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\DETECTING AND CHARACTERISING INTERFACIAL FRACTURE THROUGH THE FACE SHEETS OF SANDWICH STRUCTURES USING MIRROR-ASSISTED IMAGING TECHNIQUES

Hiu Ling Leung[1], Janice M. Dulieu-Barton[1] and Ole T. Thomsen[1]

[1]Bristol Composite Institute
Faculty of Engineering, University of Bristol, UK
Email: emily.leung@bristol.ac.uk

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ABSTRACT

Composite sandwich structures often have complicated geometry that limits optical access, which prevents deployment of full field imaging techniques, such as Digital Imaging Correlation (DIC) and Thermoelastic Stress Analysis (TSA). During testing, it is difficult to use traditional inspection approaches to internal regions where debonds may occur in the interfaces between the face sheets and core material. Here, mirrors are utilised to allow optical access to face sheets of sandwich specimens loaded in bending, so that TSA can be employed to characterise interfacial debonding through the face sheets. To separate the surface thermoelastic response, ΔT, from that generated from the interfacial regions, DIC is used to obtain the surface strains. From this, ΔT from the surface in the vicinity of a debond is estimated. The interface ΔT is then obtained by subtracting it from ΔT obtained from TSA. From this, the interfacial fracture process can be characterised.

Sandwich structures have been commonly used in a range of applications due to their high bending stiffness and strength-to-weight ratios. Damage such as face sheet wrinkling, local indentation, and face/core debonding can reduce the stiffness and strength of the structure and can lead to a catastrophic failure with no/little prewarning. Studies [1,2] have shown that the combined use of FE analysis and full-field imaging techniques, including DIC and TSA, can be used to identify the crack tip response at the face sheet/core interface and the subsequent damage progression. However, most studies have considered simple beams, so that the internal features can be observed by viewing the transverse plane of the sandwich structure. Such methodologies will not be applicable to investigating in-service structures, where the transverse plane cannot be observed without disassembling or cutting the structure. Hence, to gain an understanding of the actual sandwich structure performance, techniques are required that can monitor the damage initiation and progression from the exterior of the face sheet. Large or complex geometry structures can limit the use of full-field imaging techniques because of limited space for imaging equipment. Therefore, a mirror-assisted imaging methodology is developed to observe the face sheets and to characterise the face sheet/core interface fracture behaviour through the thin face sheets of sandwich structures.

Sandwich specimens were manufactured using 100 kg/m^3 PVC foam core (Divinycell H100 manufactured by DIAB, Sweden) and $[0]_3$ CFRP face sheets (IM7/8552), as shown in Figure 1. Teflon film was inserted between the face sheet and core to create two symmetrically located debonded regions. The face sheets were bonded to the core using adhesive film (XPREG® XA120). The debond sizes were a = 10, 20 and 30 mm. The sandwich beams were loaded in 3-point bending, where the debonded side of the specimen was facing downwards. A front-coated mirror, stereo DIC and TSA were used to detect the debonded region through the face sheets. To conduct TSA, the specimen with a=20 mm debond was loaded cyclically from 1.1 Hz to 10.1 Hz, with a mean load of -550 N and a loading amplitude of 450 N.

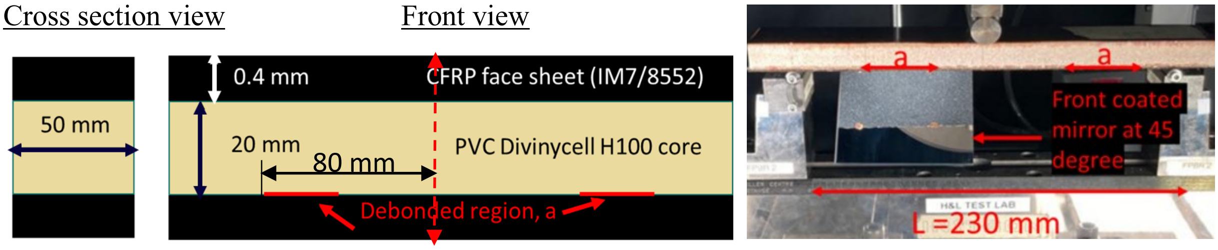

Figure 1: Sandwich specimens configuration (Left) and Mirror set up (Right)

The image on the left of Figure 2 shows the specimen loaded cyclically at 1.1 Hz, and that two regions of high ΔT of 0.04 - 0.02 K are evident at the edges of the debond. The regions of high ΔT reduce as the cyclic loading frequency increases (image to the right). This indicates that heat transfer at low loading frequencies reveals the subsurface damaged region at the interface between the face sheet and the core. DIC images were captured during the cyclic loading so that the change in strain, Δε, was obtained using the same (lock-in) algorithm as for TSA [3]. This enabled ΔT to be calculated without any effects of heat transfer which was then subtracted from ΔT obtained from the TSA to estimate the subsurface thermoelastic response.

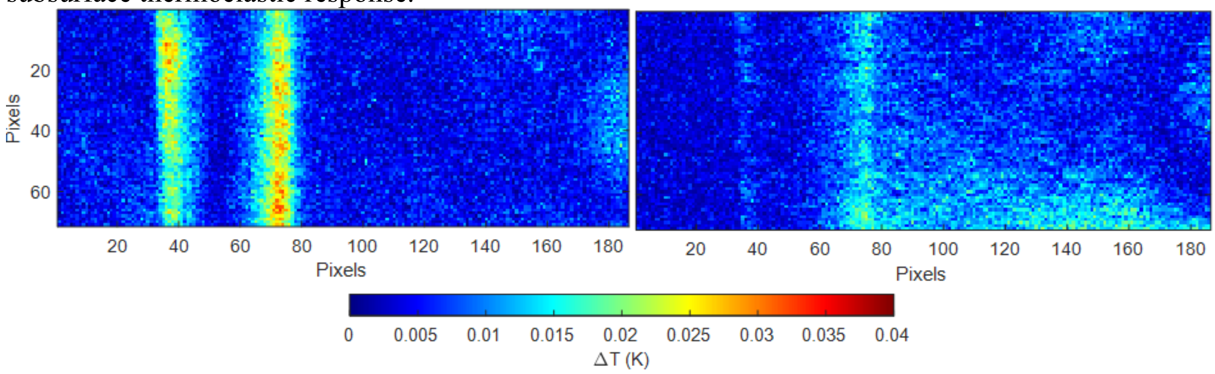

Figure 2: ΔT of 20 mm debond length specimen loaded at 1.1 Hz (Left) and 8.1 Hz (Right)

High temperature changes at the debonded region were observed through the face sheets using a thermal camera and a front-coated mirror. It was concluded that to observe the damaged region at the interface through the face sheets, heat conduction from the sub-surface is required. The stresses at the debonded region can be obtained from a FE model and be used to derive an estimate of the thermoelastic response. This thermoelastic response can be used to identify the 'real' subsurface thermoelastic responses obtained from the experiment. The stress intensity factor at the crack tip may be estimated, and the debond fracture behaviour can then be characterised through the face sheets of sandwich structures. The new approach might be used in the future to study core/face sheet debonding behaviour in composite sandwich structures through the exterior of the face sheets.

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