Advances in Structural Health Monitoring for Life Assessment of Composite Airframes

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Significant advances have been made in recent years into combining Structural Health Monitoring (SHM) and smart repair technologies with a probabilistic design philosophy, and hence improve the operational safety of composite airframe. Structural health monitoring is a relatively new approach in aeronautics, however, it has advanced significantly to improve damage detection in composite structures. The basis of SHM is the application of permanent fixed sensors on the structure combined with the necessity of a minimum manual intervention to monitor the structural integrity

The talk will concentrate on the advances in ultrasonic guided wave SHM utilising PZT transducers and provide an overview of the recent work by the author and co-workers as part of the Cleansky II, SHERLOC project. Implementation of SHM systems for real structures, reducing design constraints and safety factors, rests largely on the effectiveness and cost efficiency of such systems.

The performance of SHM system should at least match that of existing non-destructive testing procedures, in addition to minimising added weight. The main challenge in detecting damage is the influence of environmental conditions (temperature, humidity, background noise etc) on the guided waves. This talk will report on the robustness of permanently mounted transducers used in airborne structural health monitoring systems, when exposed to the operational environment. Typical airliners operate in a range of conditions, hence, structural health monitoring (SHM) transducer robustness and integrity must be demonstrated for these environments. A set of extreme temperature, altitude and vibration environment test profiles are developed using the existing (RTCA)/DO-160 test methods. Commercially available transducers and manufactured versions bonded to carbon fibre reinforced polymer (CFRP) composite materials are tested.

Optimal placement of sensors/actuators in order to detect, with high probability and reliability, any damage prior to it becoming critical is a key factor in uptake of any SHM system. The interference of the sensor system with the design of composite stiffened panel is required to be minimum. On the other hand the SHM system must be able to detect various probable damage scenarios with high reliability. Therefore, optimisation analysis needs to be carried out to find the best sensor layup (number and location). The position of sensors can have a significant influence on the values of the damage index (DI). An optimal sensor placement algorithm for attaining the maximum area coverage (MAC) within a sensor network is presented. Also presented is a hierarchical methodology to quantifying uncertainties in damage detection will be presented.

A novel lightweight diagnostic film with sensors/actuators and a multiple-path wiring option using inkjet printing was developed recently as means of reducing the added weight and cost of on-board SHM system. . The diagnostic film allows for systematic, accurate, and repeatable sensor placement. Furthermore, the film is highly flexible and adaptable for placement on complex configurations. The film can be attached to the surface of the structure through a uniform secondary boundary procedure or embedded within the composite layup during curing. The surface-mounted film can simply be peeled off for repair or replacement without scratching or damaging the part. The film offers significant weight reduction compared to other available technologies.

To detect critical impact events methodology has been developed that considers soft and hard impact with different angle trajectories. A low-power high-response wireless structural health monitoring system (WSHMS) is designed, implemented, and experimentally evaluated for impact detection in composite airframes. Due to the rare, random, and transitory nature of impacts, an event-triggered mechanism is adopted for allowing the system to exhibit low power consumption when no impact occurs and high performance when triggered.

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