Advanced inspection techniques for life-cycle monitoring of aerospace structures

Martin PERTERER, Uwe C. MUELLER, Horst BAIER, Institute of Lightweight Structures, Munich, Germany

Abstract. The growing number of applications of composite (CFRP) structures in the aerospace industry implicates adaptation and further development of current inspection techniques and NDT methods. During the whole product life-cycle, data has to be obtained starting with curing and testing up to operation and maintenance in order to identify, locate and evaluate damages as well as to prevent structural failure. Defects such as cracks in the CFRP fibers and matrix, delaminations, inclusions and porosity have to be detected and evaluated reliably.

To reach this goal, life-cycle monitoring using distributed Fiber Bragg Grating (FBG) sensors was investigated. Therefore, a versatile FBG strain measurement system with high strain resolution and the capacity to measure large strain was created which detects high frequency signals and allows the simultaneous measurement of strain in several channels with negligible delay time. This allows the monitoring of dynamic loads and stresses during the operation of the structure, as well as dynamic strain-based displacement field reconstruction. An application of dynamic strain-based displacement estimation was demonstrated as well as a demonstration of modal analysis up to frequencies of 1.5 kHz. Frequencies of more than 10 kHz were measured successfully allowing the use of the system for Structural Health monitoring (SHM) based on modal vibrations analysis. The theoretical maximum bandwidth of the system would be more than 100 kHz.

In addition to FBG sensors, solid waves (lamb waves) were investigated to identify and locate damages during operation using piezo-ceramic actuators acting simultaneously as transmitters and receivers. Test results of aluminum alloy and CFRP beams as well as of CFRP sandwich structures indicate that large inaccessible structures can be monitored with this technique. Significant inhomogeneity e.g. due to cutouts, inserts or stiffeners can lead to highly complex signal processing, interpretation and influences therefore strongly the number of applied actors and receivers.

As soon as changes in the structure’s behavior were identified and defects were located, external NDT methods were used to classify these defects. Thermography was applied to detect and evaluate two-dimensional defects on large aerospace structures. Investigations on honeycomb and foam sandwich structures using heat conduction thermography and pulse thermography show a high potential for detecting and evaluating face sheet delamination as well as inclusions and defects in the core material. In addition to defects caused by fatigue, investigations of barely visible impact defects on CFRP specimens were successfully carried out and verified using other NDT methods such as ultrasonic systems. Results of both techniques allow the determination of correlations between the impact energy and the defect size within the structures; especially concerning the lateral area and the depth of the damage.

Finally, the information obtained by these NDT methods was correlated with decreased matter constants and reduction ratios to evaluate the influence of the detected damages. Further research on the implementation of adapted structural models is currently being investigated.