EFFECTS OF TEMPERATURE ON FIBER TENSION FRACTURE TOUGHNESS OF COMPOSITE LAMINATES AT HIGH LOADING RATE

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Abstract
The understanding of fracture toughness associated with fibre dominated tensile failure is of great important for safety design of composite structrures threatened by extreme loading conditions, such as high/cold temperature and high rate loading. The dynamic fracture toughness of composite laminates in fibre tension is characterized under different temperatures (e.g. -55 °C, 23 °C and 90 °C) with compact tension (CT) sample, at loading rate of 8 m/s using a tension Hopkinson bar intergrated with a experimental chamber. Digital image correlation (DIC) with high-speed imaging is employed for obtaining the full-field strain fields and crack tip location.

1. Introduction
It is understood that the unidirectionally-reinforced (UD) composite materials during their life cycles will undergo thermal cycling and mechanical fatigue in wet conditions that would lead to the deterioration of a component's mechanical properties and its capability to withstand impact threats such as bird or ice impact. limitation of compoisite remains its brittle response to impact in harsh, thermal and mechanical environments – such as those in aerospace and aviation applications. This paper aims to capture the failure mechanisms when composite laminates are subjected to impact loading and at temperatures relevant to service (-55°C, 90°C). The ultimate goals are to delineate and to characterise the role of temperature on fibre debonding and fibre breakage as they occur during impact loadings.

2. Results
Dynamic compact tension tests were performed using a tension Hopkinson bar intergrated with an experimental chamber and a ultra-high speed camera at 1000000 fps. The highlights are described as below:

a. The pososed DIC method is capability of capturing the real-time crack tip postion with different crack propagation behavior induced by temperature and high-rate loading. Further calculation in fracture toughness are possible by the precision determination of crack length, pin opening displacement and force history.
b. Effect of temperature was systematically explored and was shown to be an important factor in fibre tension fracture toughness of composites. It was shown that increasing temperature significantly affect the dynamic initiation fracture toughness of composites.
c. The failure mode is dominated by the fibre failure within the expected crack regions. For room and high temperatures, one main crack initiates and propagates during the dynamic loading, while several secondary cracks generated near the main crack at lowing temperature.

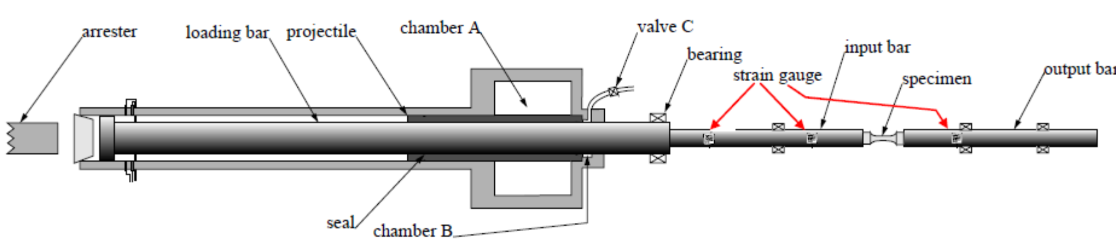

Fig.1 – Split Hopkinson tension bar (SHTB) for tensile loading

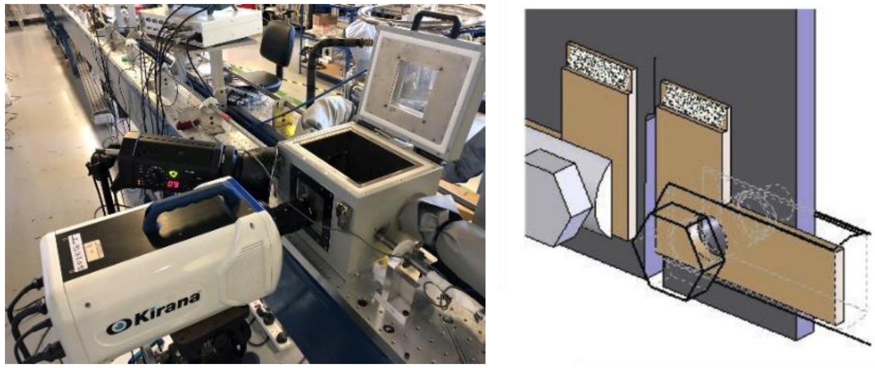

Figure 2 Ultra-high speed camera, environmental chamber and ‘displacement tracker’ to allow for a DIC-based determination of the opening displacement

Effects of temperature on the force-pin opening displacement curves and energy release rate in CT composite laminates were shown in Fig. 3. The impact velocity is 8 m/s and the temperatures during these tests are -55 °C, 23 °C and 90 °C, respectively. It is observed that fiber tension fracture toughness is greatly dependent on the temperature, it increases with temperature from cold (-55 °C) to hot (90 °C) condition. An increase in temperature promoted ductility in the epoxy and toughened phase ductile flow, leading to an overall increase in peak force and fracture toughness. The cold condition promoted the brittle of the epoxy and cleavage of the toughened phase. The cold/wet condition excerbrated plucking of the toughened phase, resulting in a lower fracture toughness.

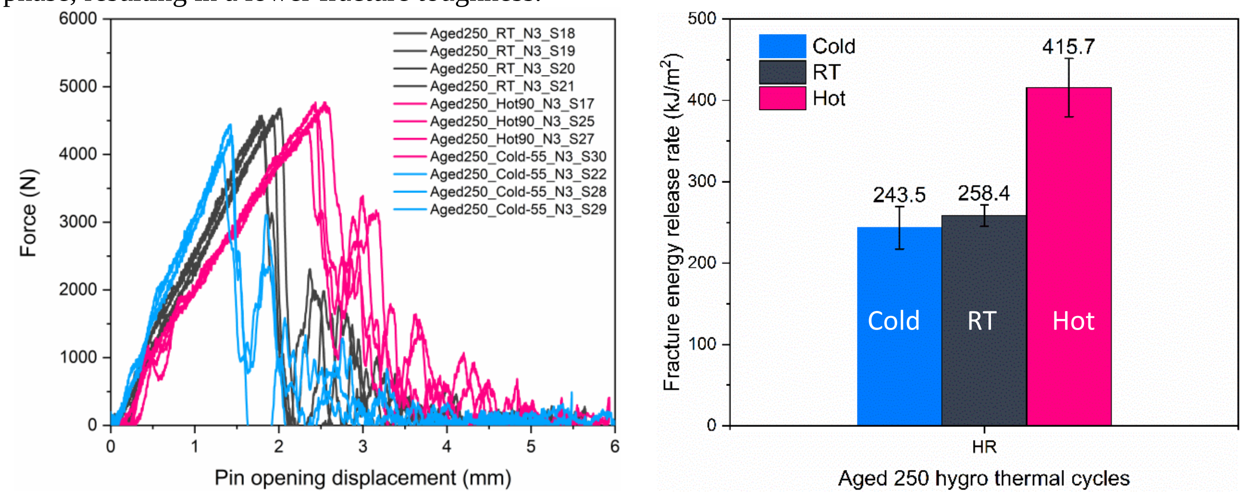

Fig.3 – Deformation and energy realease rate of composite under high-rate compact tention and different temperatures (e.g. -55 °C, 23 °C and 90 °C)

3. Conclusions

Compact tenion testing methodologies integrating split Hopkinson tension bar with digital image correlation (DIC) and environmental chamber are promising for measuring the fibre tensile fracture toughness of composites. Fibre dominated tensile fracture toughness and crack modes are dependent by the loading rate and temperature. It may well be layup dependent and further investigation is required.

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