proceedings

Abstract

Pulse Compression Favorable Thermal Wave Imaging Techniques for Identification of Sub-surface Defects in Glass Fiber Reinforced Polymer Materials

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Non- Destructive Testing and Evaluation (NDT & E) plays a vital role in inspection of wide varieties of materials without influencing its future serviceability. Among the widely used NDT&E techniques Ultrasonic Testing, Radiographic Testing, Eddy Current Testing, Magnetic Particle Inspection, InfraRed Thermography gained its importance due to its inherent merits. However, NDT & E demands a safe, remote, fast, quantitative inspection approach which can easily deployed for on-field inspection services.

Infrared Thermography involves mapping of the thermal profile over the object under inspection to reveal its surface and sub-surface features [1]. This can be implemented either in a passive or in an active approach. Even though passive approach has several merits such as simple, fast, and easy to deploy in field inspection, it has a major limitation in providing a quantitative information regarding the sub-surface features of smaller spatial dimensions specially located deep inside the test object. Identify to these types of smaller and deeper sub-surface features along with their quantitative details with enough detection sensitivity active thermography is preferred. In this former approach an active thermal stimulus is imposed on to the test object to probe the thermal waves with a predefined amplitude and the bandwidth. Due to its predefined imposed thermal response, obtaining the reliable quantitative information about the sub-surface features is possible.

Among the widely used active thermographic approaches pulse- based thermographic methods and the modulated thermographic approaches are more prominent. Due to limitations like shallow probing depth, the need for high peak power in pulse-based methods, and the repetitive testing required at different frequencies in lock-in thermography, these techniques are less suitable for applications that require continuous depth scanning using low to medium peak power sources within a moderate experimentation time. These limitations can be overcome by adopting the recently proposed Frequency Modulated Thermal Wave Imaging (FMTWI) approaches with pulse compression favorable correlation based matched filter post-processing [2].

This present work highlights the capabilities of FMTWI technique with correlation based post-processing approach for NDT&E of various materials such as steel and sandwich materials for inspection to identify the sub-surface anomalies/ interface bond quality. The obtained results from various post-processing approaches such as Frequency Domain Phase (FDP), Time Domain Phase (TDP), Cross Correlation Coefficient (CCC) have been considered based on their superiority while detecting the sub-surface defects [3].

Metal and sandwich materials are used in the experimental investigation which are commonly utilized in shipbuilding, automotive and aerospace industries [4-6].

Experiments have been carried out and thermal data has been acquired during the experimentation for Pulse, Lock-in, Frequency modulated Thermal wave imaging and other coded excitation schemes using the active thermal imaging system developed by InfraRed Vision and Automation Pvt. Ltd., Rupnagar, Punjab, India, along with state-of-the-art associated post-processing software. Two high-intensity (each 1200 W) Light Emitting Diode (LED) lamps used to impose with predefined incident heat flux over the sample under examination. The sample was placed 1 meter away from the lamps to ensure uniform heating across the surface. Lamp intensity was modulated via a source control unit for the specific adopted excitation scheme.

