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FOCUS

Laser Shearography of Aerospace Composites

by Terry R. Tamberg* and Matt Crompton†

Over the last few decades, the aerospace industry has turned increasingly to carbon composite structural materials to make aircraft lighter and more economical. With this increased use, it has become apparent that conventional nondestructive testing methods are often impractical or unsuitable for tests of these materials.

Many current composite designs use concepts similar to the sheet and stringer methods found in conventional aluminum airframes. However, designers today may use long unibundle laminate tape plies (stringers) to reinforce honeycomb composite sandwich panels (sheet or skins). Where conventional aluminum structures may have been riveted or welded in the past, today's modern aerospace composite structures are adhesively bonded.

The ability to find discontinuities (including those introduced during the manufacturing process and those that result from use) in composite structures with conventional nondestructive testing has proven to be challenging. As a result, laser shearography has become one of the primary methods used for nondestructive inspection of composite structures.

Using Laser Light to Detect Surface Deformation

Laser shearography is a large area optical inspection technique that uses laser light to detect very slight surface deformations that form when subsurface discontinuities are present and the test part is subjected to an appropriate change in strain. The noncontact, full field technique allows large areas to be covered quickly. The results are also near real time. Shearography uses the interference of coherent, monochromatic laser light to detect surface displacements as small as 30 nm.

Surface deformations caused by the presence of discontinuities may be generated by subjecting the part to controlled stressing mechanisms such as:

- pressure,
- heat,
- mechanical force or
- vibration

In many cases, a reference image is recorded first. An excitation (stressing) technique is then used to generate a response in the material while a second image is recorded. The second image is subtracted electronically from the reference image. This subtraction or correlation results in an image that shows only the differences between the excited surface and the unstressed surface. The resulting surface deformations are directly linked to surface strains and with the correct excitation method, the images show subsurface weaknesses or indications that may be discontinuities or structural information in the test object. In reality, the images update in real

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FROM THE EDITOR

In this issue, Terry Tamberg and Matt Crompton provide an overview of laser shearography as used in the interrogation of the carbon composites finding increased use in the manufacture of aircraft.

Rod Stanley's article on "Demagnetization" discusses what it is, why it's necessary and some of the methods used to achieve it in ferromagnetic materials

In our "Practitioner Profile," Scott Brown describes his career path from mountain guide to NDT practitioner using rope access.

Not least in our list of content, Jim Houf responds to an "Inbox" query in which he points out the fundamental differences between *SNT-TC-1A* and *CP-189*.

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time. A technique called *phase stepping* allows the direction of surface movement to be determined and images with higher resolution to be obtained.

In order to detect internal discontinuities, it is necessary to stress the test object with the appropriate type and magnitude of excitation in a manner that causes the internal discontinuity to manifest itself as a deformation of the surface.

Laser shearography is sometimes referred to as *electronic speckle pattern shearing interferometry* (ESPSI). The term speckle refers to the grainy appearance of the laser light that reflects from the surface in a diffuse manner. When coherent and monochromatic laser light is projected through a diverging lens onto a surface, the illumination appears not as an even spread, but as a speckled, granular pattern. Minute areas of high and low intensity light, these speckles are generated by the interference of the reflecting laser light on the viewing optic. They form the basis of shearography and without them, measurement would not be possible (Fig. 1).

In comparison to other nondestructive testing techniques, laser shearography can offer the advantage of performance testing. Indications are seen as the result of applied stress and can therefore be indicative of the materials or structural strength. Conventional NDT methods can show discontinuities that may or may not be related to actual strength. A typical shearography result shows the gradient of deformation of the surface and not the absolute deformation. The corresponding colors, typically white and black or blue and red, come together to form a shearography result. Commonly referred to as a *butterfly* image, this pattern shows the positive and negative gradient of surface deformation above the discontinuity or anomaly as the point is stressed (Fig. 2).

Detecting Discontinuities and Anomalies

Within size and depth limitations, laser shearography can detect many of the discontinuities that commonly occur in composite structures. These include:

- delaminations,
- disbonds,

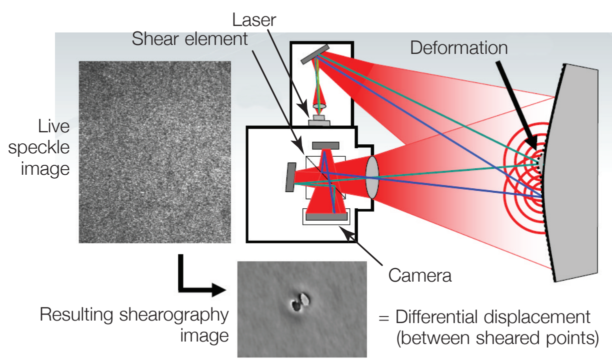

Figure 1. Optical setup for laser shearography inspection.

