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QualiTi

A COLLABORATIVE EUROPEAN PROJECT

developing a novel quality control system for inspecting titanium components in the aerospace industry

DR HARSHAD VIRJI PATEL

highlights how the project will stimulate and improve competition among SMEs

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QualiTi assurances

Based at TWI NDT Validation Centre (Wales, UK), **Dr Harshad Virji Patel** is leading the QualiTi programme, a collaborative European project which is developing a new system to inspect titanium billets used in critical aeroengine component manufacturing. Here, he highlights how the project will stimulate and improve competition among SMEs operating in the aerospace industry

Could you tell us a little about the focus and context of QualiTi and the TWI NDT Validation Centre (Wales)?

The QualiTi project focuses on the inspection of titanium, which is a strong but relatively light material, widely used in the manufacture of safety critical components for the aerospace industry. The manufacturing process of titanium billets can produce sub-surface defects that are particularly difficult to detect during the early stages of the production. There have been a number of aircraft incidents in the past, including the crash of flight UA232 at Sioux City, Iowa in July 1989 with 111 fatalities, which have been attributed to such defects and resulted in tragic loss of life.

TWI NDT Validation centre's mission is to deliver world-class services in non-destructive testing (NDT), joining materials, engineering and allied technologies to meet the needs of a global membership and its associated community. For many years, the development of NDT techniques has been a major part of the centre's business. Activities at the Centre include the development of advanced inspection technologies, research into applications of conventional and novel inspection methods, and practical inspection work. Consultancy services, such as Level III support, troubleshooting, advice on applications and procedure development/ approval are also available from the Validation Centre.

What are the problems with – or limitations of – the reliability and consistency in current inspection systems for titanium components?

Titanium alloys strongly attenuate acoustic waves, making ultrasonic inspection very difficult. Current ultrasonic inspection systems are either classed as 'conventional', using single transducers, or multizone inspection (MZI), using a number of transducers focused at different depths in the material. The conventional systems achieve relatively low sensitivity, especially on large diameter billets. Whilst MZI achieves higher sensitivity than the conventional method, due to the fact that each transducer focuses the beam at specific zones in the material, independent studies have shown that large variations in response can occur when using the MZI method.

What solutions is QualiTi developing?

QualiTi is developing a new and novel automated quality control system for the inspection of titanium billets that combines phased array ultrasonics (PA) and eddy current (EC) technology. Previous studies have shown PA to be capable of achieving the same or better sensitivity than MZI, and overcoming the issues with response variation. In addition, the entire depth range of the billet will be inspected with only one transducer, making the alignment of the PA probe much easier. The EC system will aim at covering the near surface 'dead zone' – a 5mm margin beneath the surface of the billet – which is inherent to ultrasonic inspection techniques. As an integrated system, QualiTi will detect defects much earlier in the production process and will significantly reduce the likelihood of defective parts entering service.

How important has an interdisciplinary and collaborative approach been to the project?

An interdisciplinary approach is very important as the project requires specialist knowledge of EC and PA ultrasonics. Combining these two inspection techniques provides 100 per cent inspection coverage of the titanium billet – a major success of QualiTi. As well as being central to technological development, partnership and collaboration is important to the project in a much wider sense, involving SMEs (Vermon, Tecnitest, I.S.O.Test), RTDs (Validation Centre, West Pomeranian University of Technology) and end users (TIMET).

What might be the positive economic and ecological implications of the QualiTi project and the new inspection system?

European SMEs in the field of non-destructive testing (NDT) do not have the technological capability to reliably test titanium materials and, as a result, risk losing competitiveness in this global market worth 600 million euros. Titanium is an important material in many leading industries, including aerospace, but in-service failures cause loss of life and significant commercial damage through loss of public confidence. By outsourcing the research, and developing new intellectual property (including revolutionary new sensors), the SMEs collaborating within QualiTi will become more competitive and increase their share of the global market. Moreover, more accurate inspection techniques will allow aircraft manufacturers to increase the amount of titanium used in aircrafts and hence increase fuel burn efficiency.

Improving inspections where it matters

Titanium has become an essential material in aerospace engineering, but manufacturing processes can produce sub-surface defects, which, if undetected, can have catastrophic consequences. QualiTi brings together SMEs and RTDs to develop more effective inspection technologies

TITANIUM IS A relatively new engineering material: it was discovered in the late nineteenth century, much later than other commonly used materials, and was not used in commercial applications until the late 1940s. Since the introduction of titanium and titanium alloys, these materials have, in a relatively short time, become the backbone materials for a wide range of industries. Because of titanium's excellent corrosion resistance, it is used for chemical processing, desalination, power generation equipment and prosthetic devices. Its high strength-to-weight ratio and ability to withstand extreme temperatures makes it especially well suited to Structurally Significant Item (SSI) applications in aerospace engineering.

