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Failure of Aerospace Composites under Compressive Load in Fire

A.G. Gibson, G. Kotsikos and P. Di Modica

Stephenson Building, Newcastle University, Newcastle upon Tyne NE1 7RU UK.

Main Message. This paper discusses the modelling of failure times of aerospace carbon-epoxy laminates under constant in-plane compressive stress and one-sided heat flux. These are conditions relevant to post-crash fires and similar occurrences. The thermal field within laminates exposed to fire can be modelled using the Henderson Equation, as, for instance, with the COM-FIRE model. The main difficulty lies in acquiring the necessary mechanical data to model the failure event under these conditions. Large numbers of mechanical measurements over a temperature range well beyond Tg, are not a practical option. Instead, the measurement of simple matrix-influenced properties, was investigated: compressive strength (CS), interlaminar shear strength (ILSS) and Young's modulus from dynamic mechanical analysis (DMA). It was found that these properties do not all follow the same property vs. temperature law. The strength-influenced properties (CS and ILSS) behave similarly and drop off more rapidly as a function of temperature than the Young's modulus. For the mechanical modelling an average strength approach was used, which, combined with the thermal modelling, gave reasonable predictions of the time-to-failure for laminates 5-15mm thick and heat fluxes of 75-185 kW/sq.m. It is proposed that, by expressing stress as the ratio of applied stress/failure stress, it should be possible to use the same model for laminates with different ply sequences.

Keywords: carbon fibre epoxy, fire behaviour, compressive failure.

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Introduction

This work relates to modelling the times-to-failure of CFRP laminates held under constant compressive load and exposed to constant heat flux. Fig. 1 shows an example of the modelled thermal profile for one particular laminate thickness and heat flux. To support the modelling, time-to-failure experiments under fire exposure were performed on laminates with quasi-isotropic (QI) ply sequences. To examine the use of thermo-mechanical data for modelling purposes, three single point properties were measured vs. temperature: compressive strength (CS) interlaminar shear strength (ILSS) and ply transverse modulus. These were normalised and modelled with a previously reported relationship. Using normalised property values, the laminate average strength was calculated vs. fire exposure time, and used to predict the times to failure.

Results and Discussion

Figure 2 shows normalised property values vs. temperature fitted by Equ(1), in which *k* and Tg were constants. CS and ILSS behaved similarly, with Tg of 127ºC. In contrast the modulus fell away less rapidly an did not fit Equ.(1).

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(1)

The failure times in fire were modelled using Equ(1) to calculate the average remaining strength from the thermal profiles, and the predicted and experimental results are compared in Fig. 3.

References 1. Gibson, A.G., *et al.*, J. of Composite Materials (2012) 46(16) 2005–2022.

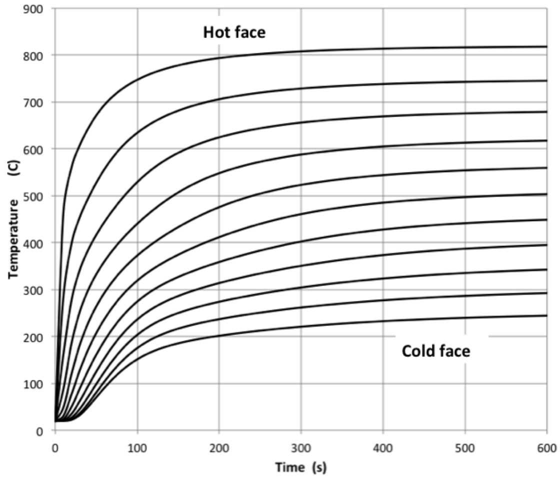

Figure 1. Example of aCOM-FIRE modelled thermal profile for a 9 mm thick CFRP laminate, exposed to a one-sided heat flux of 116 kW/sq.m, with cold face open to air.

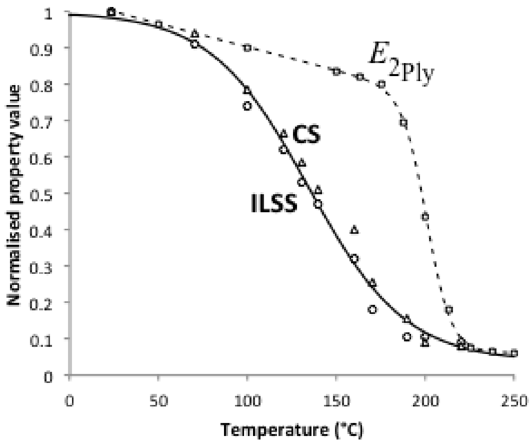

Figure 2. Normalised property values for a 5 mm thick CFRP laminate. CS: Compressive strength; ILSS: interlaminar shear strength; E2ply: DMTA transverse modulus for a unidirectional ply.

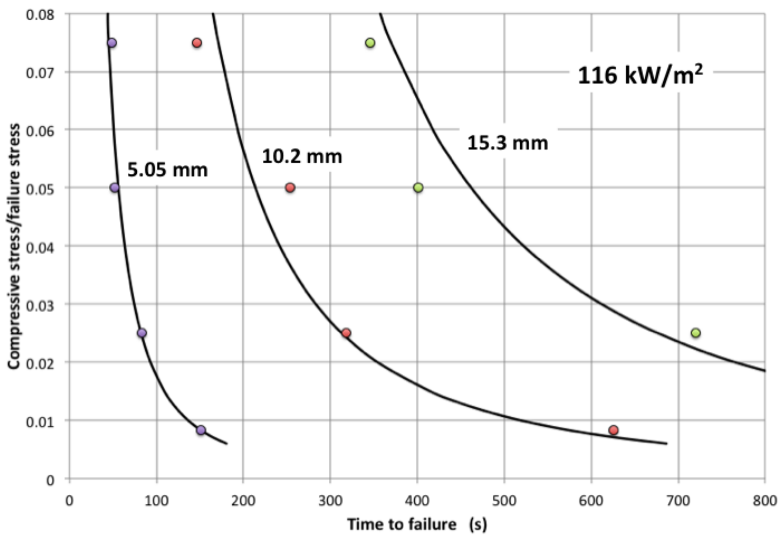

Figure 3. Experimental and modelled time-to-failure of laminates of 3 different thicknesses: 5.05, 10.2 and 15.3 mm, exposed to a heat flux of 116 kW/sq.m. Modelled curves employ the CS/ILSS relationship from Fig. 2.