SelfScan

Neural Net based defect detection system using Long Range Ultrasonic Testing (LRUT) technology for Aircraft Structure Health Monitoring

Summary of description of project context and objectives

The periodic maintenance and inspection of aircraft is both costly and time-consuming. 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.

Guided wave technology is a promising technique for structural monitoring. It provides large area coverage from a limited number of sensors, combined with potentially high defect detection sensitivity. However, due to the complex nature of ultrasonic guided waves, the often complex geometry of the components requiring monitoring and the variable environmental conditions they exist in, the interpretation of the captured signals can be very challenging. Within SelfScan, it has been shown that such complex signals can be used as input for a neural network system to facilitate in-situ defect detection. The main goal of the project was to develop a guided-wave and neural networks based monitoring system for critical aircraft components using permanently installed sensors to allow the testing of critical and inaccessible areas without the need to dismantle during every inspection. The detectability of defects is increased when historical data is used to identify changes over time.

The aim for the legacy of the project is to 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 has been demonstrated in laboratory tests on representative aircraft components.

Description of work performed and main results

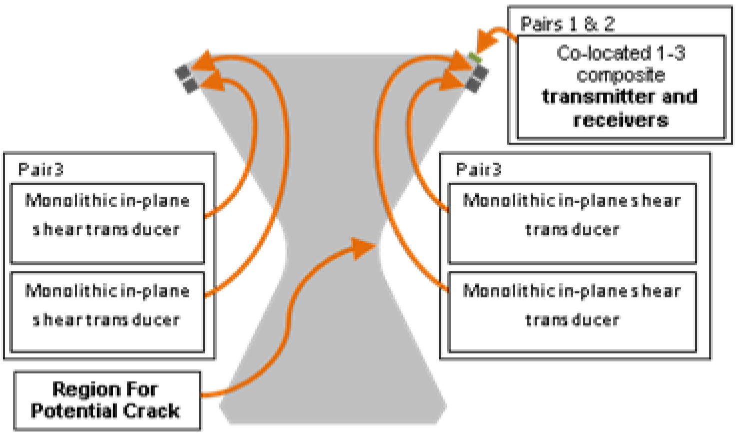
At the beginning of the project, with the advice of the end users, the consortium has identified the cases where the application of guided wave technology would be most beneficial to resolve the most critical problems within the aircraft industry.

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

Generally the approach used for inspection or monitoring with Ultrasonic Guided Waves is to establish a means of transmitting waves through a structure and receiving them after they have interacted with potential defects. The signals are interpreted to identify features of the signals that correspond to defects, and often the emphasis of the technique development is on producing a system that yields simple signals so that a human can easily see from the signals where defects occur. This often introduces a requirement for many sensors and elaborate electronics to simultaneously operate the sensors. It is also limited to structures that do not lead to very complicated signals due to their geometric complexity. In the case of many aircraft components the geometries are complex and 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.

The consortium has performed fatigue tests on the representative samples to understand the effect of crack growth on the guided wave response. This data has been useful for further training of the neural network algorithm. The SelfScan project has included experiments to monitor the life of aircraft components over long periods. Since, the monitoring 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. The use of Macro Fibre Composite (MFC) transducers, monolithic shear piezoceramic transducers and 1-3 piezocomposite transducers was evaluated for use in aircraft monitoring. Finite Element Analysis was used to evaluate the excitation of guided waves in the target structures using idealised sources, which was compared to equivalent experiments using the transducers evaluated.

Laser vibrometry and direct measurement was used and compared with the modelling work and it was found that transducers could be used to transmit and receive the ultrasonic guided waves in a suitable manner for monitoring.



A neural network classification system has been developed and demonstrated for distinguishing between healthy and defective aircraft components using data gathered from an ultrasonic guided wave based monitoring system. Experiments were conducted to produce sets of data from components that were used to evaluate the performance of a number of neural network approaches.

The performance of the neural networks were evaluated both on sets of data for fixed temperature and for mixed sets where temperature was used as a feature for input into the neural network. High accuracy of defect detection was demonstrated (100% of test signals were correctly classified) using both isolation of similar temperature data and through using temperature measurement as an input feature.

Expected final results and potential impacts

The project achieved its goal of demonstrating the application of ultrasonic guided wave based monitoring and defect detection through neural networks. Such condition monitoring has great potential to increase understanding of the structural integrity of aircraft components, increasing their service life and greatly reducing the risk of catastrophic failures.

It was presented that the developed neural network system was able to differentiate between data from defective and non-defective cases with high accuracy. It was shown that the most optimal neural network developed was able to distinguish between data from non-defective cases and those with a fatigue crack of surface length equal to or greater than 2.5mm with high accuracy in laboratory conditions. This was achieved despite the defective region being more than a few hundred millimetres from the sensor location and in a location considered inaccessible to other means of inspection.

The SelfScan project has developed an advanced integrated system for structural health monitoring (SHM) and impending failure detection for aircraft components. The project was very successful and achieved all intended objectives and it was demonstrated that defect detection could be achieved with high accuracy using the guided waves and Neural Networks.

A project website, www.selfscanproject.eu was set up at the start of the project to facilitate and act as a communication tool for the consortium. It provides an overview of the project for the dissemination of information about the SelfScan project. There are also introductions to all SelfScan consortium members with links to their respective websites. The website provides latest news about the project progress and has a feedback facility through the 'Contact us' section for public use.

SelfScan is a collaboration between the following organisations: TWI LIMITED, Przedsiebiorstwo Badawczo-Produkcyjne Optel sp.Z o.o., Phillips Consultants, Isotest Engineering s.r.l, Smart Material GmbH, Cereteth, NDT Expert.