CALCULATING RISKS

Such SSI components originate from the initial manufacture of a titanium billet, a circular solid bar of up to 400mm in diameter and several metres in length. The manufacturing process may produce sub-surface defects that are particularly difficult to detect at the stage of production. Failure to detect these incipient defects can lead to subsequent in-service failure, the consequences of which can be disastrous. One such catastrophe was the crash of flight UA 232 in 1989, which resulted in 111 fatalities and was due to a titanium engine disc failure. The cause of this disaster was directly attributable to metallurgical defects not detected during the manufacturing process, and whilst it is the most well-known of such incidents it is by no means the only one. Indeed, the current level of service failures indicates that detection methods are still inadequate, with low sensitivity, low repeatability, high cost and high intrusion on the production process.

It is to this situation that Dr Patel's project – 'Development of New and Novel Quality Control System for the Inspection of Titanium Components in Safety Critical Applications in the Aerospace Industry' – responds. Appropriately abbreviated to 'QualiTi', the project addresses the obvious and urgent need to develop improved and advanced NDT technologies for application during the manufacture of titanium destined for aircraft components. QualiTi brings together partners from across Europe to develop a new and novel NDT system to fully inspect titanium billets using combined phased array ultrasonic and eddy current technology. The system employs sensors applied by an automated system, minimising the use of manual inspections and therefore improving reliability and reducing waste.

The QualiTi system employs phased array (PA) technology as an alternative to the conventional, multizone inspection ultrasonics which are currently used. The PA ultrasound inspection system is being developed at the TWI NDT Validation Centre (Wales), UK. A phased array probe has been designed with the aid of Acoustic Ideas Inc. Probe Designer software, and has been manufactured by Vermon SA, France. The probe uses a total of 255 elements (figure 1) and has an ultrasonic centre frequency of 5MHz. The design uses a customised contour represented by a fifth order set of cosine basis functions. The probe is an elliptic shape with a long axis of 98mm and a short axis of 78mm. It has been designed to deliver a 2.5mm diameter beam spot at all inspection depths from just beyond the blind zone (5mm) to half an inch past the centre of the 10" billet (139mm from the surface) (figure 2).

The benefits of using state-of-the-art phased array technology over conventional UT stems from its ability to use multiple elements to steer, focus and scan beams with a single transducer assembly. Beam steering, commonly referred to as sectorial scanning, can be used for mapping components at appropriate angles, which can greatly simplify the inspection of components with complex geometries. The small footprint of the transducer, and the ability to sweep the beam without moving the probe, also aids inspection of components in situations where there is limited access for mechanical scanning. The ability to test materials with multiple angles from a single probe greatly increases the probability of detection of anomalies. Electronic focusing permits optimising the beam shape and size at the expected defect location, thus further optimising probability of detection. The ability to focus at multiple depths also improves the ability for sizing critical defects in volumetric inspections.

COMBINING FORCES

With ultrasonic testing (UT) inspection, the strong interface echo from the front face of the billet makes it impossible to reliably detect defects near the surface; the interface echo creating a blind zone of approximately 5mm at the edge of the billet. QualiTi has developed an innovative solution to this problem, as Patel explains: "We employ a complementary eddy current inspection system using a hybrid probe of 5 coils, which has been developed at West Pomeranian University of Technology, Poland". This complementary inspection system is able to inspect the titanium within 5mm of the

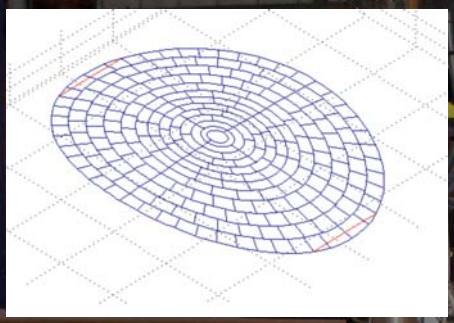

FIGURE 1. 255-ELEMENT 3D PHASED ARRAY ULTRASONIC PROBE

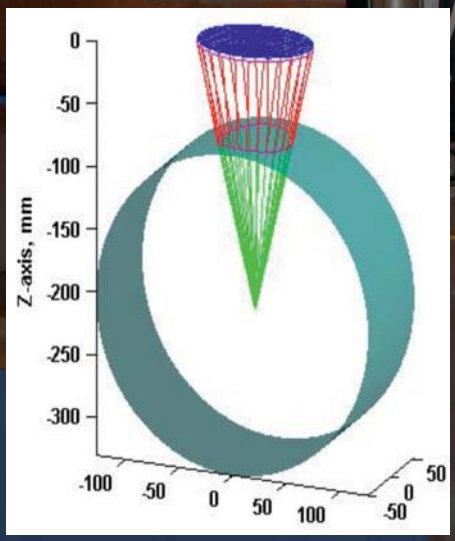

FIGURE 2. PA PROBE FOCUSING AT A DEPTH OF 139MM IN A TITANIUM BILLET

FIGURE 3. UNIBIG EDDY CURRENT TRANSDUCER

QualiTi brings together partners from across Europe to develop a new and novel NDT system to fully inspect titanium billets using 3D phased array ultrasonics and eddy current technology

surface, which, when combined with PA, ensures complete inspection coverage.

