# Acoustic emission and passive thermography monitoring of transverse cracking in CFRP cross-ply laminates

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## Introduction

The progressive evolution of damage in carbon fibre-reinforced plastics (CFRPs) has attracted vast research interest because of its critical impact on the mechanical performance, durability, and reliability of composite structures. In particular, under quasi-static, fatigue, and impact loading conditions, the initial and dominant damage mechanism is the development of transverse matrix cracks within the laminate (an intralaminar failure mode) [1, 2].

Acoustic emission (AE) monitoring has emerged as a powerful non-destructive evaluation technique for observing damage in situ and in real time. AE techniques detect transient elastic waves produced by localized micro-failure events, offering detailed insight into the initiation and progression of damage within the material [3]. Likewise, infrared thermography provides an optical two-dimensional measurement of surface temperature fields; the thermal maps obtained can reveal localized overheating associated with damage and degradation processes [4].

One of the challenges for using the acoustic emission technique efficiently is differentiating between various damage modes, which requires characterising their distinct acoustic emission signatures [4, 5]. In this study, AE and passive thermography are combined to advance understanding of matrix cracking evolution and to corroborate AE-based damage assessments.

## Methodology

Acoustic emission and passive thermography were utilized during quasi-static uniaxial tensile testing to examine the initiation and propagation of matrix cracking in two distinct cross-ply laminates with layups of $[0_3/90_6]_S$ and $[0_2/90_6/0]_S$. Two infrared cameras were used to track damage, a cooled sensor infrared camera (Telops FAST M3k) on the side opposite of the mounted acoustic emission sensors, while an uncooled microbolometer (InfraTec VarioCam HD) was utilised on one of the specimen's free edge. The experimental set-up can be observed in Fig.1.

The infrared camera on the specimen's surface captured sub-surface matrix cracking, while the other captured the cracking development on the side of the specimen. The temperature signal acquired from both thermal cameras was post-processed to identify the spatial and temporal distribution of cracks through temperature rise measurements. The matrix cracking was additionally observed using an in-house AE system with two wideband sensors. In Fig.2, the correlation of the thermal and the acoustic emission data is shown, as the first crack transverse crack detected from both thermal cameras is aligned with the first acoustic emission activity (described from the two acoustic emission damage indicators, cumulative absolute energy, and cumulative counts).

## Conclusion

Preliminary results demonstrate that integrating acoustic emission (AE) with passive thermography offers a robust approach for investigating the initiation and evolution of matrix cracking in composite materials. The synergistic use of thermal and acoustic data enables a detailed characterization of damage mechanisms. Moreover, the identified acoustic signatures associated with matrix cracking present a valuable basis for training machine learning algorithms aimed at automated damage classification.

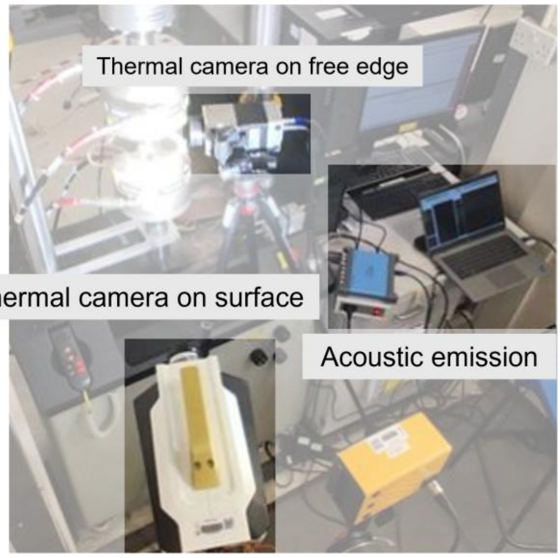


**Figure 1. The experimental set-up highlighting both the thermal cameras monitoring, the front surface and the free edge of the specimen, and the acoustic emission equipment.**

