The International Society for Optical Engineering

SPIE Newsroom

10.1117/2.1200609.0399

Using shearography to detect damage in gas pipelines

Analucia Vieira Fantin and Alex Dal Pont

Shearography can be used to scan large areas at high resolution to reveal delaminations and debonding in layered, composite materials.

Many modern mechanical systems use composite materials. This drives a need for new approaches to non-destructive testing (NDT) that can reliably monitor the condition of these composites. Various features of the materials—such as being nonhomogeneous—often lead to interior defects, which decrease the mechanical performance of the system. These defects can arise from impacts, such as tools dropped during the maintenance of pipes, or even when applying layers of composites for corrosion protection or as a structural reinforcement.[1] As a result, scientists and engineers seek manufacturing techniques that improve composite materials and approaches to NDT that allow periodic inspections.

Many NDT techniques exist, but only a few allow in situ analysis. Most techniques include other limitations, as well. For example, using strain gages to take a high number of measurements at different points requires many transducers, which is time-consuming and can still produce inadequate spatial resolution. Moreover, this industry needs lower-cost methods of inspection that provide non-contact capabilities plus greater reliability, sensitivity, and user friendliness, as well as higher operational speed for online inspection and applicability to increasingly complex materials and structures.[2]

Electro-optic methodologies—especially those based on lasers—promise improved approaches to composite-material inspection. One of the most-studied techniques is digital shearography. This directly measures the strain deformation of surfaces by capturing the deformation gradient rather than the deformation itself. The technique works in a wide range of testing situations and is relatively insensitive to environmental disturbances.[3] For instance, the rubber industry routinely uses shearography to evaluate tires. Other applications include measuring strain, material properties, and residual stresses.[4]

Digital shearography requires only three basic elements: an illumination system, an interferometer, and software that drives the acquisition of the images (see Figure 1). An expander breaks a laser into a collection of beams, which is aimed at the material. Reflected beams pass through an interferometer, and a CCD camera records the results, or speckle patterns. Importantly, an interferometer for shearography is much simpler than those for electronic–speckle pattern interferometry (ESPI), since the former does not require a reference beam. This also makes shearography more stable than the other speckle techniques.[4]

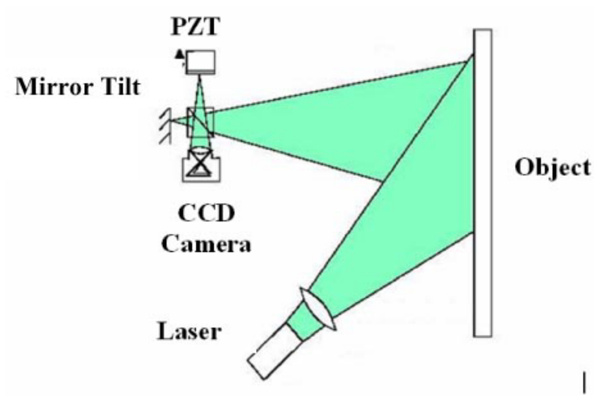

Figure 1. In digital shearography, an expanded laser beam illuminates a sample and generates a speckle pattern on the surface.

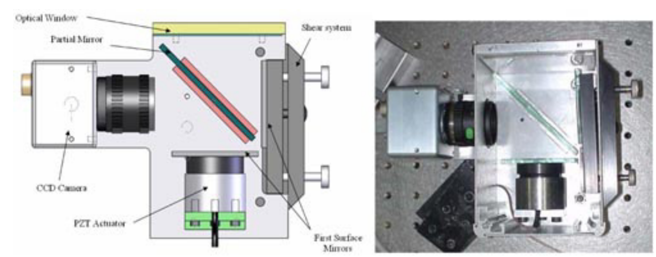

Figure 2. In a shearography sensor head, a simple system of mirrors forms the laterally sheared image of the surface.

Continued on next page

Figure 3. The authors created an artificial delamination in this repaired gas pipe.

