CRACK ARREST IN FINGER JOINTED THERMOPLASTIC PES INTERLEAVED CFRC

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ABSTRACT

Pre-cut unidirectional carbon fibre prepreg (M21/194/34%/T800S) composites were tested in tension with a 20 mm overlapped finger joint architectures. In between the overlapping finger jointed region the effect of introducing polyethersulfone (PES) interleaves is investigated. Samples with the addition of a thick PES interleave arrested the initial crack which formed at the pre-cut site. The strain-to-failure of the thick PES interleaved samples was over 3.2%, an increase of 85% compared to the baseline samples, and catastrophic failure was delayed in the majority of instances.

1 INTRODUCTION

Interleaved composites have shown promise in altering the failure mode(s) of composites and offer a facile approach to modify traditional carbon fibre reinforced composites (CFRCs). The addition of thermoplastics has been shown to enable easy repair [1], as well as controlled alteration of the stiffness upon heating [2]. The addition of a tough thermoplastic interleave in a CFRC is expected to improve shear properties in tension in matrix dominated failures/configurations [3]. This investigation follows previous methodology for unidirectional discontinuous carbon fibre/epoxy prepreg composites for introducing pseudo-ductility [4].

2 EXPERIMENTAL

2.1 MATERIALS

- Unidirectional carbon fibre prepreg, M21/194/34%/T800S, Hexcel (GB)
- Epoxy film, M21 resin, 35 gsm, item recipe# B910330, batch# F367695B03, 2000-04-15, Hexcel (GB)
- Thermoplastic polyethersulfone (PES), 50 µm and 20 µm films, LITE S, LITE (Lipp-Terler) GmbH (AT)

2.2 COMPOSITE ARCHITECTURES

The composites tested are schematically shown in Figure 1 with details provided in Table 1. The tensile specimens in all instances were 200 mm x 25 mm, with sample thickness dependent on the interleave architecture.

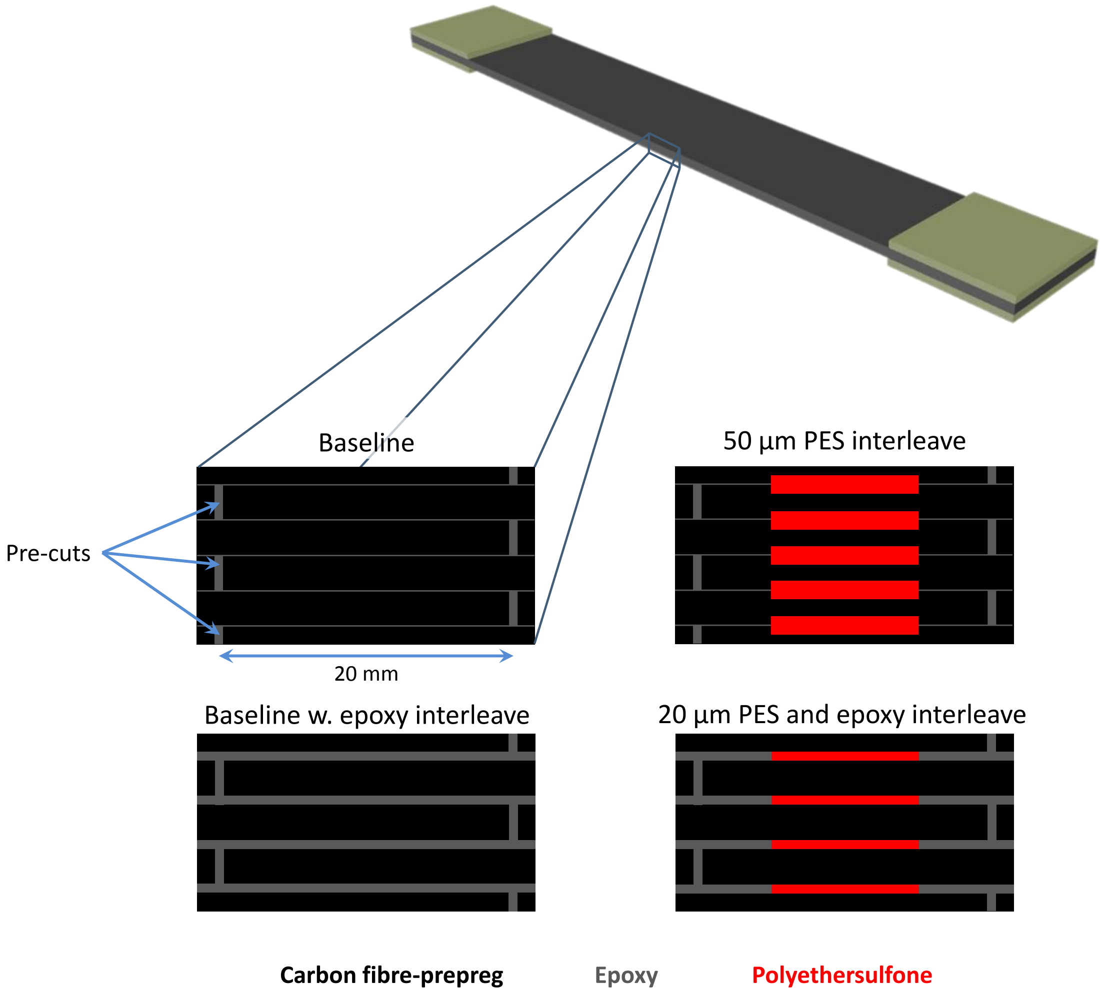

Figure 1: Schematic representation of the cross sections of finger joint architecture samples with/and without epoxy or PES interleaves. N.B. All of the carbon fibres in the finger joint arrangement were cut, such that no fibre(s) span the full length of any sample.