· impact damage,
· wrinkles,
· kissing bonds,
· separation of structural components,
· crushed core and
· porosity

Additionally, structural information such as ply drops, overlaps, bulkheads, splices and ribs may also be shown.

Establishing System Capability with Evaluation Standards

Test or evaluation standards are essential as points of reference when conducting any nondestructive inspection. In any inspection, these standards demonstrate the capabilities of the inspection system for detecting anomalies or discontinuities within the components being investigated. Evaluation or reference standards are used to determine the sensitivity of the inspection technique and to demonstrate the ability of the technique to detect the maximum size discontinuity allowed per the part's established acceptance criteria.

Nondestructive testing evaluation standards are necessary for setting up inspection parameters. The configuration of the nondestructive inspection evaluation standard should be representative of the test part/assembly with respect to thicknesses, material types, ply layups, orientation, bonding medium, and underlying structure. It is possible to use a replica of a part or sections of actual production parts as evaluation standards. It is also possible to use parts taken from service that may have discontinuities caused by normal loading or overloading to represent the type of discontinuity being investigated. The evaluation standard may have built in discontinuities placed in proper locations with respect to the area of inspection and the type of anomaly being investigated. The standard should have the same surface characteristics such as coating, paint or finish as the part being tested.

Composite test panels can also be fabricated representing structures similar to those being tested with engineered voids of specific sizes placed in specific locations to represent disbonds or delaminations. It is important to ensure that surfaces of the engineered voids do not bond to the structure during panel fabrication. Typically two circular pieces of peel ply or fluorocarbon resin tape are placed against each other to form a small pillow. The edges of the pillow are sealed prior to placement in the test panel to prevent the entrance of resin or adhesive into the space between the pillow plies. This technique ensures that a known nonbonded surface exists in the composite test panel (Fig. 3).

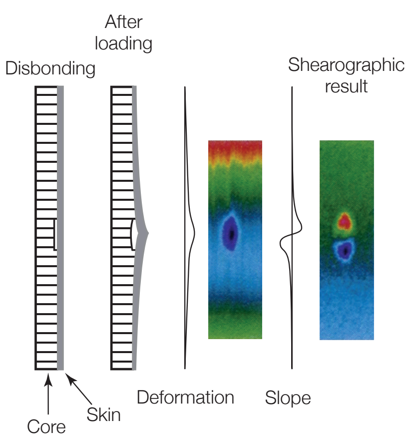

Figure 2. Illustration of shearography result for detection of disbond in honeycomb material.

Setup and Inspection

Inspection of aerospace composite structures typically follows established procedures that have been developed or approved by the original equipment manufacturer in compliance with government or industry standards.[1] The procedure should call out an area of inspection for each shearogram that is based on pixel count, types of discontinuities to be found, maximum allowable discontinuity size and rejectable discontinuity size limits.

Depending on the laser shearography equipment used for the inspection, the procedure will define the image scale and shear vector as well as the stand-off distance required for a portable system using a camera or the grid pattern required for inspection with a vacuum hood type system. In the case of a portable camera laser shearography system using thermal excitation, a quartz lamp would be used to load the surface by heating the part. Only a degree or two of change in the surface temperature is required to conduct a proper evaluation for laser shearography (Fig. 4). The camera and inspection software are activated and, once the surface is loaded, the real time image update can be used to observe the material as it responds to the heat. Individual images may be captured or recorded for future evaluation. An automatic procedure can also be set up with predefined timings for both loading and image acquisition.

Evaluating Images

Live laser shearography images can be used for real time evaluation of the test part during the initial inspection or the images can be captured and stored for evaluation at a later time. Images can be viewed in grayscale or color. Similar to other graphical inspection methods, the results of the inspection should be compared to a known sample or test standard. Structural dissimilarities and discontinuities can be compared to a valley, hill or ridge standing out in relief on a topographical map (Fig. 5).

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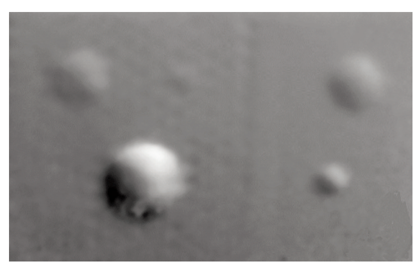

Figure 3. Shearography result for evaluation standard showing multiple engineered disbonds on honeycomb core (left) and foam core ((right).

