4.2.3. ULTRASONIC INSPECTION OF COMPOSITE AEROSPACE STRUCTURES WITH COMPLEX GEOMETRY

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The use of fibre reinforced composites in both civil and military aerospace structures is steadily increasing. A challenge is the fabrication of thick, complex shaped and highly loaded components for example in landing gear applications. Special fabrication techniques are being developed for these components, such as robotic fibre placement and the resin transfer moulding (RTM) technique. Especially the replacement of thick metal forgings of conventional design (of steel or aluminium) by composite components is attractive because they may lead to a reduction in weight or cost. This was demonstrated in several technology programmes at the NLR.

The increasing thickness and complexity of the composite structures pose special challenges to the production control of these components. For example, higher volumes of RTM material may decrease the product performance due to cure related material degradation like the formation of shrinkage defects. And complex geometry may limit the accessibility of conventional inspection techniques. The prime non-destructive inspection (NDI) technique for composite structures with complex geometry is ultrasonic testing (UT). For this purpose the NLR has a 12-axis ultrasonic C-scan facility that can inspect double curved components with both the pulse-echo and through-transmission technique (simultaneously) in both the immersion and squirter inspection mode. Complex scan profiles can be generated from CATIA or by teach-and-learn.

Fig. 1. Drag brace

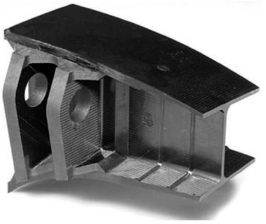

Fig. 2. Bracket spar

Fig. 3. Trailing arm

Fig. 4. 12-axis ultrasonic C-scan

Fig. 5. Ultrasonic phased array inspection

Instead of using a single transducer and beam the ultrasonic phased array technique (UT-PA) uses transducers with multiple ultrasonic elements that can each be driven independently. Different electronic time delays applied to the elements create beams that can be electronically scanned, steered and focused at different depths, thus enhancing the volumetric inspection capability of UT inspection. The UT-PA technique features real-time imaging during scanning, improved sizing of defects, and the inspection speed can be much faster than with conventional, single crystal transducers.

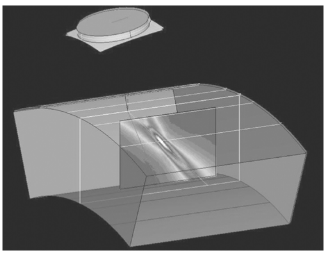

Fig. 6. CIVA ultrasonic field computation

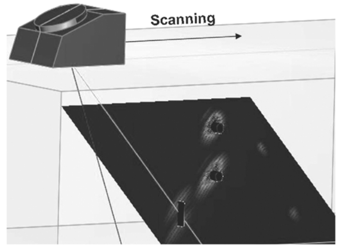

Fig. 7. CIVA simulation of flaw responses

Modelling of UT inspection can be used to give a better understanding of the underlying physics and to predict the inspection performance for parts with complex geometry. The NLR applies CIVA^{nde} software to predict and visualise the ultrasonic field within a part and to predict the interaction of this field with flaws of different types. Modelling can then be used to optimise the inspection performance by careful selection of inspection parameters such as the transducer characteristics (especially for UT-PA inspection).

In this paper the different capabilities of C-scan inspection, UT-PA inspection and CIVA modelling for composite aerospace structures with complex geometry are treated. Examples with parts of different material (thermoset, thermoplastic) containing defects of various types (both artificial and real defects such as porosity and delaminations) are given. The inspection and modelling results are discussed and recommendations for optimised inspection performance are given.