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Numerical Modelling and Experiment of a Composite Single-Lap Joint Reinforced by Multifunctional Thermoplastic Composite Fastener

Authors : Wenhao Li, Shijun Guo

Abstract : Carbon fibre reinforced composites are progressively replacing metal structures in modern civil aircraft. This is because composite materials have large potential of weight saving compared with metal. However, the achievement to date of weight saving in composite structure is far less than the theoretical potential due to many uncertainties in structural integrity and safety concern. Unlike the conventional metallic structure, composite components are bonded together along the joints where structural integrity is a major concern. To ensure the safety, metal fasteners are used to reinforce the composite bonded joints. One of the solutions for a significant weight saving of composite structure is to develop an effective technology of on-board Structural Health Monitoring (SHM) System. By monitoring the real-life stress status of composite structures during service, the safety margin set in the structure design can be reduced with confidence. It provides a means of safeguard to minimize the need for programmed inspections and allow for maintenance to be need-driven, rather than usage-driven. The aim of this paper is to develop smart composite joint. The key technology is a multifunctional thermoplastic composite fastener (MTCF). The MTCF will replace some of the existing metallic fasteners in the most concerned locations distributed over the aircraft composite structures to reinforce the joints and form an on-board SHM network system. Each of the MTCFs will work as a unit of the AU and AE technology. The proposed MTCF technology has been patented and developed by Prof. Guo in Cranfield University, UK in the past a few years. The manufactured MTCF has been successfully employed in the composite SLJ (Single-Lap Joint). In terms of the structure integrity, the hybrid SLJ reinforced by MTCF achieves 19.1% improvement in the ultimate failure strength in comparison to the bonded SLJ. By increasing the diameter or rearranging the lay-up sequence of MTCF, the hybrid SLJ reinforced by MTCF is able to achieve the equivalent ultimate strength as that reinforced by titanium fastener. The predicted ultimate strength in simulation is in good agreement with the test results. In terms of the structural health monitoring, a signal from the MTCF was measured well before the load of mechanical failure. This signal provides a warning of initial crack in the joint which could not be detected by the strain gauge until the final failure.

Keywords : composite single-lap joint, crack propagation, multifunctional composite fastener, structural health monitoring
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