PROJECT FINAL REPORT

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1 Executive Summary

The inspection of titanium billets for use in the manufacture of components such as engine turbine blades is of particular interest in the field of aerospace non-destructive evaluation (NDE). This stems from the risk of component failure, induced by material defects in safety-critical components, with the potential for catastrophic consequences. Existing inspection systems can meet the prevailing requirements of production controls in terms of sensitivity to a minimum defect size. However, the increasing demand on the performance of jet engines has created a need to inspect more thoroughly and detect ever smaller defects. In addition, there is a distinct economic advantage in reducing the costs associated with manufacture and inspection. A drive now exists to develop advanced and reliable inspection technologies that support a defined specification for defect inspection, while minimising costs.

Current production billet inspection systems are either ‘conventional’, using a single ultrasound transducer, or ‘multizone inspection’ (MZI), using a number of strategically positioned transducers to focus the ultrasonic beam at various depths in the material. The current approach relies on an ultrasonic transducer scanning across the surface of the component. This inspection technique takes place in a water-filled immersion tank, which provides an efficient ultrasonic medium between component and transducer. Conventional inspection systems achieve relatively low sensitivity, particularly on large diameter billets, whereas MZI achieves higher sensitivity but exhibits large variations in response. These variations are attributed to the setup of the individual probes within the system and misalignment of the system with respect to the centre of the billet. The challenge faced in detecting smaller defects is to increase the sensitivity while overcoming the variation due to misalignment.

Previous work has demonstrated that phased-array ultrasonic probes (PAUT) can better, or equal, the sensitivity achieved by MZI systems. The application of PAUT enables the steering and focus of the ultrasonic beam, offering advantages over conventional inspection techniques. The advantages include the inspection of larger areas without moving the probe while minimising the size of the beam spot, which enhances inspection sensitivity.

Therefore, a PAUT probe, generating a number of ultrasonic sound beams that are designed to correct potential misalignments of the probe, can be introduced almost simultaneously at each sampling point on the billet. However, this approach does not automatically overcome the material losses due to the ultrasonic dead zone. This region receives unformed and incoherent acoustic energy, which results in a certain amount of material depth being uninspected. An automated system that overcomes this loss, while maintaining the tighter specification for defect inspection in titanium billets, is a solution that is not currently available in the titanium billet manufacturing industry. The development of an automated system to address the challenges has been carried out by a European part-funded consortium called QualiTi. Comprising several European companies and research institutes, the consortium is developing an integrated solution that brings together two complementary NDT techniques.

1.1 Concept design

A 2D Annular-Segmented Phased Array with Dual Concavity (ASDC) has been manufactured, which detects defects within the volume of the billet, employing beam steering to correct for variations in flaw response caused by misalignments. The ASDC system implements a 255 piezoelectric transducer elements array and has a centre frequency of 5MHz. The probe has an elliptic shape with a long axis of 98mm and a short axis of 78mm, delivering a constant 2.5mm diameter beam spot at all inspection depths.

To overcome the ultrasonic dead zone, a complementary multicoil eddy current (EC) inspection probe will detect surface and sub-surface flaws. The EC probe implements a novel configuration of five coils, which, when working in combination, can detect defects in any orientation. Combining the ASDC and EC inspection techniques in tandem, helps to attain 100% inspection coverage of the titanium billet.