Application of optical fiber-based strain sensing for the Full-scale static and fatigue tests of the Heron TP UAV structure

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An optical fiber based Rayleigh backscattering distributed strain sensing system was adopted as the main structural integrity monitoring tool for the IAI's HERON-TP UAV Full-Scale ultimate test. The strain signature, as measured by the optical fibers, at each loading step was recorded and analyses in real time. A human interface developed enabled easy tracking of emerging damage-related non-linear phenomena.
A total of 200 m of optical fibers were embedded and surface bonded to track all critical structural component. During the test the measured fibers were interrogated at a special resolution in the order of 1-5 cm. This optical fibers based sensing net was embedded in part during the wing and horizontal tail manufacturing and accompanied by surface bonded fibers. Such a sensing net is equivalent to thousands of conventional electrical strain gauges and was applied at a fraction of the cost. The central wing segment was equipped with fibers along both the front and rear spars at the upper and lower caps. Additionally, a second fiber was also routed around all access panels on both the upper and lower wing skins. Similarly, the booms, vertical and horizontal stabilizers were equipped too. The strain signature at each loading step was recorded and analyses in real time during the test. Typical strain signature along the wing front spar upper cap can be seen in Fig. 1.

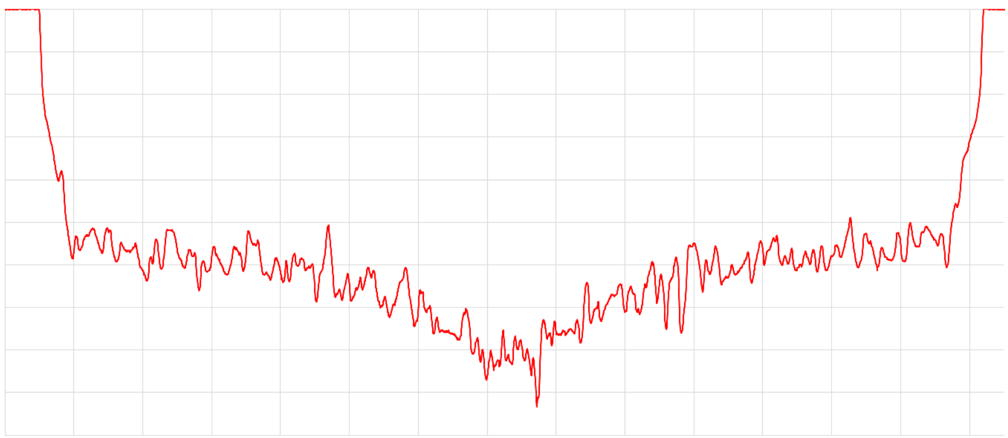

Figure 1. Typical strain signature along the wing front spar upper cap

A dedicated human interface was developed, enabling simultaneous evaluation of 4 fibers 70 m long each in real time. During the test, the actual strain readings of all fibers were displayed for evaluation as a decision making tool whether to continue the test (Fig. 2).
Additional fiber that was considered as the one routed at the most critical locations was evaluated in more details. For each loading step, the strain signature of this fiber was also compared to the expected strain, as calculated based on the previous steps. In this manner, nonlinear phenomenon can be detected in real time. In addition, strain at selected locations, defined by the stress department, were extracted and plotted vs load. This was also used as a focused tool to monitor both the maximum strain and linear behavior at location of special interest.
During the final loading stage, a significant nonlinear behavior was detected. This record of significant nonlinear was easily traced by the optical fiber at high special resolution, enabled us to get full understanding of a possible failure mode.

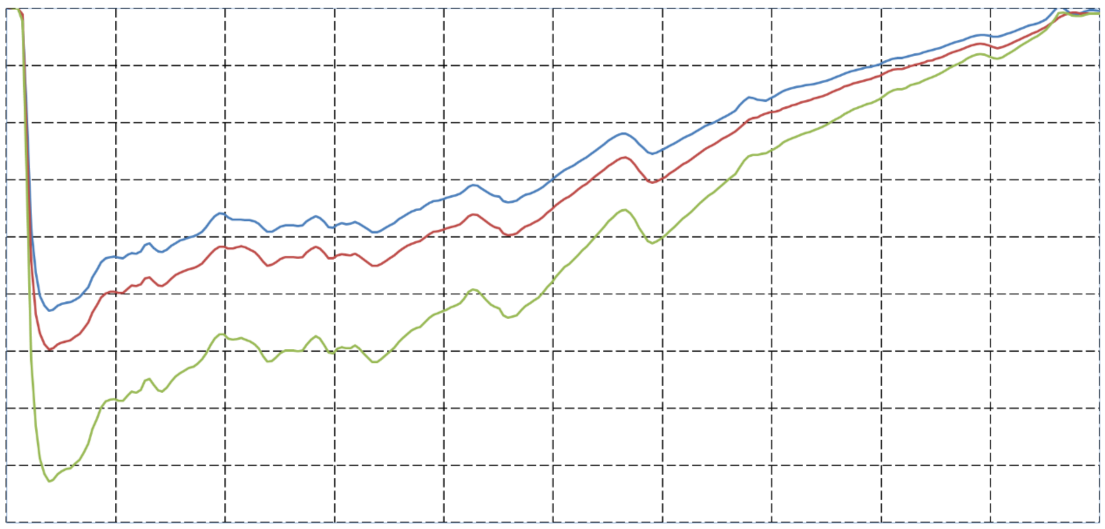

Fig. 2 Typical strain distribution along the outer wing front spar upper cap at several loading increments. Stiffness changes are well observed

This ultimate test followed a sires of fatigue and static tests, all monitored by optical fiber sensing technologies. These tests demonstrated the reliability and repeatability of both the structure tested and the sensing concept.

In conclusion, using the optical fiber based Rayleigh backscattering distributed sensing for UAV structural integrity monitoring, during Full-Scale static and fatigue tests, enables tracing of strain signature along critical component at unprecedented special resolution at low cost. Applying this concept to HERON TP ultimate test proved itself as a mean of tracing the initiation of a critical nonlinear phenomena that eventually led to failure.