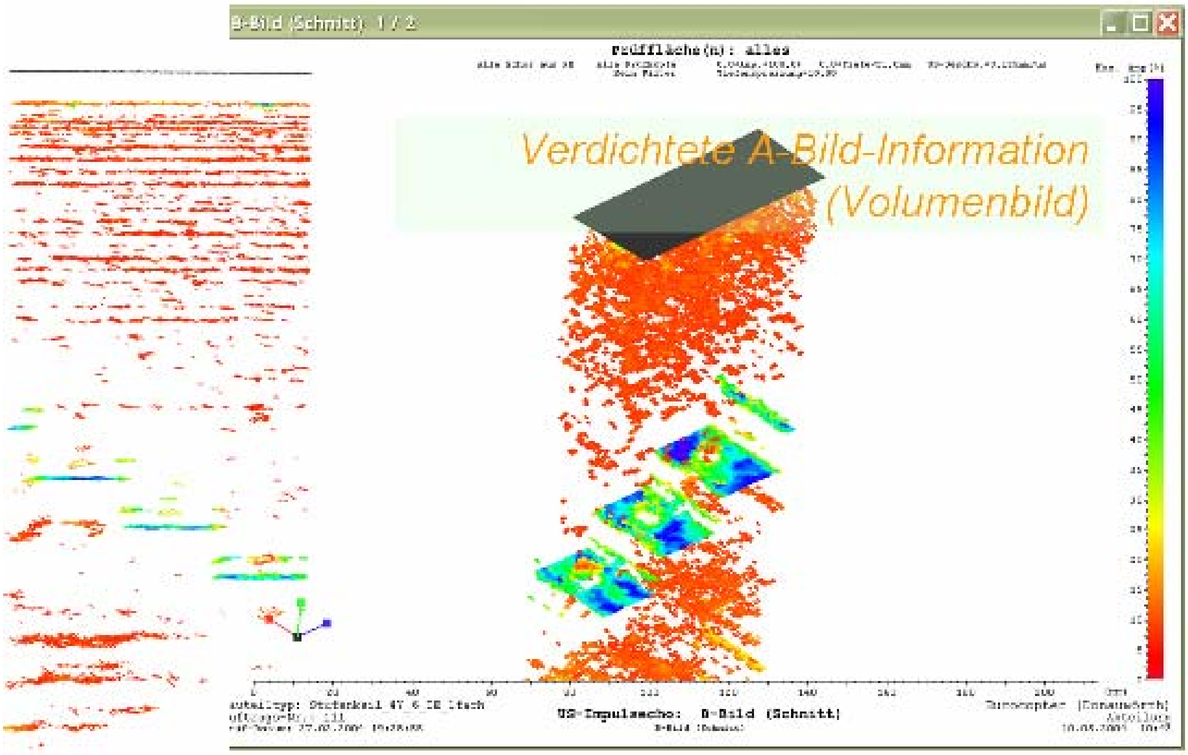

Bild 4: Step wedge with artificial defects close to the inspection surface and the back wall. Also the structural noise due to reflections from the CFRP layers is clearly visible

A completely new software was developed therefore, yielding fully three dimensional acquisition, storage, presentation and evaluation of the UT data in relation to the CAD geometrical information, fulfilling all requirements with regard to accuracy, simplicity, and speed for the processing of the results.

8. Gateless Data Acquisition

As UT equipment, the latest intelligeNDT technology is applied, the SAPHIR*Plus* generation of versatile UT instrumentation. It is equipped with 16 channels conventional, but can readily be extended to more channels or phased array technique, also in mixed mode.

Particularly for the inspection of CFRP, it is very advantageous that the system is based on full A scan recording, rather than gate based acquisition. Hence, the significant variations in wall thickness and speed of sound inside the material can be readily accounted for, a prerequisite for detection of defects close to the back wall surface, which is not provided by gate based acquisition systems.