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Advantages

Advantages of the laser shearography technique include the following:

- noncontact – does not use or require couplant,
- portability for use in field,
- provides full field inspection and overcomes many problems of recording and interpreting point measured data of large area,
- real time display of results,
- uses multiple stressing techniques applicable to wide range of materials, structures and discontinuity types,
- quickly covers large areas with high sensitivity and
- personnel qualifications are established[2,3,4]

Limitations

Limitations of the laser shearography technique include the following:

- requires mains power for lasers and vacuum pumps,
- laser safety issues from site to site,
- deep discontinuities and monolithic structures may prevent detection of discontinuities and
- thick composite structures and metallic structures may not lend themselves to laser shearography inspection

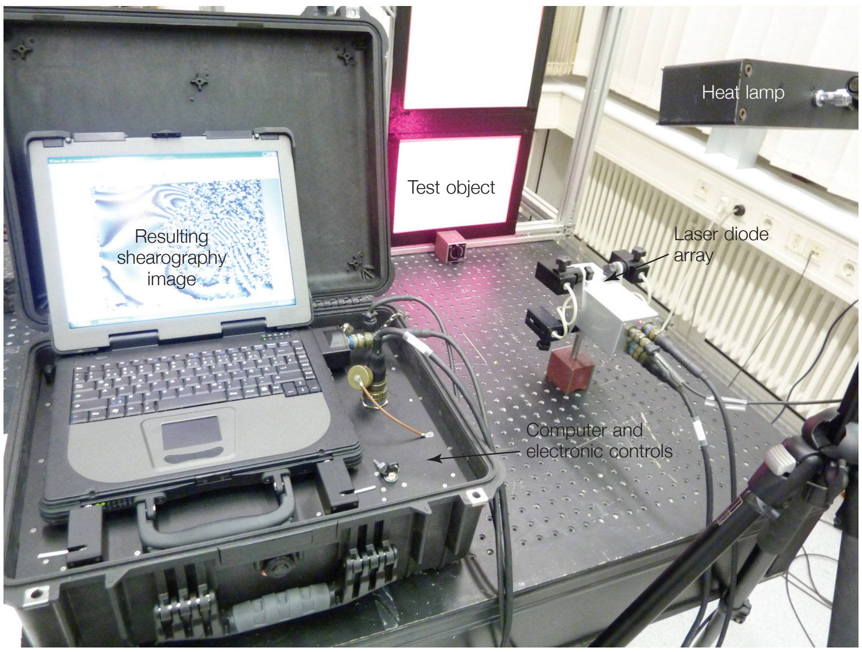

Figure 4. Laser shearography setup for portable camera system.

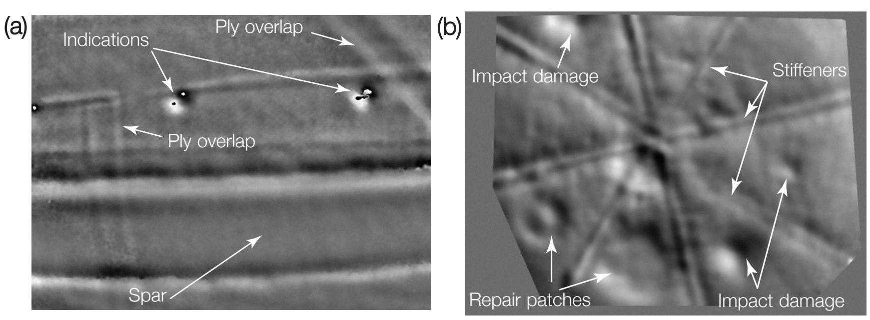

Figure 5. Laser shearography images captured during inspection of carbon composite structures: (a) section of wing structure and (b) section of radome.

Conclusion

Compared to other NDT techniques such as ultrasonic testing, X-ray, or bond testing, laser shearography offers the advantage of a fast, full field and noncontact inspection technique. The detection of discontinuities is done while stressing the sample and identifying local changes in material properties such as stiffness and adhesion due to the excitation. Laser shearography can rapidly inspect areas up to 0.5 m^2 (5.4 ft^2) in one test, while being noncontact and nondestructive. The technique works well on sandwich construction with honeycomb or foam cores.

References

1. ASTM E 2581, *Standard Practice for Shearography of Polymer Matrix Composites, Sandwich Core Materials and Filament-Wound Pressure Vessels in Aerospace Applications.* West Conshohocken, PA: American Society for Testing and Materials. (2007).
2. *ASNT Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing.* Columbus, OH: American Society for Nondestructive Testing (2006).
3. CEN EN 4179, *Qualification and Approval of Personnel for Non-Destructive Testing.* Brussels, Belgium: European Committee for Standardization (2006).
4. AIA NAS 410, *National Aerospace Standard Certification and Qualification of Nondestructive Test Personnel.* Arlington, VA: Aerospace Industries Association of America (March 2008).