Exploiting the non-adiabatic thermoelastic response for assessment of CFRP

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Abstract. In Thermoelastic Stress Analysis (TSA) it is assumed that the stress induced temperature change, ΔT, occurs adiabatically [1], so that the thermoelastic response is considered to be from the material surface alone. Adiabatic conditions are achieved by cyclic loading at such a rate that thermal diffusion is limited over small volumes. However, it has been shown that for multidirectional CFRP laminates ΔT is influenced by the subsurface even at relatively high loading frequencies [2] [3] [4]. Thus an opportunity arises to use TSA to monitor subsurface features and debonds, and identify any damage progression from such defects. Unlike other thermal NDE techniques, the internal heat sources are developed during the cyclic loading of CFRP components, which means that defects that relatively deep in the structure can be monitored. The application of the technique is of particular interest for structural fatigue testing of CFRP structures and looking to the future in-situ monitoring of structures under fatigue loading such as wind turbine blades.

Firstly, it is demonstrated that heat sources can be developed in simple multidirectional laminates and that ΔT changes considerably depending on the loading frequency (Fig. 1). A wrinkle type defect is clearly observable at certain loading frequencies. A FE model of the heat sources is used to determine the location of the defect in the laminate.

A delamination test case is studied of a Centre Crack Ply (CCP) test, commonly employed to evaluate mode II fracture toughness of laminated composites. Unidirectional IM7/8552 CFRP specimens with $[0_4, \underline{0}]_s$ and $[0_4, \underline{90}]_s$ (where the underline indicates the cut plies) were manufactured, with artificial defects are incorporated into the specimens using thin steel film inserts (5 mm thick). TSA and Digital Image Correlation (DIC) are employed to obtain full-field temperature, displacement and strain data. The $[0_4, \underline{90}]_s$ specimen was also included to exploit the different thermoelastic response of the 90 and 0 degrees plies, providing better thermal contrast for monitoring the subsurface damage progression (see Fig. 2). The CCP specimens were tested under monotonic loading to failure, to assess the fracture toughness, with DIC being used to identify the strain distributions on the surface at damage initiation and failure. It is shown that the TSA can identify the subsurface damage alongside damage progression in the coupon.

Finally, A CFRP face sheet foam-cored sandwich beam with an interface debond was tested under a 3-point bending configuration. TSA and DIC were used to image the face sheets in the region of the debond. It is demonstrated that the crack-tips of the can be identified through the face sheet material. A growing delamination can be monitored using the heat source developed from a stress concentration in the core at the debond, which exhibits a large thermoelastic response (Fig. 3).

The potential of TSA to reveal subsurface defects during is-situ testing is demonstrated. A discussion of the limitations applying the technique to quantify damage severity is included in the presentation alongside the future outlook for in service evaluations using TSA.

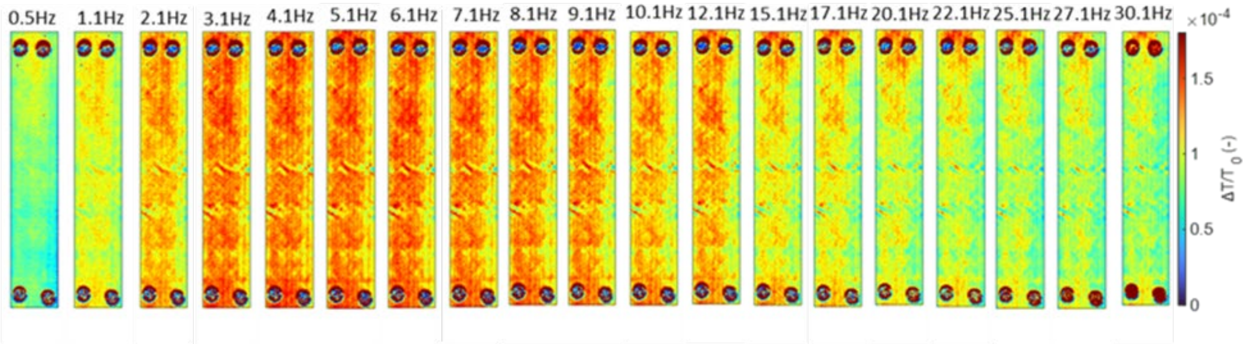

Fig. 1. Subsurface wrinkle defect revealed in a [0,0,0,45,-45,0] CFRP laminate.

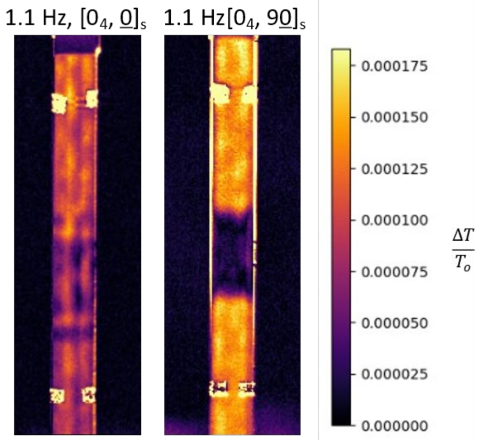

Fig. 2. CCP specimens with 0 degrees (left) and 90 degrees (right) cut plies.

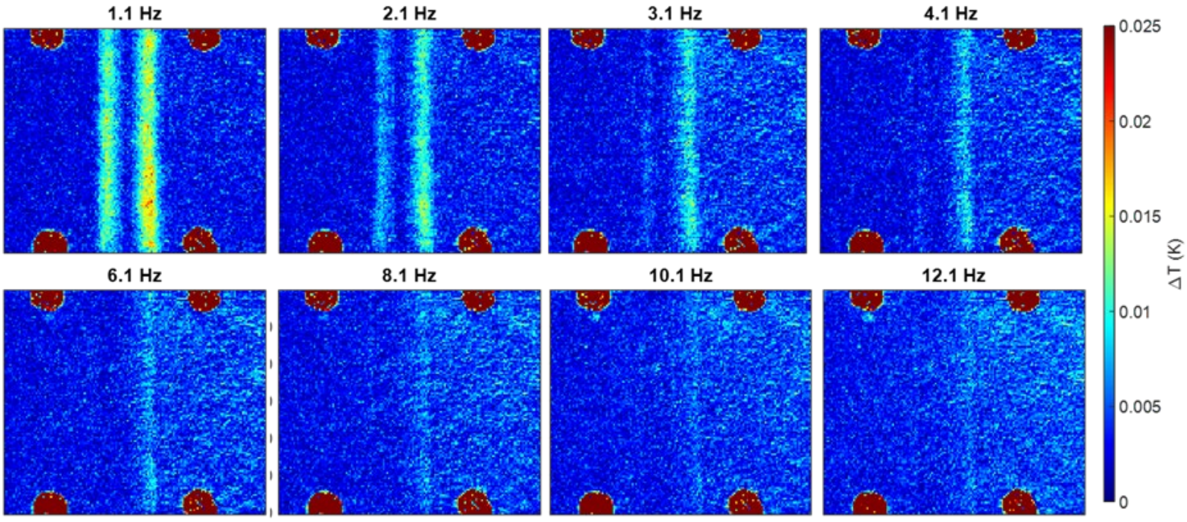

Fig. 3. CCP specimens with 0 degrees (left) and 90 degrees (right) cut plies.

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