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IT'S WHAT'S INSIDE THAT COUNTS

Mike Richardson meets with Diagnostic Sonar's chief engineer Dave Lines to discover how the company's FlawInspecta ultrasonic array system is finding increasing acceptance in ultrasonic NDT applications.

Many major aircraft OEMs now face some very unique and specific test and measurement challenges, due largely to the increasing use of carbon fibre composite materials found within the structures of civil aircraft programmes like the Airbus A350 and Boeing 787 Dreamliner.

This in turn creates a demand for the kind of inspection systems that can rapidly identify potential composite material quality issues, such as those introduced during aircraft production and those that have come as a result of barely visible impact damage (BVID) due to a bird strike or an unintentional collision with an aircraft on the ramp.

A variety of inspection methods are being employed in the aerospace industry such as phased arrays for ultrasonic non-destructive testing (NDT) applications which enable technicians to identify certain anomalies inside the composite material. However, the requirement for every part to be 100% inspected sees growing concern over the additional time and resources that will be needed to complete such tasks. It's even been said that the amount of carbon fibre



Diagnostic Sonar's FlawInspecta: Uses two PXI slots for full matrix capture and total focusing at real-time rates

composite parts Airbus and Boeing intend to produce will need 'hundreds' of extra people just to analyse the inspection data taken from the composite structures. Therefore there is a growing demand to introduce semi-automated inspection systems to identify certain anomalies and features within the data.

Established in 1975 primarily to develop real-time medical imaging solutions, Diagnostic Sonar Limited (DSL) has been designing phased arrays for ultrasonic NDT applications for over 30 years. By chance, the company was approached by British Aerospace (now BAE Systems) regarding some critical inspection issues it was experiencing with carbon fibre composite items. DSL

provided the company with one of its medical ultrasonic array systems typically being used in the obstetrics sector and with some modifications, enabled British Aerospace to conduct in-depth analysis of its carbon fibre material.

"The aerospace test and inspection sector is undergoing some unique and specific techniques where large amounts of carbon fibre composites are being used in the aircraft production process," begins DSL's chief engineer, Dave Lines. "We've collaborated with Boeing by providing our FlawInspecta hardware coupled to a mobile automated scanner and inspection system to enable Boeing's technicians to image carbon fibre parts at real-time rates. We've also been



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Acquiring the data: NI's FlexRIO card with digitiser

▶ working with companies like QinetiQ to help them examine carbon fibre-based issues like 'ply wrinkling'."

Along with its ANDSCAN mapping and analysis software, QinetiQ is using FlawInspecta's integral 3-axis position sensing hardware to analyse ply wrinkling and characterising 'out of plane' waviness. There are also issues with the residual strength of the composite material from which an NDT technician will need to decide whether to pass or fail it. Then there is the task of assessing problems like delamination, dis-bond and porosity. FlawInspecta can provide rapid data collection over the entire length of aircraft on components like wings, for example.

The problems posed by the collection and analysis of this type of inspection data are manifold and various constraints – such as high channel count and data rates – have prevented this approach until now. Not only does the technology need to see 'inside' the composite material plies and correctly interpret the image data relayed back, but the huge amount of number-crunching involved in acquiring this data can have serious repercussions in terms of additional production time – and ultimately cost.

"Aircraft OEMs are looking to perform 100% NDT inspection of all their critical carbon fibre composite parts and this involves a huge amount of raw data collected for analysis," confirms Lines. "This could potentially slow their aircraft production down so it's a huge issue. It's all very well collecting the data, and we

can provide the mechanisms for doing this rapidly so that production throughput of inspection on the aircraft isn't delayed. However, the issue then becomes one of analysis and what the technician decides they must do with the data."

For conventional imaging, steering and focusing is achieved by applying differential delays in the excitations to each element and in the received signals from each element. The delays compensate for the varying path lengths between elements and focal point, to produce constructive interference at this point.

DSL uses a technique it terms as 'full raw data' (FRD) acquisition and processing to investigate optimised steering and focusing of the composite material images. Rather than exciting a large group of elements to produce a transmit beam with well-defined focus, a much smaller group – typically just one element – is activated to produce a widely divergent sound field. Received signals from all elements are collected as usual, but rather than being delayed and combined to form the receive beam, they are stored for later processing. This is repeated for each element in turn on transmit to produce a data set of signals corresponding to all combinations of transmit and receive elements.

DSL was faced with the challenge of creating a flexible and scalable architecture for acquiring ultrasonic array data and processing it in real-time, whilst being mindful of the additional production time and processor-frying issues that the manipulation of such huge swathes of raw data this would involve.

"We were always trying to push the envelope to speed up the data acquisition process, so we migrated to using field programmable gate arrays (FPGAs)," Lines continues. "As soon as

we realised that National Instruments' (NI) acquisition systems – including its LabVIEW FPGA platform and development environment used in tandem with its FlexRIO 5752R series – was available, we knew it would be the best route to adopt.

"We're using the power and speed of LabVIEW's real-time imaging acquisition hardware and digitising products to acquire the full raw data into our FlawInspecta system. A FlexRIO 5752 32-channel digitiser adapter module performs the data acquisition as part of a flexible imaging development system for NDT applications. FlexRIO offers a different approach to a normal digitiser or oscilloscope because it provides far more flexibility for acquiring data for analysis and manipulation without compromising performance. Because it's reconfigurable, we can pull in all the raw data using a conventional beamformer as you would normally do with any traditional system, or perform full raw data processing to provide dynamic focusing on transmit and receive. One benefit is that it allows the user to steer



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Dave Lines: Chief engineer, Diagnostic Sonar

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▶ the beams retrospectively, permitting many offline operations, such as adaptive imaging, without needing to rescan.”

Lines says that if you see a feature within the composite material and want to characterise it better, you can analyse it and manipulate the orientation to help find flaws, such as when dealing with the problem of ply wrinkling.

“It is usual to have the inspection beams at right angles to the plies so that the typical defects reflect straight back and are easily seen,” he explains. “However, this inspection angle will need to change to follow the plies in curved components or the defect echo may be missed as the energy bounces in a direction away from the array. You can compensate for this if the curvature is known, but ply waviness is by definition

unplanned. FRD processing allows the beams to adapt to optimise the detection without rescanning.”

Wipe the flaw

Lines points to the aircraft wing and how its features change profile throughout its length: “If you take a phased array scanner and run it along the length of a wing section, you either have to define all the focusing laws at the beginning or be aware of the whereabouts of any delay profiles. FlawInspecta collects the full raw data, independent of any changes in delay profile, as it is moved along the wing. The user then simply changes the post-processing on the image and adapts it to focus optimally the whole way along using the same data set.”

Lines notes that one key advantage

of FlexRIO is its ability to acquire very high data rates – just over 3GB/sec even on the most basic FlexRIO board – which he says needs local buffering before streaming over the backplane.

“This results in a bottleneck as you scale it up to 64- and 128-channel systems,” he concludes. “What we’ve done is acquire the data, transfer it into the host for processing and all this is being done at about 20 frames/sec. Once debugged, this same code can then migrate into the FPGA for local processing of the images for a further speed-up. Without NI’s help we would have almost certainly needed to obtain a customised solution which would have been much harder to deploy.”

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