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On-line evaluation of ultrasonically welded carbon fiber reinforced thermoplastic laminates by means of infrared vibrothermography

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The aerospace industry's growing demand for lightweight and sustainable solutions is driving the increased adoption of thermoplastic matrix composites. These materials offer enhanced processability and recyclability, notably through advanced welding techniques like ultrasonic welding (USW). USW provides high-quality, repeatable joints, but its widespread aerospace implementation requires robust non-destructive testing (NDT) methods to ensure structural integrity and optimize process parameters.

Infrared thermography (IR-NDT) is a promising candidate NDT technique due to its ability to detect internal defects across large surfaces, with easily integrated setups and rapid post-processing. This study proposes an innovative integrated IR-NDT setup, utilizing vibrothermography, to monitor and optimize USW of carbon fiber-reinforced LM-PAEK thermoplastic composite panels.

The USW process, employing sonotrode-induced vibrations and an energy director layer, generates localized heating via viscoelastic straining and hysteretic heat, thereby welding the adherends. Optimal weld quality depends on precise parameter tuning, including vertical stroke (amplitude), welding time, applied pressure, step size, and rest time. Understanding these parameters is crucial for enhancing joint quality and mechanical performance.

Vibrothermography exploits the principle that mechanical vibrations induce heat dissipation, concentrated at defect interfaces like cracks or delaminations, creating thermal signatures on the surface. In this work, a high-speed (100 Hz) cooled-sensor infrared camera (Flir SC 7000) monitors the welding quality. To assess the welded area, the same sonotrode applies controlled vibrations post-welding, utilizing reduced vibration time and amplitude. The resulting transient heat distribution effectively marks off the welded spot boundaries and the effective welded area.

This methodology enables rapid and reliable inspection of welded joints, with potential for online monitoring of USW procedures on complex geometries and varying material compositions. The proposed approach significantly advances quality assurance in aerospace composite structures assembled by USW, fostering broader industrial adoption of this joining technique.

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