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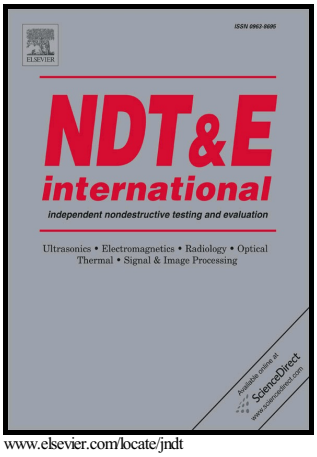

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Research on the fiber lay-up orientation detection of unidirectional CFRP laminates composite using thermal-wave radar imaging

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Abstract

A depth dynamic-resolution thermal-wave radar imaging (TWRI) was used to detect fiber lay-up orientations in the unidirectional CFRP laminate composite. A phase characteristic of thermal wave radar (TWR) signal was proposed and calculated by discrete fractional Fourier transform (DFrFT). The DFrFT phase distribution contour line was approximated as an ellipse and fitted by a non-standard elliptic equation. The ellipse ration angle dependent on the DFrFT phase (defined as Ellipse Angle Curve, EAC) was found to be sensitive to the fiber lay-up orientations of CFRP composite. An inverse methodology was developed to quantitatively characterize the fiber lay-up orientation angle through reconstructing DFrFT phase distribution. A cost function that minimized the square of DFrFT phase difference between TWRI inspection and numerical calculations was constructed, and a hybrid algorithm that combined the simulation annealing (SA) with Nelder-Mead simplex research (NM) method was employed to solve the cost function and find the global optimal solution of the fiber layer-up orientation angle. Experimental investigation of a 7-layer CFRP laminates $[0°/45°/90°/0°]_s$ validated the feasibility of estimating carbon fiber layer-up orientations by TWRI.

Keywords: Fiber orientation; CFRP composite; IR Thermography; Finite element analysis (FEA)