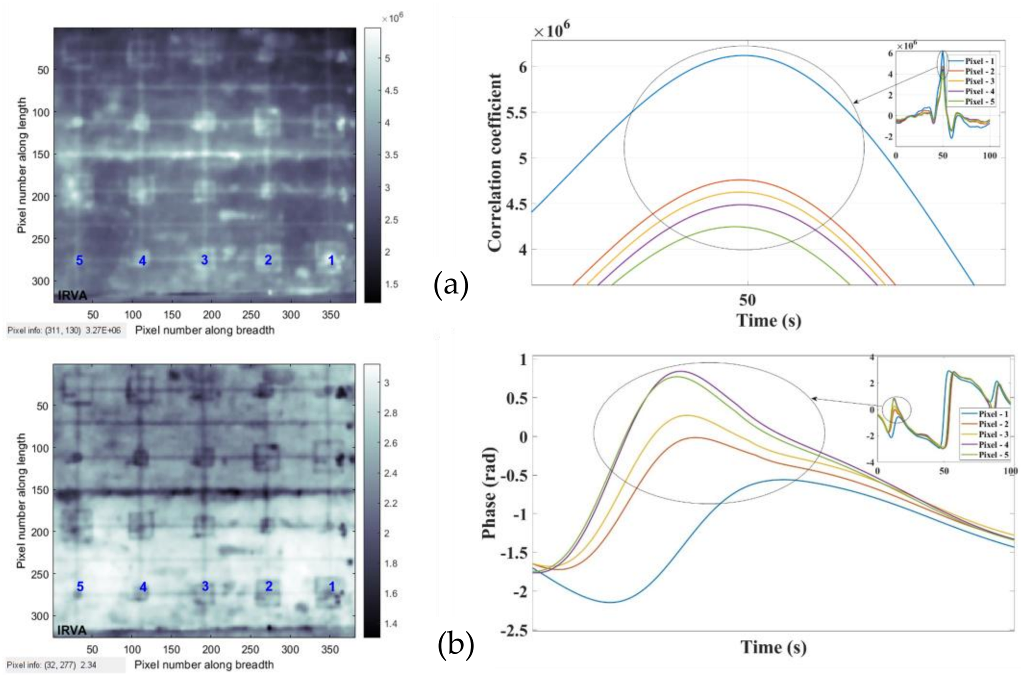

Figure 1. Obtained thermographic images from the (a) cross-correlation coefficient and (b) time domain phase-based post processing analysis schemes using FMTWI.

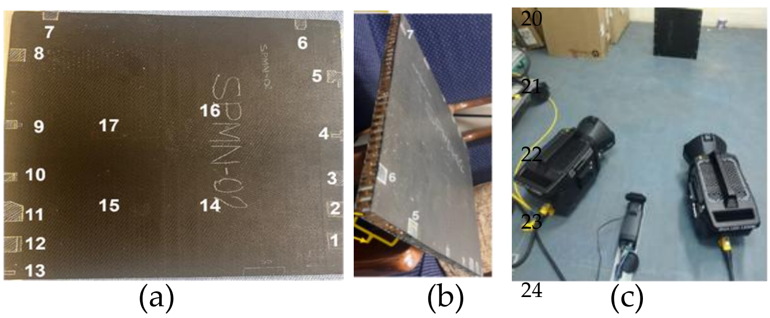

Figure 2. (a) Top and (b) cross-sectional view of the honeycomb test specimen used in experimentation (c) Experimental set up used for carrying out the PT, LT and FMTWI.

