FIBER-OPTIC JOINT VALIDATION

Structural integrity is only as good as the joining methods used. Testing and validating these is solved with high-definition fiber-optic sensing

The introduction of composite materials in aircraft manufacturing has created challenges in the joining of complex assemblies. The methods for joining and inspecting metal-to-metal assemblies are well tested. These same processes for composites, which require a greater use of special bonding adhesives for joints, are less clearly understood.

At issue is not just a joint's integrity at the time of manufacture, but also its strength over the aircraft's service life. Adhesive selection, surface preparation, joint assembly and curing are all variables that impact the integrity and strength of adhesive joints used in aircraft production.

To address these complications, great progress is being made in refining joining methods and this is particularly true for joints using adhesives. In parallel with methodological advances is similarly rapid progress in the technologies used to validate joint strength and reliability. This is where high-definition fiber-optic sensing (HD-FOS) is poised to play a leading role. HD-FOS, with its ability to be embedded within joints and to provide measurements of strain in millimeter increments, is the ideal technology for characterizing and validating new adhesive-based joining methods.

The HD-FOS sensor is constructed using standard fiber-optic cable and comes in lengths from 1-50m. The sensor is bonded to a structure's surface similar to traditional electrical strain gauges and is flexible enough to be routed in a serpentine pattern to increase sensor coverage across the structure. In composite applications, the fiber-optic cable can actually be embedded within the structure.

The fiber sensor comprises a series of densely spaced virtual strain gauges, whose gauge length and location are defined by the software in Luna's optical distributed sensor interrogator (ODiSI). The sensor can be configured to provide strain measurements every millimeter along the fiber. As the test progresses, gauge lengths and locations along the sensor can be virtually configured by changing software settings without physically changing the location of the HD-FOS fiber sensor.

University of Mississippi researchers embedded HD-FOS sensors in a double lap shear joint fabricated in accordance with ASTM D 3528-96. With the fibers embedded, the test article was gradually loaded in tension until reaching its failure point. Strain measurements were taken every 1.25 seconds in 1cm increments along the length of the embedded sensor. This test was repeated under identical conditions without the embedded sensor. Results demonstrated that embedded sensors had no impact on the strength of the joint under test. Data provided by the embedded HD-FOS sensors offers a complete characterization of the strain profile within the adhesive joint. Comparisons of test results to finite element analysis (FEA) predictions shows excellent correlation.

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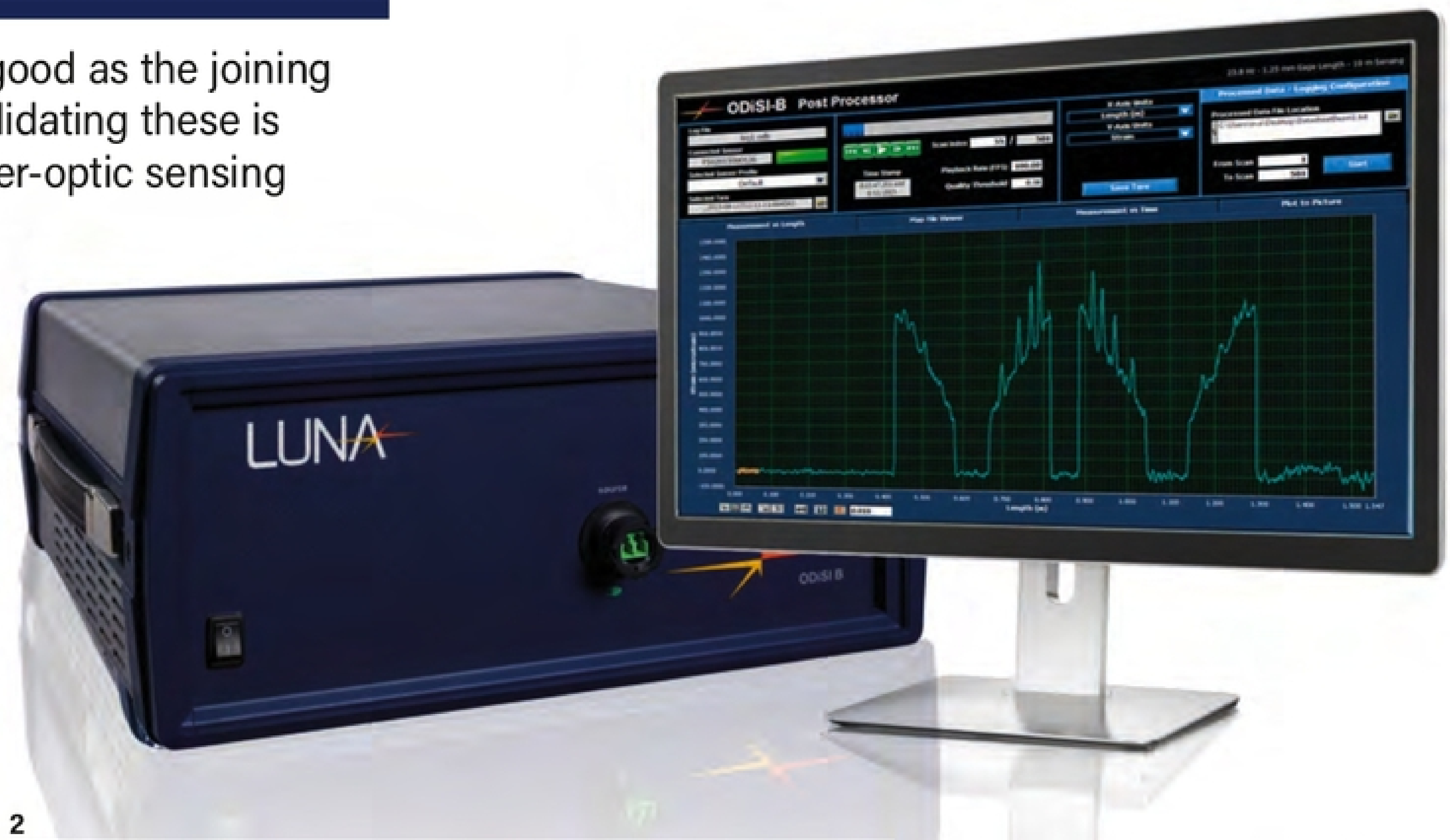