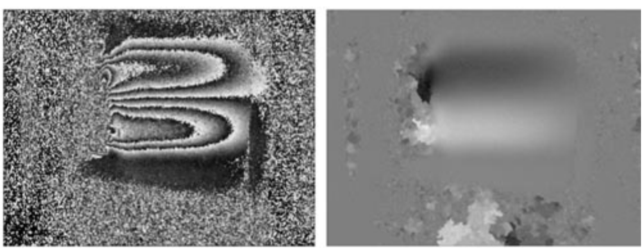

Figure 4. (a) The difference-of-phase map reveals the delamination in the gas pipe shown in Figure 3. (b) The absolute-phase map can be used to quantify the gradient of the displacement.

Two screws control the direction and the amount of lateral shear imposed by the user to form a sheared image (see Figure 2).[5] Internal defects, if properly excited or loaded, can be revealed by their effects on the surface-displacement field. The fringe patterns are obtained by subtraction of the speckle patterns recorded in two different states: before and after loading. Phase-stepping and phase-unwrapping techniques are used to calculate the phase distribution. The phase-stepping can be accomplished with a mirror guided by lead zirconate titanate.

Figure 3 shows a repaired pipe used at oceanic platforms for gas extraction. To repair external failures caused by corrosion or indentation, a composite-material sleeve is molded on-site. Thicker sleeves—with more than 20 layers—are also applied on the pipes for structural reinforcement after corrosion attacks. To demonstrate the performance of the shearography system, we created a delamination between the thin cover (4mm) and the pipe.

Using a 500W halogen lamp, we applied thermal loads to the composite sleeve to excite the delaminations and create the two required states for shearography measurements. Figure 4(a) shows the resulting difference-of-phase map, which reveals the delaminations through the fringe pattern. Figure 4(b) is the absolute-phase distribution calculated using a phase-unwrapping algorithm.[6] We can use the absolute-phase map to quantify the gradient of the displacement.

Overall, shearography proves particularly advantageous when a high number of measurements must be taken at different points. Furthermore, it is a low-cost and user-friendly technique.

Author Information

Analucia Vieira Fantin
Mechanical Engineering
Federal University of Santa Catarina
Florianópolis, Santa Catarina, Brasil
http://www.posmci.ufsc.br

Analucia Fantin is a mathematician and holds a Dr Eng in mechanical engineering. She teaches and does research in the Mechanical Engineering Departament at the Federal University of Santa Catarina. In addition, she has written papers about holography, shearography, and speckle metrology for SPIE conferences.

Alex Dal Pont
Photonita
Florianopolis, Santa Catarina, Brasil
http://www.photonita.com.br

Alex Dal Pont earned an MS in mechanical engineering. He works as a researcher at Photonita, a company in the optical-metrology sector.

References

1. F. Santos, M. Vaz, and J. Monteiro, *A new set-up for pulsed digital shearography applied to defect detection in composite structures*, **Opt. Laser. Eng. 42**, pp. 131–140, 2004. doi:10.1016/j.optlaseng.2003.07.002
2. C. Meola, G. M. Carlomagno, and L. Giorleo, *The use of infrared thermography for materials characterization*, **J. Mater. Process. Technol. 155–156**, pp. 1132–1137, 2004. doi:10.1016/j.jmatprotec.2004.04.268
3. W. Steinchen and L. Yang, **Digital Shearography – Theory and Application of Digital Speckle Pattern Shearing Interferometry**, SPIE Press, Bellingham, Washington, USA, 2003.
4. Y. Y. Hung and H. P. Ho, *Shearography: an optical measurement technique and applications*, **Mater. Sci. Eng. R. 49**, pp. 61–87, 2005.
5. R. M. Groves, S. W. James, and R. P. Tatam, *Shape and slope measurement by source displacement in shearography*, **Opt. Laser. Eng. 41**, pp. 621–634, 2004. doi:10.1016/S0143-8166(02)00177-X
6. A. Asundi and W. Zhou, *Fast phase-unwrapping algorithm based on grayscale mask and flood fill*, **Appl. Opt. 37**, pp. 5416–5420, 1998.