A COLLABORATIVE AND OUTWARD-LOOKING APPROACH

QualiTi is funded in part by the European Commission under the Research for the Benefit of Small to Medium Enterprises programme. SMEs represent 99 per cent of all enterprises in Europe, contribute more than two thirds of European GDP and provide 75 million jobs in the private sector. They are therefore key to the implementation of the renewed Lisbon strategy for economic growth and employment. The EC programme aims to help SMEs outsource research, increase their research efforts, extend their networks, better exploit research results and acquire technological know-how, bridging the gap between research and innovation. An important aspect of all EC-funded projects is the dissemination and exploitation of the results and this is certainly true for QualiTi. For SMEs to benefit from the research and development undertaken within the project, all participants are required to commit to dissemination activities. These have included the creation of a project website in 2008, the publication of peer-reviewed scientific papers, presentations of the project to industry conferences and a planned video for further internet dissemination.

SECURING A FUTURE FOR EUROPEAN SMES

QualiTi has undertaken important research and development work with its partners, and made some very valuable advancements in inspection technologies and the development of a more integrated and accurate system of inspection for titanium billets. They hope by the end of the project to have a number of products commercially available through their SME partners: 3D beam steerable ultrasonic phased array sensor and calibration surface; an Eddy current inspection sensor and system; and the QualiTi integrated titanium inspection system (figure 4), useable and saleable by all partners. This is a considerable accomplishment and a remarkable model of what collaborative research can achieve. QualiTi goes to show just how effectively small groups of innovative SMEs and their RTD partners can solve technological problems and produce outcomes that will make them more competitive in the global marketplace.

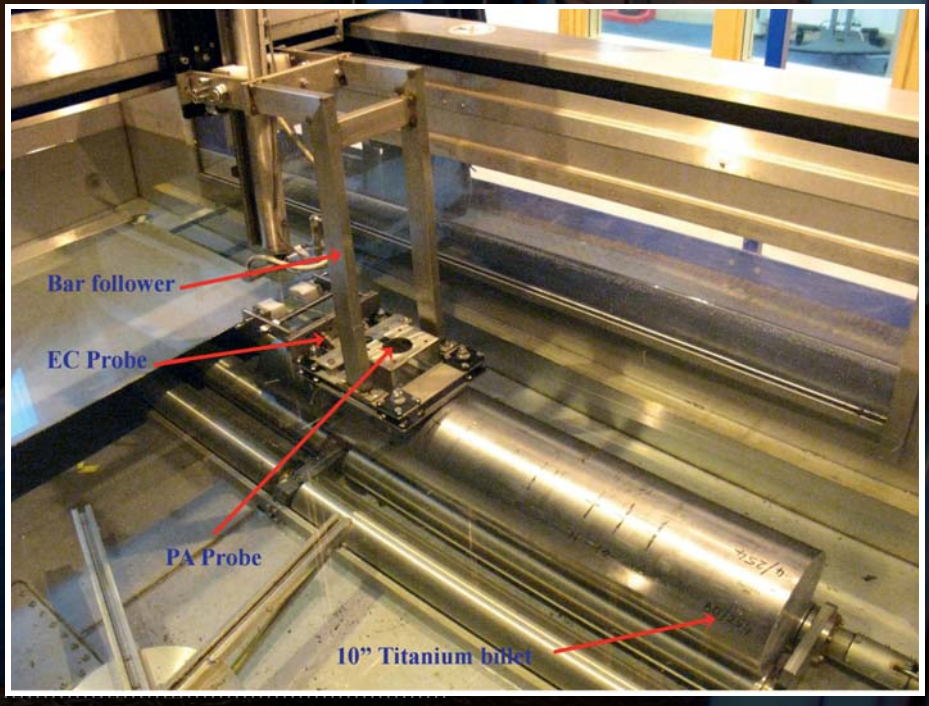

FIGURE 4. QUALITI INSPECTION SYSTEM

INTELLIGENCE

QUALITI

DEVELOPMENT OF NEW AND NOVEL QUALITY CONTROL SYSTEM FOR THE INSPECTION OF TITANIUM COMPONENTS IN SAFETY CRITICAL APPLICATIONS IN THE AEROSPACE INDUSTRY

OBJECTIVES

QualiTi seeks to develop the world's first highly sensitive combined phased array and eddy current inspection system. This will be capable of reliably and consistently detecting all of the defect types introduced during the titanium billet production process, and will increase the accuracy and probability of detection.

PARTNERS

TWI NDT Validation Centre, Wales (coordinating institute)
West Pomeranian University of Technology (ZUT), Poland
TIMET, UK
Vermon, France
TECNITEST, Spain
I.SO. Test, Italy

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DR HARSHAD VIRJI PATEL received his PhD from the School of Engineering at Cardiff University, UK in 2008. In June 2007, he joined the UK's National Physical Laboratory (NPL) as a Higher Research Scientist as part of the materials team concentrating on magnetic metrology and magnetic materials. He joined TWI NDT Validation Centre (Wales) in March 2010 as a Senior Project Leader, where he is currently working on the development of advanced NDT techniques. His current research interests deal with non-destructive testing methods, system integration and automating NDT inspection.

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