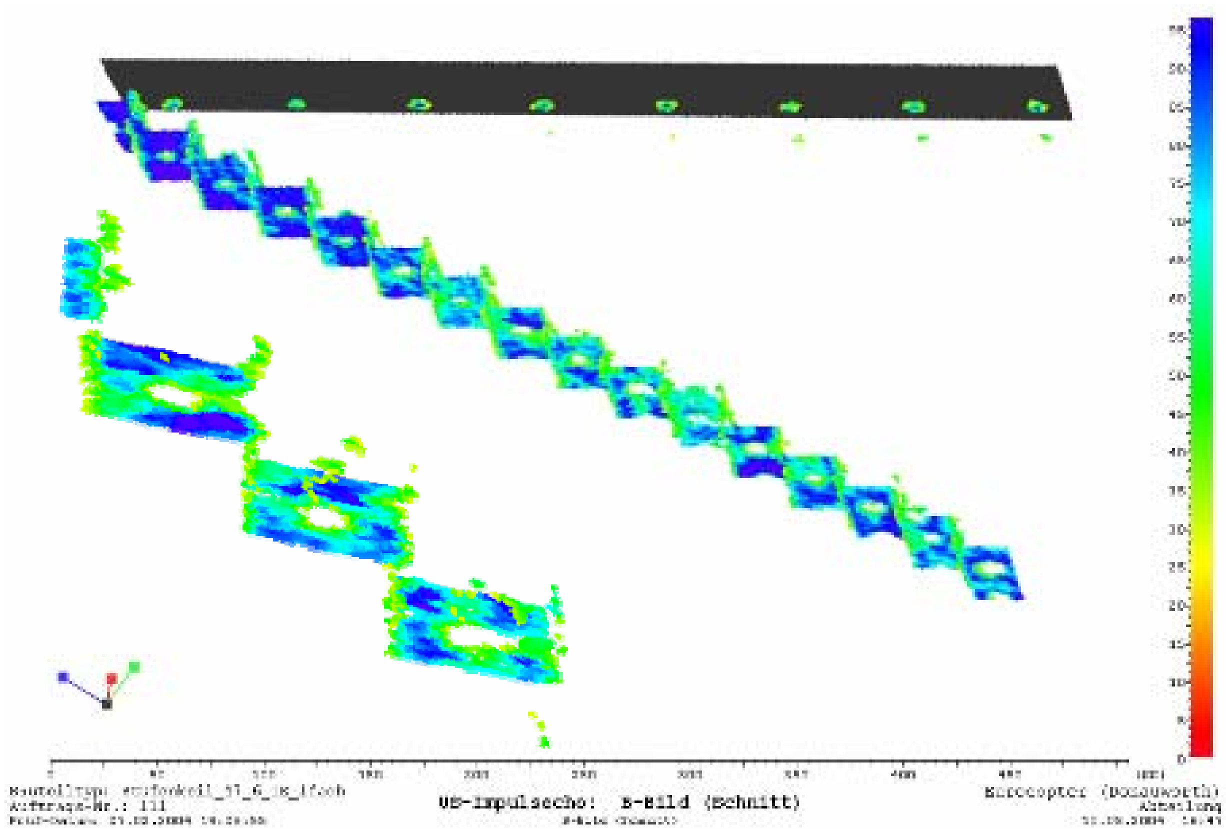

Bild 5: Step wedge: Defects close to the inspection surface and the back wall, with structural noise suppressed. Left bottom a close up of the back wall with a near defect and shadowing

A general limitation of gate based systems is as follows: Due to considerable fluctuations in wall thickness and speed of sound inside the inspected material setting gates for data evaluation induces areas of reduced or prevented inspectability close to the part surfaces. Dynamic gate control does not satisfactorily solve this matter, as no possible algorithm can discriminate between intentional and accidental change in time of flight. But this would in fact be necessary for gate based systems, as both back walls and defects with equal time of flight may occur inside one CFRP part.

In contrast to this, in the SAPHIR*Plus* UT instrument the full A Scan is digitised and can be processed in many different manners. The most effective algorithm can be configured to extract all relevant amplitudes and discard the rest, allowing to store the relevant information at acceptable speed and data volume. Hence, all relevant information is available for post processing and display, applying intelligent algorithms.

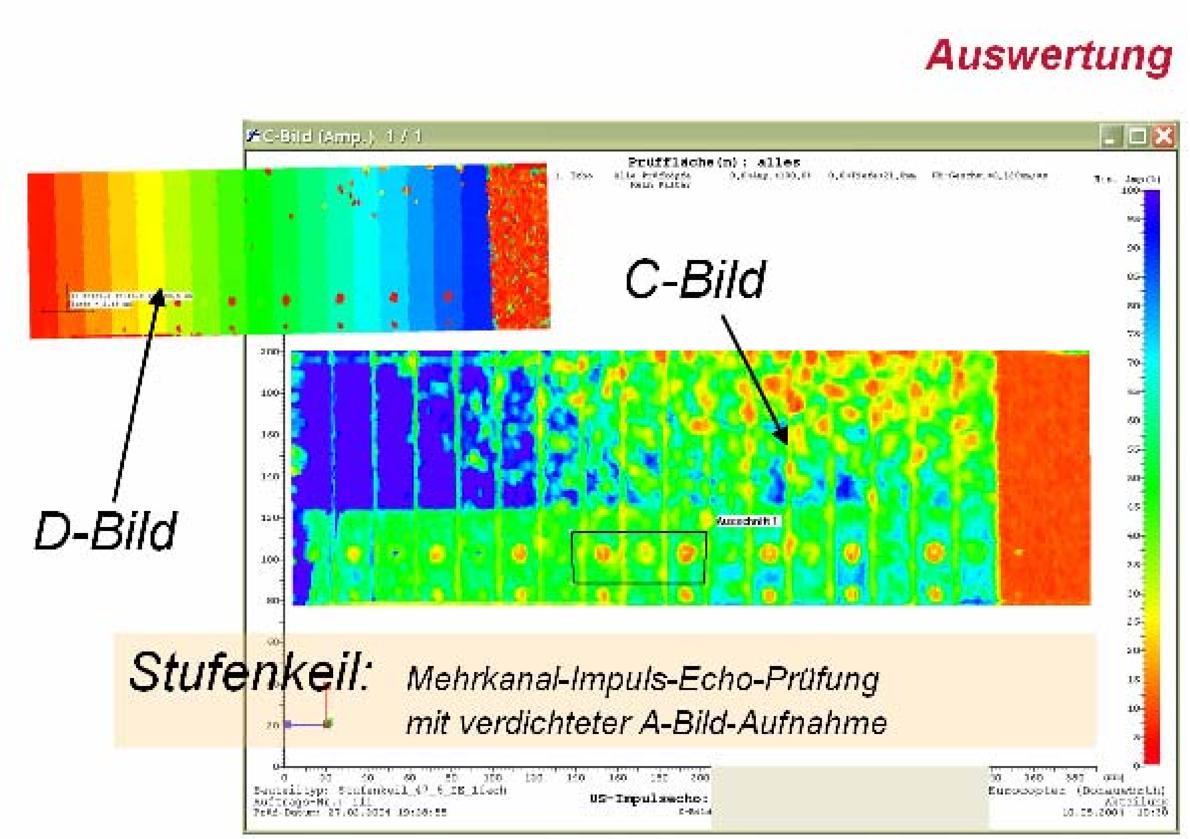

Bild 6: C scan and D scan of a Step wedge with artificial defects and areas of increased porosity