Heat Excitation Solutions

Shearography System for NDT Quality Control and Inspection of Composites Components

Composites in the industry[1]

One of the best ways to judge an industry's vitality is to look at end product demand. For composites, the picture is promising: Demand for end products reached $21.2 billion in 2014. Such demand, in turn, leads to a healthy composite materials market.

The U.S. composite materials market grew by 6.3 percent last year to reach $8.2 billion in value and 5.5 billion pounds in terms of annual shipment. Demand in the U.S. composites market is expected to reach $12 billion by 2020 with a compound annual growth rate (CAGR) of 6.6 percent. Approximately 65 percent of U.S. composites growth by value is expected to be driven by the aerospace, transportation and construction industries.

Defects detection under heat input

By essence, a defect weakens the structural properties of a component. Its mechanical behavior under a load is consequently modified. This modification can be localized and of very little importance for the entire structure lifecycle. During daily use, it faces fatigue, chemical erosion and weather variations. Under these circumstances a small defect can become a serious threat.

Due to its nanometer sensitivity on displacement variations, Shearography can easily help any inspector to detect all of these small defects before they expand. A slight heat input of a few degrees is generally enough to trigger a visible skin displacement of the inspected surface. Dantec Shearography heat excitation solutions are reliable and extremely fast NDT solutions for any composite inspection needs.

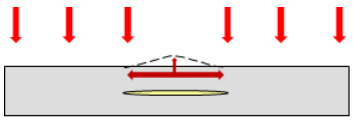

Figure 1 - Cross sectional view of a composite inner defect under heat excitation

Taking into account the material heat-wavelength absorption

Composites design is so diversified that it hugely influences the final component heat absorption. Consequently, one's ability to deform a structure by heat excitation depends on how the thermal input dissipates through the material layers.

Dantec's Shearography heat excitation options offer a wide variety of non-contact heaters in order to provide the best input for your composite material: convective heater, spotlight heater and tungsten heater.

This application note provides a study of our heating devices against different widely used composites structures and a metal part, namely:

① Dantec Shearo composite test panel, an aluminum-honeycomb black sample
② A $CFRP_{3mm}$-$Cardboard_{honeycomb}$-$CFRP_{3mm}$
③ A 4mm-thick CFRP laminate
④ A 1cm-thick aluminum block

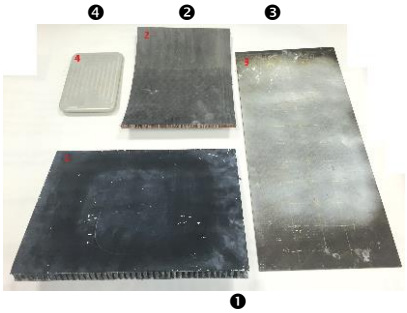

Figure 2 - Evaluation Samples

[1] http://compositesmanufacturingmagazine.com/2015/01/what-will-drive-composites-growth-in-2015/

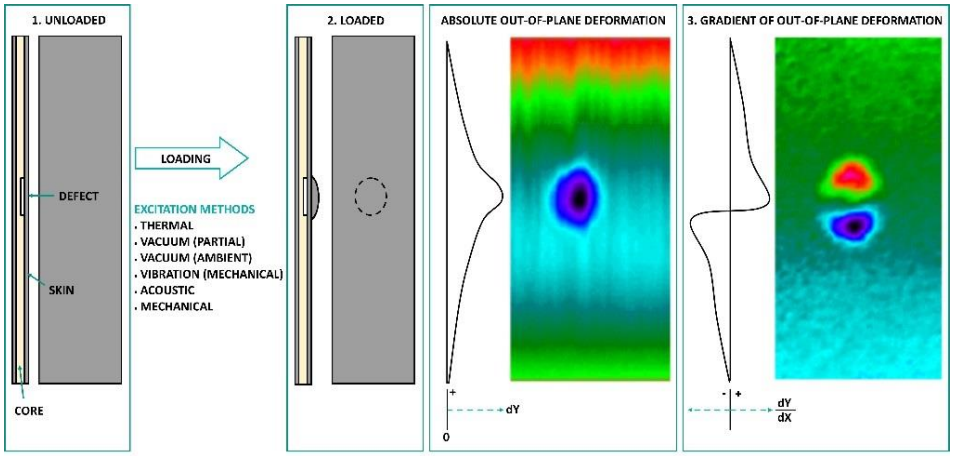

Figure 3 - Shearography Principle

Shearography Measurement Principle

Shearography is an optical, NDT technique that provides fast and accurate indications about internal material discontinuities or anomalies in non-homogenous materials. Using laser light, a shearing interferometer is able to detect extremely small (sub-micrometer) changes in surface out-of-plane deformation. When a test object is subjected to an appropriate load, a proportional strain is induced on the test surface. If underlying discontinuities are present, the surface will deform unevenly at these locations. This is then interpreted through the shearing interferometer as a change in the phase of the laser light.

