Exploring the Frontiers of Non-Destructive Techniques: Shearography, Ultrasound Laser and Thermography

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Abstract. Non-destructive testing (NDT) techniques serve as indispensable tools across diverse industries, facilitating material and component inspection without inflicting damage. This article underscores the paramount importance of NDT methods in enhancing product quality, safety, and cost-effectiveness. Leveraging advanced techniques such as shearography, ultrasonic laser, and thermography, manufacturers can proactively identify defects during the production process, thereby reducing scrap and rework costs while enhancing overall product integrity. Shearography excels in surface defect detection, while ultrasonic laser offers sensitivity without necessitating direct contact, and thermography enables versatile temperature-based inspection. The synergistic coexistence of these techniques within NDT protocols maximizes inspection efficacy, ensuring high-quality and safe outcomes across various industries. By embracing a comprehensive approach to NDT, industries can optimize operational efficiency, minimize risks, and uphold stringent quality standards. In conclusion, the integration of shearography, ultrasonic laser, and thermography in NDT practices represents a cornerstone in maximizing inspection effectiveness and maintaining superior quality and safety standards across industrial sectors.

1 Introduction

Non-destructive techniques (NDT) are crucial in various industries, offering benefits such as reduced production costs, improved safety, extended lifespan of structures, reduced environmental impact, and fostering technological innovation. They are particularly important in inspecting composite materials, which are valued for their high strength, light weight, and durability. This article compares several NDT methods used for inspecting composites, including shearography, thermography, and laser ultrasound. Each technique has its strengths, such as detecting surface deformations, thermal anomalies, or internal defects, helping to ensure the integrity and safety of composite structures [1-3].

2 Methodology

2.1. Shearography

Shearography is a non-destructive technique used to detect surface defects in materials, particularly effective in composites. It uses lasers and interferometry to detect surface deformations caused by stress or temperature changes. A laser illuminates the material and a camera captures interferometric images, which are compared to identify defects such as delamination, cracks, and bubbles. Shearography allows large areas to be quickly inspected by detecting small changes in deformation without damaging the material, making it ideal for inspecting critical components. [4]

2.2 Thermography

Thermography is a non-destructive technique that detects temperature changes on the surface of materials using infrared cameras. [5] By measuring the emitted infrared radiation, thermography detects defects such as delamination or air inclusions. This technique is advantageous because of its speed, non-invasiveness, sensitivity to temperature changes even on complex surfaces, and ability to inspect opaque and transparent materials. In addition, it is safe and environmentally friendly, as it does not use chemicals or ionizing radiation.

2.3 Ultrasonic Laser

The ultrasonic laser is an advanced nondestructive technique for detecting internal or surface defects in materials, particularly effective on composites. It uses a laser pulse to generate high-frequency acoustic waves that interact with the material. [6] These waves, detected by a sensor, allow defects such as voids, cracks, and delaminations to be identified and evaluated. Advantages include high-resolution inspection of irregular surfaces, the ability to detect defects in depth, noncontact

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measurements, and the speed and accuracy of the process, which provides reliable results in a short time.

3 Results

In this study, a detailed analysis was conducted on several CFRP (Carbon Fiber Reinforced Polymer) panels characterized by variations in size and thickness. The objective was to compare the results obtained through the application of three different non-destructive techniques: shearography, thermography and ultrasonic laser. Each panel had been specially prepared with defects of various types, distributed at different depths, of different materials and sizes. All the techniques used clearly revealed the presence of the defects at precise instants. Image 1 provides a visual representation of the results obtained by shearography on CFRP panels, characterized by a thickness of 4.8 and 1.6 mm, respectively. it was possible to visualize clearly and in detail the surface defects of different materials and sizes. Image 2, on the other hand, shows the results obtained with the laser ultrasonic technique (LUT) on CFRP panels with thicknesses of 4.8 and 1.6 mm. The analysis performed allowed us to accurately identify defects present at different depths within the material, highlighting the effectiveness of this technique in detecting anomalies even in the thickest materials. Finally, Image 3 shows the results obtained with the application of thermography. Again, an almost complete detection of defects in CFRP panels was observed. Interestingly, thermography provided better resolution in the thinner panels, underscoring the importance of considering specific material characteristics during analysis.

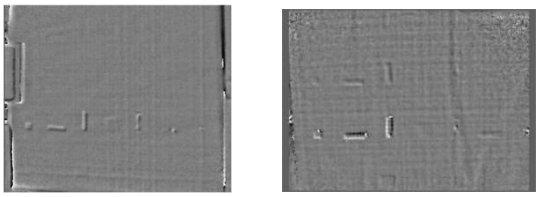

Fig.1- Typical shearographic results for the 4.8-mm panel on the left and the 1.6-mm panel on the right

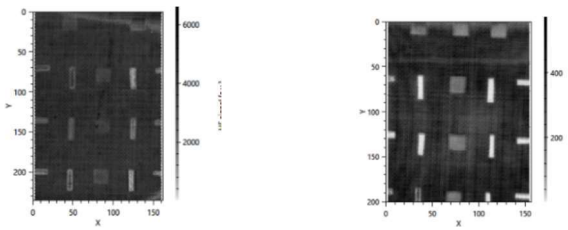

Fig.2- LUT results for the 4.8-mm panel on the left and the 1.6-mm panel on the right

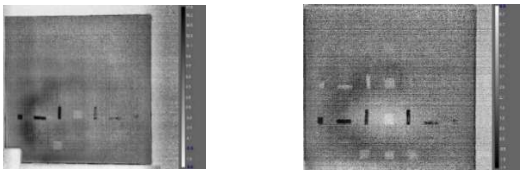

Fig.3 – Typical thermographic results for the 4.8-mm panel on the left and the 1.6-mm panel on the right

4 Conclusion

In conclusion, the integration of non-destructive techniques proves to be crucial in the inspection of composite materials. Shearography stands out for its accuracy in detecting surface defects, while ultrasonic laser and thermography demonstrate high effectiveness in detecting defects at different depths in the material. The synergistic adoption of these methodologies enables comprehensive and accurate assessment of the condition of composite materials, ensuring the safety and reliability of structures in various industrial settings. With the ability to detect anomalies and defects early, this integrated approach promotes reduced manufacturing costs and promotes more sustainable production. In summary, the joint application of these non-destructive techniques is a key pillar for progress and safety in the composite materials industry.

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References

1. Duchene, Pierre, et al. "A review of non-destructive techniques used for mechanical damage assessment in polymer composites." Journal of materials science 53.11 (2018): 7915-7938.
2. Russo, et al. "Investigation of damages in impacted thick composite panels by NDI methods." Behavior and Mechanics of Multifunctional Materials XVIII. Vol. 12947. SPIE, 2024.
3. Vespini,et al. "Multimodal NDT inspection and characterization of composite honeycomb sandwich samples with programmed flaws." Health Monitoring of Structural and Biological Systems XVIII. Vol. 12951. SPIE, 2024.
4. Sirohi, Rajpal. "Shearography and its applications–a chronological review." Light: Advanced Manufacturing 3.1 (2022): 35-64.
5. Qu, Zhi, et al. "Development and application of infrared thermography non-destructive testing techniques." Sensors 20.14 (2020): 3851.
6. Song, Peng, et al. "All-optical laser ultrasonic technique for imaging of subsurface defects in carbon fiber reinforced polymer (CFRP) using an optical microphone." Journal of Applied Physics 131.16 (2022): 165106;