Smart aircraft

Current aircraft safety inspections can be both costly and lengthy. **Alex Haig** (TWI), **Kamer Tuncbilek** (TWI) and **Pavlos Stavrou** (Cereteth), discuss how the SelfScan project is set to improve defect detection capabilities by using embedded systems for improved long-range ultrasonic testing

ALEX HAIG

Could you begin by describing the goals of the SelfScan project?

KT: The main aim of the project is to develop a guided-wave based monitoring system for critical aircraft components without the need to dismantle during every scheduled inspection. The purpose is to detect cracks and measure their growth on the frames and fittings within aircraft. The project will develop an advanced integrated system for structural health monitoring (SHM) and impending failure detection for aircraft components.

What are some of the limitations in current monitoring techniques? How do you hope to alleviate these issues?

KT: Structural components in an aircraft are required to undergo periodic maintenance procedures. Present detection methods include visual and thorough ultrasonic inspections. Since the area that needs to be inspected is large and complex (with stiffeners and rivets), careful examination of these components translate into long downtime hours for airline operators. Through SelfScan, the consortium aims to apply ultrasonic guided wave technology. Guided wave sensors can send low frequency signals which can travel further along the component. Reflections are generated from features such as cracks and can be picked up at multiple locations. Therefore, in a monitoring scheme, where such sensors are permanently attached to the component, the changes in signal can indicate growth of defects and, consequently, their timely detection.

For those who are unfamiliar, what are neural networks, and can you offer some insight into their application?

PS: Neural networks are employed in a vast range of applications where classification is needed. In the SelfScan project we have to primarily classify specimen as defective or defect-free utilising the acquired line replacement unit (LRU) measurements from the inspection system. Since the acquired signals are complex in this scenario and one cannot reach a decision by simply examining the visual representation of the signal, the need to build a statistical model over the LRU measurements arises.

What role do SMEs play in this project? How is their contribution mutually beneficial?

KT: SME partners in this project form a supply chain that includes SMEs that manufacture non-destructive testing (NDT) instrumentation for in-service aircraft inspection and monitoring, supply monitoring software for the NDT aerospace sector and provide NDT services to the aerospace companies in Europe. The project will help the SMEs to increase their market share in the aerospace inspection sector. It is expected that the project will create new EU employment opportunities through new spin-off SMEs formed to exploit the results.

What progress has the project made to date, and have you encountered any surprising or notable findings?

AH: To date, ultrasonic guided waves have been studied in riveted sheet and thick structural aluminium aircraft components. Finite element modelling has been used to evaluate the complexity of the waves in these complex structures. Approaches to testing have been devised and evaluated. Initially the aim was to work at relatively low ultrasonic frequencies (approximately below 200 kHz), as this reduces the complexity of the signals. However, the research has shown that high frequency is necessary to achieve required sensitivity to small cracks.

A neural network solution has been developed. Experimental data is being gathered for a number of samples over a range of environmental conditions. During this process defects will be introduced. This data will be used both to train and trial the neural network's ability to classify healthy and defective components.

How do you propose to test your new system? How will you ensure that its results are accurate and reliable?

AH: Finite element modelling is being validated against experimental tests. Both modelling and experiments are used to demonstrate the interactions between ultrasonic waves and the defects of interest. An experiment, where a sample is put through accelerated fatigue, will be used to collect data from a structure as a defect is introduced. The fatigue experiment simulates the wear and tear normally experienced by such an aircraft component, and results in a realistic crack. The defect will grow in size and data is captured as this happens. This data will be processed using the developed method to demonstrate its defect-finding capability.

Revolutionising **aircraft maintenance**

The **SelfScan** project, backed by a range of SMEs and research organisations, aims to realign inspection and maintenance strategies in aircraft with a neural net based defect detection system using ultrasonic guided wave technology

THE AVIATION INDUSTRY has transformed dramatically over the past century. Advancements in aerospace engineering have taken great strides, which have led to an era where low cost airlines are possible and aviation has changed the world. Today's global market is unimaginable without the existence of aircraft, and developments in aerospace technology play a major role in driving change and engineering innovation in other fields. Yet with achievements come challenges; the social, economic and technical demand placed on aircraft designers and operators plays off against a continuously ageing fleet of aircraft requiring complex maintenance and inspections.

The periodic maintenance and inspection of aircraft is both costly and time-consuming. In April this year, the Nigerian Civil Aviation Authority grounded 18 aircraft following the discovery of structural defects of the Boeing 737-300, 400 and 500 aircraft series. The emergency inspection that ensued sought to ensure none of the aircraft operating in Nigeria contained metal fatigue and cracks known to be responsible for major disasters. Engineering design, service conditions and environment, and the construction material are but a few of the factors influencing the fatigue life of an aircraft component. As such, the maintenance of an aircraft (whether routine or due to an unscheduled event) can result in long periods of unavailability.