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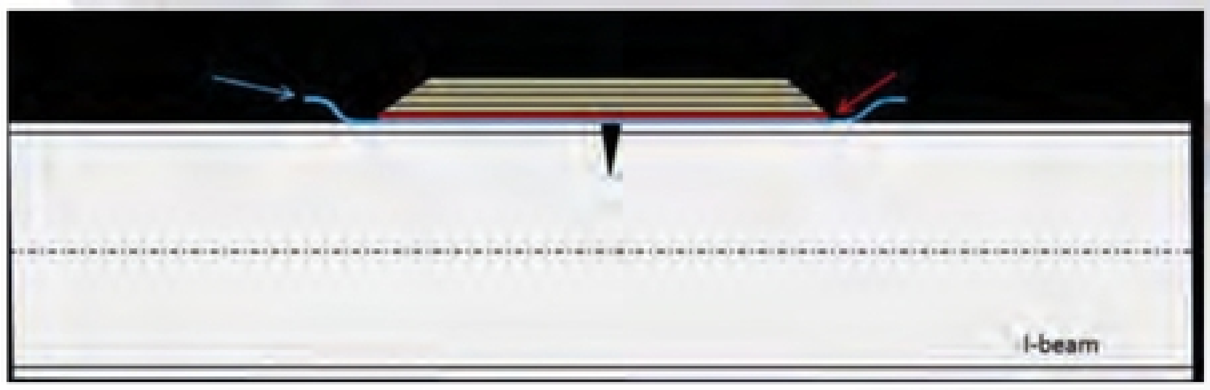

1 // Luna's ODiSI-B high-definition fiber interrogation system

2 // Schematic of fiber sensor embedded in adhesive joint of composite patch repair on notched I-beam

HD-FOS can also be used to validate the performance of adhesive joints used to bond dissimilar materials. Researchers at the Norwegian University of Science and Technology (NTNU) investigated the structural behavior of composite patch repairs applied to notched metal I-beams in a four-point bending test. The embedded sensors in the adhesive layer provided a view into the nonlinearities associated with debonding and crack growth at the metal notch even before these events were visually evident. In this case, HD-FOS measurements correlated well with FEA predictions in the linear region.

Luna's ODiSI, with high-definition fiber-optic sensing for strain, offers unprecedented visibility into the performance of adhesive joints for bonding composite structures and dissimilar materials. Events and material behavior are reported from the joint interface, the data provided by embedded fiber sensors is highly valuable and cannot be obtained by any other test technology. \\