Failure envelops based on full field assessment of CFRP subjected to multiaxial loading

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Introduction

While many studies have aimed to develop failure envelops for composite laminates, most have considered only uniaxial loading. In most structures, materials experience mixed loading often as combinations of either tension/shear or compression shear. For this reason a modified Arcan fixture (MAF) [1] was manufactured to develop these loading states in coupon specimens. Previous work [2] using this fixture considered load displacement responses and ultimate failure load which provided new insights into the failure of multidirectional laminates under multiaxial load. However, while such data provides an indication of global component failure, extracting information on damage initiation remains a challenge. Such information would significantly aid the validation of failure theories and numerical failure prediction models. The current work aims to apply thermographic techniques to obtain full field data pertaining to the onset of damage in Carbon Fibre Reinforced Polymers (CFRP) both on the surface and subsurface. Thermoelastic stress analysis (TSA) was performed to obtain surface information, and lock-in thermography (LIT) was applied in transmission mode to identify subsurface damage.

Experimental Setup

Double notched open hole specimens were manufactured using a quasi-isotropic unidirectional carbon fibre laminate shown in Fig 1(a). A carbon veil was bonded to the back surface of the laminate as a resistive heater for use in LIT as shown in Fig 1 (b) and (c). This was isolated from the electrically conductive CFRP using a thin layer of glass fibre woven material. Electrical connections to the veil were made using copper tape onto which the carbon veil was bonded. Thermal excitation was provided by a inhouse designed modulation unit as described in [3].

a) Open Hole specimen b) CFRP with heating actuator c) End tabs and wiring installed

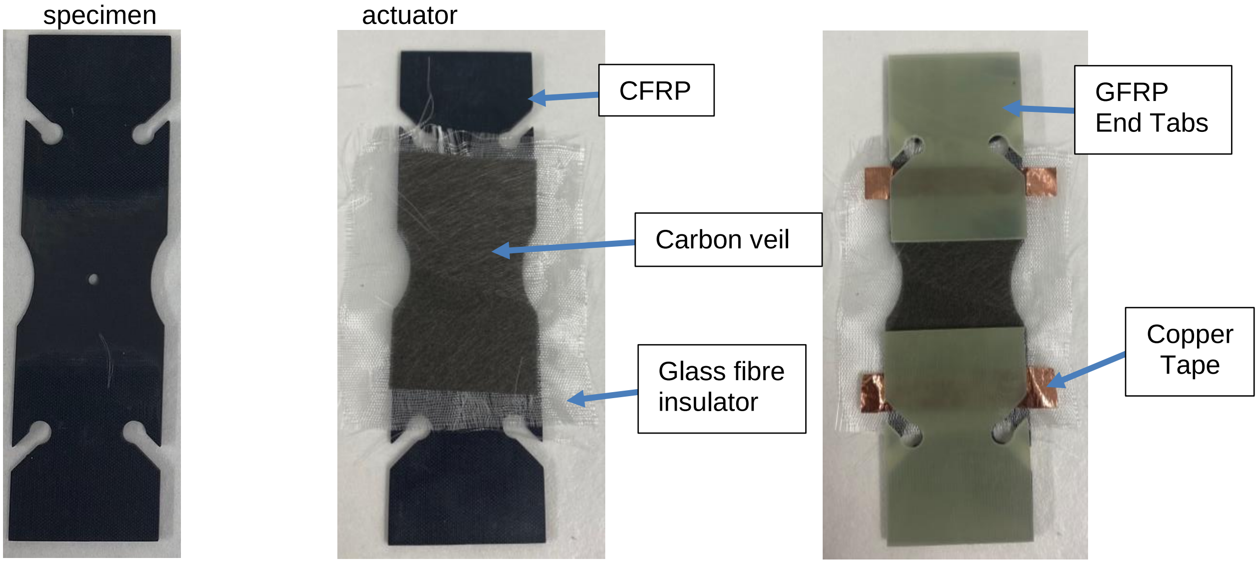

Figure 1: Specimen Configuration

The specimens were loaded into the MAF and loaded quasi-statically in load increments. The test was paused at each increment and thermal data obtained, LIT was performed under static load, for TSA a cyclic load was applied where the mean load was equal to the static load used in LIT. All thermal data was acquired using a Telops M3K FAST IR photon detector at 383 Hz frame rate and processed in a inhouse developed Matlab script.

