Optimization of Pulse Compression Thermography

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Non-destructive evaluation of materials and structures is still a key issue in some industrial scenarios as the production process and the quality inspection. In this scenario, Active Thermography (AT) is a Non Destructive Testing (NDT) technique applied extensively to the inspection of composite structures, and various measurement strategies have been developed to improve the technique [1–4]. Pulse-compression thermography (PuCT) is an emerging nondestructive testing developed by Mandelis et al. [5,6] and Mulaveesala et al. [7–9] in which the heating stimulus is in the form of a coded signal. It has some potential advantages over the well-known Pulse Thermography, such as cheaper measurement system, portable setup, frequency and time analysis, etc.

After a proper post processing, the frequency content of the signal can be tailored to the type of materials/defects under investigation, while the duration of the signal can be determined by considering the required SNR value. In recent years, various PuCT schemes have been proposed, which mainly differ in the type of coded waveforms used (binary sequences or frequency modulated “chirp” signal) or in the type of heating source. Nonetheless, some issues remain in PuCT since most of the implementations focus on the SNR gain and do not analyze the quality of the reconstruction of the impulse responses.

Our aim is thus to propose a measurement protocol that optimizes both the SNR gain and the quality of the impulse response reconstruction.

Proposed solution and Results

For the use of the PuC in active thermography, one of the main practical issues is the difficulty to realize a bipolar heat source. All heat sources used in thermography are unipolar, which will not normally generate PuC waveforms correctly. As a consequence, the true excitation signal \( S_{TR}(t) = S(t) + S_{SQ}(t) \) is a superposition of a coded excitation \( S(t) \) and a square pulse \( S_{SQ}(t) \). Therefore, before completing the PuC operation the unwanted contribution \( S_{SQ}(t) \) of the square pulse to the acquired thermograms must be removed. In order to reach this goal, we designed a proper fitting function.

Sample under test was a carbon fiber composite laminate contained twelve plies of carbon fiber fabric. The fibers orientations were 0° and 90° and the matrix was an Epoxy Resin made with appropriate procedure. Artificial delaminations was realized by inserting square pieces of Teflon tape with lateral dimensions of 20 mm×20 mm at different depth.

Figure 1: At the right a Detailed sketch of the SUT. At the left Example of the thermal image of the sample from the Barker & Step sequence at the instant of maximum SNR value for the D7 defect. The defects were labeled from D1 to D9 depending on the increasing depth from the inspection surface.
A proper application of the fitting function on the samples thermal response after coded excitation allow for obtaining a better pulse compression procedure than the state of art and improving the SNR in correspondence of the defects. The optimized pulse-compression procedure was also compared with pulsed thermography PT, showing a good agreement between the results obtained with the two different approaches.

References


