Phased Array Application in Industrial Scanning Systems

Albrecht MAURER, Wolfgang HAASE, Walter DE ODORICO, GE Inspection Technologies, Alzenau, Germany

Abstract. In conjunction with the extended use of composite material in airframes, quality testing after production of the components becomes more important. Starting in the past with relatively small components like flaps, composites now are used in major structural parts. With the extended application of composite for aircraft parts, productivity, integration into the production process, and ease of use become a major issue in testing. The present paper deals with the latest improvements in this process with the following highlights:
- integration of the parallel B-scan phased array technology for high-speed and advanced detect ability
- reverse phasing for complex curvature testing
- automated multiple part testing (batch scan- capabilities)
- automated evaluation
- automated test data storage
The above new features are integrated in a variety of production test systems applying squirter, contact, and immersion technique. The systems and the results are presented.

Introduction

With the design of new commercial aircraft, advanced materials tend to replace more and more metallic structure of aircraft. The components are composed from lightweight and high strength fibres like Glass, Kevlar, and Carbon as well as fibre-honeycomb structures. All components are designed by bonding multiple layers of composite fabrics. The bonding quality is vital to the designed strength of the components and needs to be non-destructively tested. The current paper describes the application of Phased-Array-Technology for productive and reliable test of advanced aircraft components.

Parallel B-Scan Inspection

1.1 Basic Principle

Parallel B- scan is an Ultrasonic Detection Method by use of a Phased Array Probe with a number of elements being larger than the Ultrasonic Aperture of an individual synthetic probe. In the current case, 128 element arrays are used. All elements are fired at the same time in phased or non-phased mode. The returned signals are also detected at the same time and are immediately digitized, so that a real time B- scan can be displayed. In order to
obtain a result, which is not affected by edge effects, additional elements can be added which are used only in transmission, not in detection.

1.2 Advantage of Parallel B-scan over conventional Phased Array Test

The major advantage of the Parallel B-scan technique over conventional techniques is, that, due to its wide aperture, it receives signals from both pitch/catch and dual element (V-reflection) at the same time. The advantage of this feature is, that, beyond its high aperture and thus high inspection speed, it is a very “robust” and forgiving method due to its capability to supply results even under difficult inspection conditions.

1.2 Results on real parts

In the below B-scan, a parallel CFC reference plate was tested with a slope of 15° between the probe array and the part itself. In spite of this strong mismatch, front- and backwall as well as a delamination in the center are clearly visible.
The following picture shows a B-Scan result taken from a real composite part with integrated reference flaws. This part has both curved front and back surfaces and has been scanned, in spite of its complexity, by a simple linear scan, and without having to set up complex phasing algorithms.

The same part is shown in the next picture in a C-scan view. The part has a round shape with changing thickness.
1.3 Automated Sound Field adaptation (reverse phasing)

In case of higher complexity of parts, parallel B-scan will lead to a reduced coverage, as reflected beams will not hit the probe within its aperture. In this case, a self-learning phasing scheme adapted to the actual surface of the part will be applied. The principle is explained in the following figures 6 to 8:
Fig 6 shows the basic shape of a complex stringer. The resulting B-scan is shown in figure 7.

Due to the strong curvature of the part, the interpretation of the results is limited, as only a fraction of the sound will hit the sound in the outer sections. In order to obtain a better quantitative result, the phasing scheme will be adapted to the actual surface.

This technology has two major advantages in automated testing:
- high coverage even in curved part sections
- the same probe can be used for both flat and curved area test.

The two following C-scans compare scans of a 90° bent section in parallel B-scan technique as well as in reversed phasing technique

Fig 9: C-scan of a 90° angled part with integrated reflectors, taken in parallel B-scan technique. The blue background area represents a sector of 5° with valid evaluation conditions

Fig 10: The same sample tested in reverse phasing technique. The scan represents valid data over the full aperture.

1.4 Wide area through transmission with PA-squirters

The technological advantage of the phased array technology is not limited to pulse-echo technology, but can also be applied to through-transmission in immersion or squirter technique. The following picture shows equipment with a phased array squirter system. The squirter nozzles are shaped to grant an oval outlet of the water jet. The system has a useful coverage of 12 mm and has thus about 10 times higher throughput compared to a single probe squirter system.
The corresponding comparative results between a single element scan and a Phased Array scan are shown in the following pictures:

Number of scan lines for full part coverage: 280 (single channel) and 19 (Phased Array).
Batch Scan

In order to automate and reduce the inspection time, multiple parts can be mounted in the scanning area and then the whole scan can be performed automated without operator inspection. Each part will be scanned with its individual scan plan and ultrasonic setup. This feature drastically reduces cycle times of automated scanners. The enclosed screen shot shows a table with multiple parts being summarized in a table for batch execution.

![Batch scan setup with three scan parts in a batch](image1)

Equipment delivered

In the following, equipment in operation is presented. All equipment has been designed according to individual needs of Aircraft Manufacturers.

![Dual Bridge Robotic Squirter System](image2)
Fig 14: Single Bridge robotic equipment, total view and squirter detail

Fig 16: Four Squirter Fuselage test equipment