To alleviate the heavy demands placed on the aviation industry while keeping continued safe service, the SelfScan project was set up at the beginning of 2010. Coordinated by Kamer Tuncbilek and backed by four SME partners, one large enterprise and two strong research organisations (TWI and Cereteth), the project is developing an advanced integration system for structural health monitoring and impending failure detection for aircraft components. SelfScan is using ultrasonic guided wave technology as a technique for structural monitoring that will remove the need to dismantle critical aircraft components during every scheduled inspection, and detect cracks and crack growth in their early stages. Such a development, demonstrated in accelerated fatigue experiments and laboratory tests on actual aircraft components, will enable a fundamental realignment of inspection and maintenance strategies. It will also facilitate direct economic benefits for aircraft manufacturers and operators, insurance companies and the general public.

> The investment in this project will benefit the consortium members, aircraft manufacturers and operators, insurance companies and the general public

SIGNALLING A CHANGE

The critical structural components of an aircraft need careful examination as small cracks can appear in large and complex structures. In some cases, the defects are hidden beneath layers of other attachments, so accessing these components involves dismantling the assembly and long downtime hours for airline operators. The current detection methods applied to aircraft include visual inspection and short range ultrasonic inspection, and it is this that SelfScan aims to modernise. Through SelfScan, the consortium is developing an integrated system to monitor the condition of aircraft components – specifically on the radius of frames and fittings – using integrated transducer arrays for improved long range ultrasonic testing (LRUT). In this monitoring scheme, specific transducers are permanently bonded to aircraft components, sending low frequency signals further along the component. Data from these Long Range Ultrasonic (LRU) sensor arrays can later be analysed to detect the size and location of the flaws in the aircraft, without the need to dismantle the structure.

Transducers are highly sensitive and so many factors can initiate minute changes in the signals received. Neural networks are thus employed by the project team to separate and detect which signals are caused by defect initiation and subsequent growth, and those that are caused by other, unrelated factors. In a monitoring-

type system, neural networks are used for data interpretation and defect classification and, as Pavlos Stavrou (Neural Network specialist at Cereteth) explains, the project team use neural networks to build a statistical model over the LRU measurements: "In essence, the neural network allows us to rapidly analyse statistical properties of LRU measurements and provide an insight as to what differentiates the defective from non-defective signals. That is quantified in the form of input/output neurons, transfer functions, weights and hidden neuron layers, thus resulting in a fast and accurate detection system," he explains. The SelfScan team therefore derives features from the acquired signal; these provide the strongest discriminative ability between defective and defect-free samples.

TRANSDUCERS TO COVER ALL BASES

The SelfScan project takes an integrated approach to transform the inspection and maintenance strategies in aircraft. However, challenges have arisen for the SelfScan consortium; notably, the specific components being studied have a number of features that can scatter the ultrasonic guided waves. While the solution lies in developing a method with fewer sensors, this in itself leads to less control over the ultrasonics and can result in complex signals that are difficult to interpret. Moreover, structural health monitoring is based on an analysis of the signal changes that transducers send over time, so the consortium were tasked with developing a novel and flexible single sensor type with desirable ultrasonic control that can be stable over that period of time. Alex Haig, Project Leader at TWI, describes how the transducers were selected for specific reasons: "A selection of transducers have been chosen for use with either thin aluminium 'skin' components or for thick aluminium structural components. Methods of encapsulating the devices to protect them from a range of environmental conditions are also being developed for preserving them for long-term stability," he comments.

As such, it is clear the SelfScan project addresses some of the major challenges facing aircraft operators and designers in strategies of inspection and maintenance. By providing 100 per cent coverage of the object under inspection with only a limited number of sensors, the project team will be able to prevent the unnecessary interruption of a plane's journey. Consequently, the research will be advantageous to a host of stakeholders. "The investment in this project will facilitate direct economic benefits to Europe after project completion. It will benefit the consortium members, aircraft manufacturers and operators, insurance companies and the general public," Tuncbilek enthuses. The research could also assist other industries because the technology used will result in increased product reliability and therefore increased market opportunity for potential applications. It could thus cross over into such sectors as oil, gas and nuclear power generation.

INTELLIGENCE

SELFSCAN

NEURAL NET BASED DEFECT DETECTION SYSTEM USING GUIDED WAVES TECHNOLOGY FOR AIRCRAFT STRUCTURE MONITORING

OBJECTIVES

The project will develop an advanced integrated system for real-time, in-flight SHM and impending failure detection for aircraft components. This will enable a fundametal realignment of inspection/maintenance strategies, which can then be based on the actual momentary condition of the aircraft structure.

FUNDING

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PARTNERS

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NDT-Expert, France

CONTACT

Kamer Tuncbilek
Project Coordinator

TWI Ltd
Granta Park
Great Abington
Cambridge
CB21 6AL
UK

T +44 1223 899000
E kamer.tuncbilek@twi.co.uk

Alex Haig
Technical Consultant

T +44 1223 899000
E alex.haig@twi.co.uk

www.selfscanproject.eu

SEVENTH FRAMEWORK PROGRAMME

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