Results

Fig 2 (a) and (b) show the phase and amplitude response respectively, calculated from the acquired thermal fields for the tension shear load case. Surface cracks are easily identified in the phase and amplitude data showing both the location and length of cracks. Around the open hole stress concentrations are apparent perpendicular to the crack propagation direction. It is unclear whether subsurface data is included since the surface stress field is indistinguishable from subsurface responses and therefore TSA is useful only for surface crack detection in this context. Fig. 3 (a) and (b) show the phase and amplitude response from LIT tests for the pure shear load case. The results show clearly delamination around the centre hole of the specimens, particularly in the phase data.

a) Phase of response (degrees) b) Amplitude of response ΔT (K)

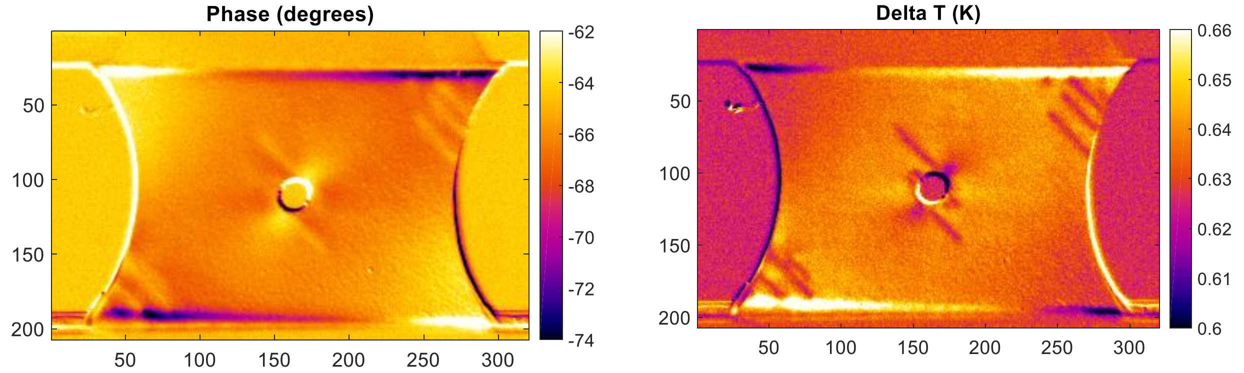

Figure 2: TSA Results tension/shear load case 10 Hz loading frequency

a) Phase of response (degrees) b) Amplitude of response ΔT (K)

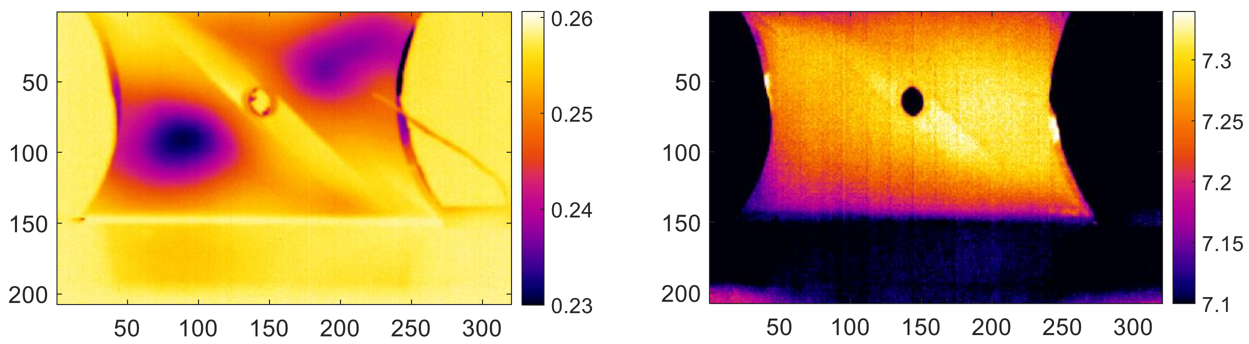

Figure 3: LIT results for pure shear load case

Conclusion

The results highlight the capability of full field thermal methods for the early identification of damage onset. The results of this work can be incorporated into validation of numerical models which could aid the development of improved failure predictions for multiaxial load cases.

References

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