Convective Heating System

Forced convection is the most efficient non-contact heating method due to its extremely focused air flow and high thermal transmission coefficient, regardless of the material composition. The heated surface then conducts this heat input through the material surface.

This is an extremely simple way of obtaining fast shearography results.

Figure 4 - Forced convection 1000W to 2300W blower

Tungsten Heating Systems

This family of emitters has proven its efficiency over the years. Its spectrum of emission covers all material absorption range with medium to high efficiency.

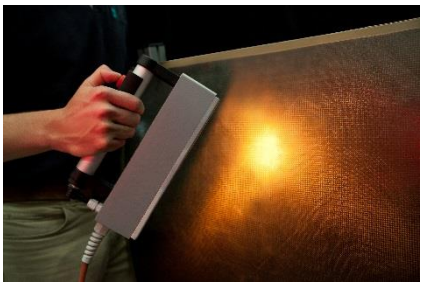

Figure 5 - Various tungsten heaters, from 375W to 3000W

Spotlight Heating System

This type of halogen emitter delivers equally both light and heat, but due to its unique spot rays concentration, parabolic reflector, a massive amount of heat is inputted to the submitted material surface. Nevertheless it is

less efficient, the total amount of excitation is independent of the distance from the sample.

Figure 6 - Spotlight 1000W halogen heater

Shearography excitation evaluation: Cooling down measurements on a composite test panel

Setup

- Setup consisted of a Q-800 Shearography sensor at a distance of 35 cm from the sample.
- Results were obtained using all the portfolio of our heating devices.
- All presented results are cooling down sample acquired.

Inspection Results

- No bare-eyes visible defects.
- 5 huge disbonds could be identified.
- The heating time necessary for obtaining this result did vary a lot depending on which heater was used:
  - Halogen emitter: 5 sec
  - Tungsten emitter: 10 sec
  - Blower: 20 sec (due to very focalized air flow)

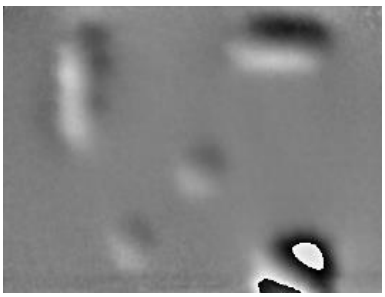

Figure 7 - Heat-Shearography, cooling down phase map

Shearography excitation evaluation: Halogen spot heaters efficiency over material types

Setup

- Setup consisted of one pyrometer facing the rear surface.
- Spotlight 1000W halogen heater, 30 sec heating at 35 cm from the samples.
- Measurements are done on 4 types of typical composite panels:
- Our Shearo composite test panel, an alu-honeycomb black sample ①.
- A CFRP3mm-Cardboardhoneycomb-CFRP3mm ②.
- A 4 mm-thick CFRP laminate ③.
- A 1cm-thick aluminum block ④.

Inspection Results

- The requested heat transfer time is approx. de same for all type of panel, namely: 7 sec only.
- Heat does not go well through sandwiches due to the present air in the core material, whatever its composition.
- Spotlight heater is very efficient for CFRP inspection but rather uneffective for metal inspection.

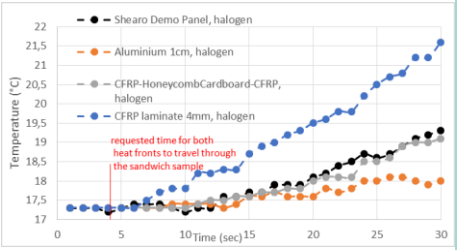

Figure 8 - Halogen spot heater efficiency over material types, rear measurement

Shearography excitation evaluation: Halogen spot heaters efficiency over distance on a composite test panel

Setup

- Setup consisted of one pyrometer facing the heated surface and one facing the rear surface.
- Spotlight 1000W halogen heater, 30 sec heating.
- Measurements are done on our Shearo composite test panel, an alu-honeycomb black sample.

Inspection Results

- Only shearo measurements during the cooling process are available.
- Transmission efficiencies in this sandwich panel is: $T_{halogen}$ = 14%

Shearography excitation evaluation: Halogen spot heaters efficiency over distance on a composite test panel

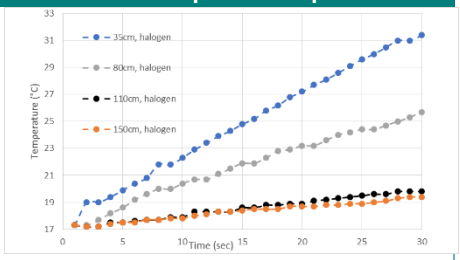

Figure 9 - Halogen spot heater efficiency over distance, Shearo test panel temperature , front measurement

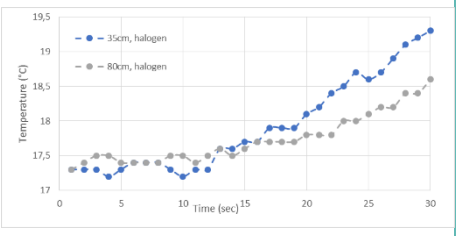

Figure 10 - Halogen spot heater efficiency over distance, Shearo test panel temperature , rear measurement

Shearography excitation evaluation: Comparing Tungsten vs Halogen spot heaters at the standard distance of 35cm

Setup

- Setup consisted of one pyrometer facing the exposed surface.
- The two compared solutions are Dantec's 1500W tungsten heater and a Spotlight 1000W halogen heater, 30 sec heating at 35cm from the samples.
- Measurements are done on our composite test panel, an alu-honeycomb black sample.

