Neural Net based defect detection system using guided waves technology for aircraft structure monitoring

www.selfscanproject.eu

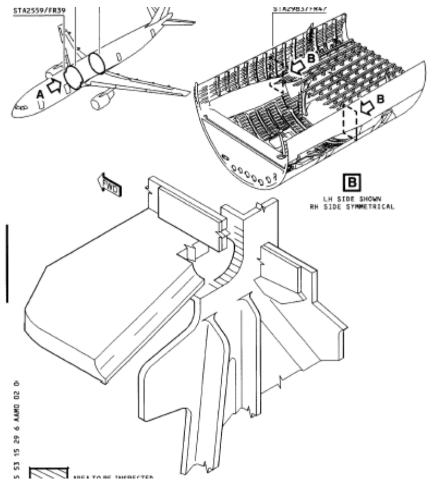
Project Goals

The project will develop an advanced integrated system for structural health monitoring (SHM) and impending failure detection for aircraft components. This will enable a fundamental realignment of inspection/maintenance strategies, which can then be based on the actual momentary condition of the aircraft structure. The capability of the developed system will be demonstrated in laboratory tests on actual aircraft components.

Guided wave technology is a promising technique for structural monitoring in that it provides large area coverage from a limited number of sensors, combined with potentially high defect detection sensitivity. However, due to the effects of dispersion of the ultrasound and to the complex non-constant geometry of the object under inspection and to the changing conditions (loading, temperature etc.), the interpretation of signals can be very complicated.

The change of a signal with time can be detected at much lower signal to noise ratios than 'absolute' signal amplitude especially when deploying a neural network in the signal processing routine. The enhanced sensitivity of our proposed monitoring technique rests in this fact.

The main aim of the project is to develop guided-waves based monitoring system for critical aircraft components without the need to dismantle during every scheduled inspection. The purpose is to detect of crack and crack growth on the radius of frames and fittings.



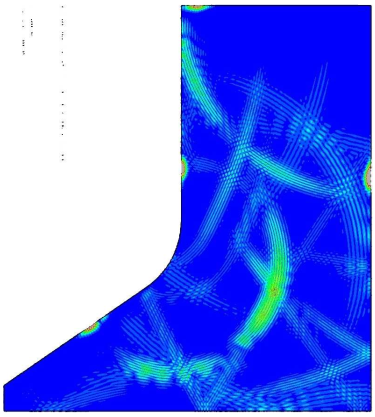
Location of critical parts in an aircraft

Achievements in the first year

The project consortium has identified two specific cases where the application of guided wave technology would be most beneficial.

Case 1: Cracks on radius of wing to fuselage fittings

Crack monitoring in frames is an expensive procedure as it requires frequent immobilisations for flight operators. For instance, Airbus recommends repair if the crack is deeper than 30 mm. The repair costs about 1.5 million Euros, takes 3,600 man-hours and 6 weeks of time. To be able to postpone a repair, an airline has to be prepared to stop the aircraft for classical NDE inspections more than once per month. For an airline, the possibility of aircraft availability until the repair is absolutely necessary (50mm) is appealing. The minimum detection target of 5 mm crack has been defined in the project. If achieved, such a system could reduce the number of immobilisations considerably.



Sound reflections in the wing to fuselage fitting

Selfscan consortium identified this case as one of the most critical problems within the aircraft industry which a guided wave technology based system could solve. In the first year of the project, simplified geometries representative of the actual component were procured to conduct guided-wave efficiency tests. Guided-wave technology based inspection is based on the understanding of the reflections received from an insonified sample. Since, the geometries are complex; it is not feasible for an operator to classify the signals. This has been shown through experiments at TWI and corresponding modelling work by Cereteth. Researchers at Cereteth are exploring the application of advanced neural network algorithms, which are common in many areas of science, in classifying complicated sound signals.

A neural network based classification system uses computational tools to identify parameters in a system which get affected by structural changes, such as growth of a defect. To establish the correlation between these parameters, a neural network has to be trained with realistic datasets covering all possible scenarios. These datasets are being generated by long-term tests on the representative sample.

Stringers in a fuselage

Case 2: Detection of frame/stringer rupture

Unscheduled events like impacts can generate maintenance tasks that require long periods of aircraft unavailability. When the footprint of an impact is visually detected its location has to be assessed. If its position is close to a frame or a stringer a detailed NDI inspection from the inside of the aircraft may be required to estimate the integrity of the structure. Since, all stringers need to be evaluated in case of an impact event; the time/cost involved to carry out complete inspection could be huge.

End-user has provided the RTD partners with a representative sample to design arrays and analyse large sections with relatively small number of sensors. Sensor arrays have been designed along with powerful finite-element models.

This case presents challenges to be solved in the second year of the project as identifying the location of the defect amongst a huge number of rivets (possible reflectors) can be very difficult.

MFC sensor array in a lab sample to test stringer rupture

Sensor development

Selfscan project aims to monitor the life of defined components over long periods. Since, SHM technique is based on analysing the changes in the signals over a period of time, it is essential that the sensors themselves stay stable over that period. Sensor performance could be affected by changes in the atmospheric conditions, changes in the adhesive layer, etc. In the last year, most of the experiments have been performed with macro-fibre composite (MFC) transducers, but specific transducers are still being developed by Smart materials, Germany. Researchers at Cereteth have also designed encapsulation layers to protect such sensors in changing environments.

Future tasks

The consortium is developing realistic fatigue tests on the representative samples to understand the effect of crack growth on the guided wave response. This data is going to be directly useful for further training of the neural network algorithm.

New sensors are being developed which fit the exact specifications required for deployment in real aircrafts. These sensors will require special pulser-receiver capabilities which are also being developed by the consortium.

The end-goal of the project is to be able to demonstrate the application of the technology in the cases defined within the project.

Impact

By developing new and novel structural monitoring techniques which overcome these limitations by monitoring all points in an air-fame with a limited number of sensors, the consortium SMEs will access the € 205 million inspection budget of European aircraft manufacturers and operators 4 years after project completion.

Project Partners

TWI, UK
Cereteth, Greece
Smart Materials, Germany
ISOtest, Italy
Optel, Poland
NDT-Expert, France
Phillips Consultants, UK

Contact

Dr. Devashish Fuloria

Project Co-ordinator
devashish.fuloria@twi.co.uk
+44 (0)1223 899 000

The research leading to these results has received funding from the European Community's Seventh Framework Programme managed by REA-Research Executive Agency http://ec.europa.eu/research/rea ([FP7-SME-2008-1] under grant agreement no [232212].