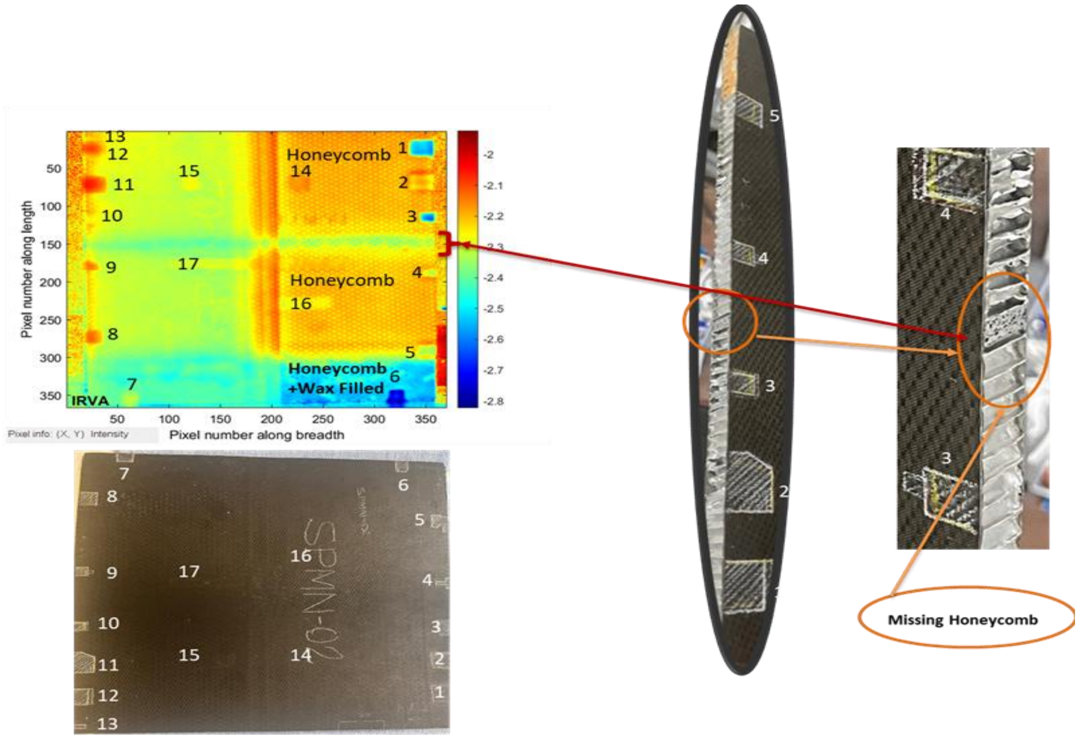

Figure 3. Obtained thermographic image from the cross-correlation coefficient post processing analysis schemes using FMTWI.

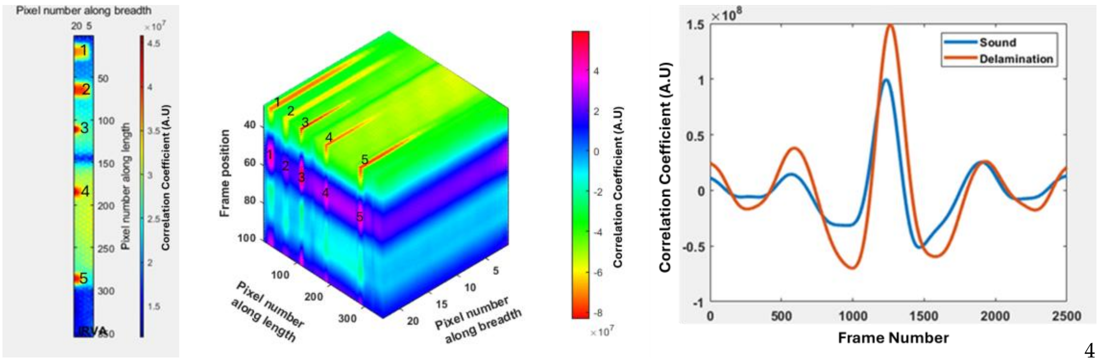

Figure 4. Obtained stack of thermographic image sequence from the cross-correlation coefficient post processing analysis schemes using FMTWI and its single pixel profile at delamination and sound region of the test specimen.

Thermal response was captured using a FLIR A655sc uncooled infrared camera, offering a spatial resolution of 640 × 480 pixels and operating within a spectral range of 8 µm to 12 µm in the far-infrared region. The camera monitors the surface temperature variations across the sample and acquired the thermal response at a rate of 25 frames per second (fps), providing detailed temporal and spatial thermal data for post-analysis. Post-analysis on the obtained thermographic sequences for the selected excitation schemes was carried out using both conventional frequency domain and advanced time domain approaches, such as cross-correlation coefficient and time-domain phase analysis, across various test samples. Figure 1 shows the interface bond quality of the metal-insulator and insulator-insulator interface whereas Figure 2 shows the experimental sample and arrangement used for experimentation for testing of the honeycomb specimen. Figure 3 shows the interface quality for the honeycomb sandwich structure, whereas Figure 4 shows the stack of the correlation coefficient image sequence. It is clear from all the obtained results for the metal and honeycomb sandwich structures that the obtained CCC post processing with FMTWI shows the better sub-surface defect detection capabilities while identifying the interface delamination [4]. Further, efforts were made to compare various experimental techniques and the proposed post-processing approaches both qualitatively and quantitatively.

Supplementary Materials: Not Applicable.

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