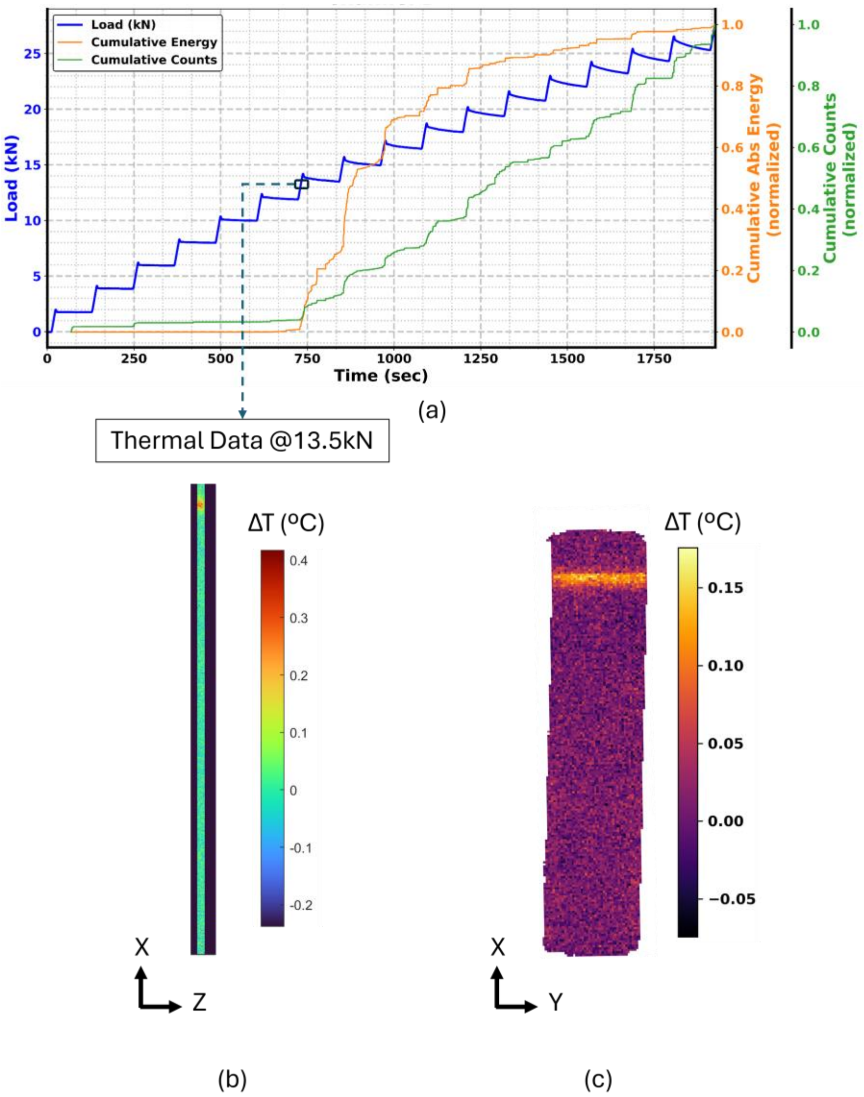


**Figure 2. Experimental results for a $[0_2/90_6/0]_S$ laminate specimen: (a) time evolution of the load and the acoustic emission features (cumulative absolute energy, and cumulative counts), map of temperature difference (b) for free edge, and (c) for the surface of the first transverse crack.**

## References


1. Nairn, J.A., *2.12 - Matrix Microcracking in Composites*, in *Comprehensive Composite Materials*, A. Kelly and C. Zweben, Editors. 2000, Pergamon: Oxford. p. 403-432.
2. Abrate, S., *Matrix cracking in laminated composites: A review.* Composites Engineering, 1991. **1**(6): p. 337-353.
3. Unnthorsson, R., *Hit Detection and Determination in AE Bursts*. 2013. p. 1-19.
4. Munoz, V., et al., *Damage detection in CFRP by coupling acoustic emission and infrared thermography.* Composites Part B: Engineering, 2016. **85**: p. 68-75.
5. Cuadra, J., et al., *Damage quantification in polymer composites using a hybrid NDT approach.* Composites Science and Technology, 2013. **83**: p. 11-21.