Application and Certification of Comparative Vacuum Monitoring Sensors for In-Situ Crack Detection

Dennis Roach [1], Jeff Kollgaard [2], Steve Emery [3]
[1] FAA Airworthiness Assurance Center at Sandia National Laboratories, [2] Boeing Commercial Aircraft, [3] Structural Monitoring Systems

ABSTRACT

Current aircraft maintenance operations require personnel entry into normally-inaccessible or hazardous areas to perform mandated, nondestructive inspections. To gain access for these inspections, structure must be removed, sealant must be removed and restored, fuel cells must be vented to a safe condition, or other disassembly processes must be completed. These processes are not only time consuming but they provide the opportunity to induce damage to the structure. The use of in-situ sensors, coupled with remote interrogation, can be employed to overcome a myriad of inspection impediments stemming from accessibility limitations, complex geometries, and the location and depth of hidden damage. Furthermore, prevention of unexpected flaw growth and structural failure could be improved if on-board health monitoring systems are used to more regularly assess structural integrity. The Airworthiness Assurance NDI Validation Center (AANC) at Sandia Labs, in conjunction with Boeing, the University of Arizona, Structural Monitoring Systems, and interested airlines is currently conducting a research program to develop and validate Comparative Vacuum Monitoring (CVM) Sensors for crack detection. CVM sensors are permanently installed to monitor critical regions of a structure. The CVM sensor is based on the principle that a steady state vacuum, maintained within a small volume, is sensitive to any leakage. Vacuum monitoring is applied to small galleries that are placed adjacent to a second set of galleries maintained at atmospheric pressure. If a flaw is not present, the low vacuum remains stable at the base value. If a flaw develops, air will flow from the atmospheric galleries through the flaw to the vacuum galleries. A crack in the material beneath the sensor will allow leakage resulting in detection via a rise in the monitored pressure. The initial goal of this project is to provide Boeing Commercial Aircraft with sufficient data to place CVM sensor technology into the Nondestructive Testing Standard Practices Manual. The test specimens include those designed to simulate the Boeing aircraft lap joint and others with single crack origination sites. The test matrix studied the affects of surface coating, skin thickness, and material type on the performance of the CVM sensors. Statistical methods using one-sided tolerance intervals were employed to derive Probability of Detection (POD) levels for each of the test scenarios. The result is a series of flaw detection curves that can be used to propose CVM sensors for aircraft crack detection. Complimentary, multi-year field tests were also conducted to study the deployment and long-term operation of CVM sensors on aircraft. This paper presents the quantitative crack detection capabilities of the CVM sensor, its performance in actual flight environments, and the prospects for structural health monitoring applications on commercial aircraft.