Inspection Results

- Eventhough less powerful, the Spotlight tungsten heater stays the best universal composites solution for shallow defects detection.
- For deep defects detection, both solution are equally efficient on this sandwich structure.

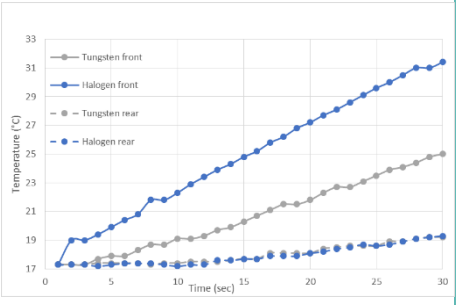

Figure 11 - Tungsten vs Halogen heaters, Shearo test panel, Front Measurement

Shearography excitation evaluation: Comparing Tungsten vs Halogen spot vs blower heaters at 3cm from the sample

Setup

- Setup consisted of two pyrometer facing both front exposed and rear surfaces.
- The three compared solutions are Dantec's 1500W tungsten heater, a Spotlight 1000W halogen heater and an air blower 1000W, 30 sec heating at 3 cm from the samples.
- Measurements are done on our composite test panel, an alu-honeycomb black sample.

Inspection Results

- The blower gives the faster heat input but the heat flux starts saturating after 12 sec. Also, due to its extremely focalized air flow (3 cm), it is not suited for large panels without sweeping and for this reasyon is also hardly to reproduce.
- After 12 sec, the halogen spot lamp dominates and do not sature the sample within 30 sec.

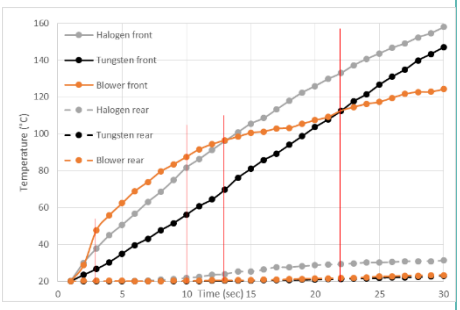

Figure 12 - Tungsten vs Halogen vs Blower efficiency at 3 cm, Shearo test panel

Summary and Benefits of Dantec's Shearography Solution

- Straightforward inspection method for normal skilled NDT operator personal.
- Very well suited NDT method for detecting composite defects in inspection and quality control.
- Fast and easy measurements can take place along the whole NDT process.
- Certified NDT technique according to standards AIA NAS 410, CEN EN 4179 and ASNT SNT-TC-1A.
- Standard NDT practice for Shearography of polymer matrix composites according to ASTM E2581.
- Can measure, record and interpret data over large areas (~m^2) with very short inspection times (~15 seconds).
- Real-time measurement solution, providing same time inspection results.
- Non-contact optical technique, means specimen under test is not polluted and measurement of non-planar surfaces easily possible.
- Compact measurement system suitable for flexible in-field or laboratory use.
- Easy and safe usage with 3R classified laser diodes.

Q-800 Portable Shearography System

The Q-800 Portable Shearography System is a non-contact, optical NDT measurement solution used for quality control and material inspection of advanced (non-homogenous) materials.

Shearography is an optimum NDT solution, tailored specifically for integrated quality control processes, as used in the Aerospace, Automotive, Wind Power, Marine, Aviation, Textile and other Composite related industries. The Q-800 actively supports the entire product life cycle from R&D, to componentry (manufacturing), assembly, end-test and in-service operation.

Applicable materials include, but are not limited to; composite honeycomb, rubber, composite overwrapped pressure vessels (COPV), ceramics, glass-fiber laminates, metal honeycombs, carbon-fiber (CFRP) laminates, fiber-metal laminates, bi-metals, foam-cores, cork, leather and metal-metal bonds.

Depending on the material strength and depth of defects within a sample, Laser Shearography can detect most defects and discontinuities that occur in composite structures, including: disbonds, delaminations, cracked cores, crushed cores, kissing bonds, wrinkling, fluid ingresses, porosity, cracks, repair defects and impact damage (BVIDs). Additional structural information such as ply drops, bulkheads, overlaps, splices, stringers and ribs, can also be detected.

Figure 13 - Q-800 Portable Shearography System

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