Sample lay-up;

Baseline laminate	$[0_L/0_R]_{3S}$
Baseline w. laminate	$[0_L/E_R/0_R]_{3S}$
Hybrid PES interleave laminate	$[0_L/PES/0_R]_{3S}$
Hybrid PES interleave w. epoxy fillets laminate	$[0_L/PES{+}ER/0_R]_{3S}$

With cuts in prepregs indicated on the left or right of centre as L and R respectively.

Table 1: Sample nomenclature, with PES and epoxy architecture.

Sample	Finger Overlap (mm)	CF prepreg cutting method	PES			Epoxy fillets	Average thickness (mm)
			Thickness (µm)	Width (mm)	Cutting method		
Baseline	20	Laser milled	NA	NA	NA	No	2.18
Baseline w. epoxy fillets	20	Knife cut	NA	NA	NA	Yes	2.32
Hybrid 50 µm PES interleave*	20	Laser milled	50	10	Laser milled	No	2.27 (2.42)
Hybrid 20 µm PES interleave w. epoxy fillets	20	Knife cut	20	10	Laser milled	Yes	2.32

* Sample bulged in the central region due to the interleaved material, with the central regions thickness provided in parentheses. The strength of hybrid 50 µm PES interleave samples were processed using the central region thicknesses.

2.2 COMPOSITE PREPERATION AND TEST EQUIPMENT

Precision cuts for the PES or prepreg were made either through laser milling or by an automated conveyorized cutter (Figure 2), using Micro Machining System with galvanometer laser, diode current 30 A, pulse frequency 30 kHz, Oxford Lasers (GB) and Genesis 2300 Blackman & White (GB), respectively. Location holes were used to ensure alignment was controlled during consolidation. Samples were cured according to manufacturer recommendations in an autoclave, LBBC Technologies, Leeds and Bradford Boiler Company Limited (GB). Cured panels were cut on a Waterjet, FlowWaterJet Mach 2 (203 lb) using FlowMaster V6, Flow (GB). Samples were end tabbed with glass-epoxy 50 mm x 25 mm x 1.5 mm with 2011 Araldite adhesive, Huntsman (USA).

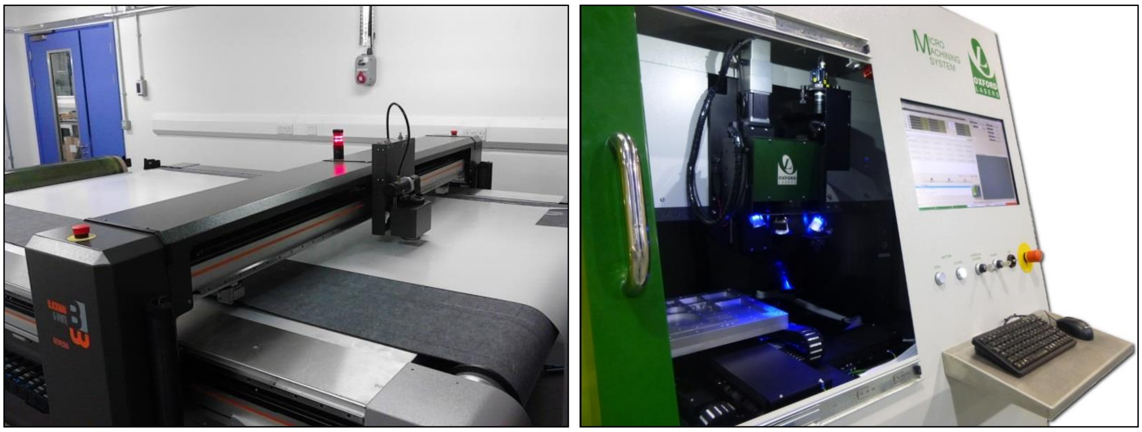

Figure 2 Automated conveyorized cutter (left) and laser milling unit (right).

Instron 5985, 250 kN load cell (manual vice 100kN grip) used with BlueHill3 software V3.41.2350 and a cross-head speed of 2 mm min^{-1} in combination with optical video gauge (Figure 3). Optical video gauge iMETRUM MG223B PoE E0022522 from iMETRUM Ltd (GB) using a iMETRUM general lens, focal length 50 mm, triggered to record in sync with Instron 5985 using an iMETRUM multifunction box, NI USB 6211 and processed using the associated iMETRUM Video Gauge Software V5.3.2. Video gauge points of reference were lines made on the composite using white fine tip paint pen (751-049, Edding (GB)) which were lit using an LED array (Microbeam 512, Flolight, USA).

Figure 3: Instron 5985 with optical video gauge.

3 RESULTS

3.1 TENSILE TEST

Pre-cut baseline samples when compared to (uncut) unidirectional CFRC have a reduced stiffness and strength (ca. 60% lower for both, Figure 4, left), as expected, but have a similar strain-to-failure, 1.6%. Samples with the addition of a thick PES interleaves, however, arrested the initial crack (Figure 4, right) which formed at the pre-cut site at approximately 1.6% strain. The sample, then extended by approximately 1%, relaxes and carries further load showing a strain hardening response until failure. The strain-to-failure of the thick PES interleaved samples was over 3.2%, an increase of 85% compared to the baseline samples, and catastrophic failure was delayed in the majority of instances. This crack arrest mechanism was also observed for the hybrid 20 µm PES/epoxy interleave; however, it was less common and delays before failure were shorter. The initial strength and stiffness of specimens with 20 µm PES interleaves were comparable to baseline. Baseline with epoxy interleaves indicated no overall strength loss through interleave addition when compared to Baseline. Toughness (area under stress-strain curve) is comparable for hybrid interleaved specimens to (uncut) unidirectional CFRC and an increase over the baseline samples on the order of 160% to 250%.

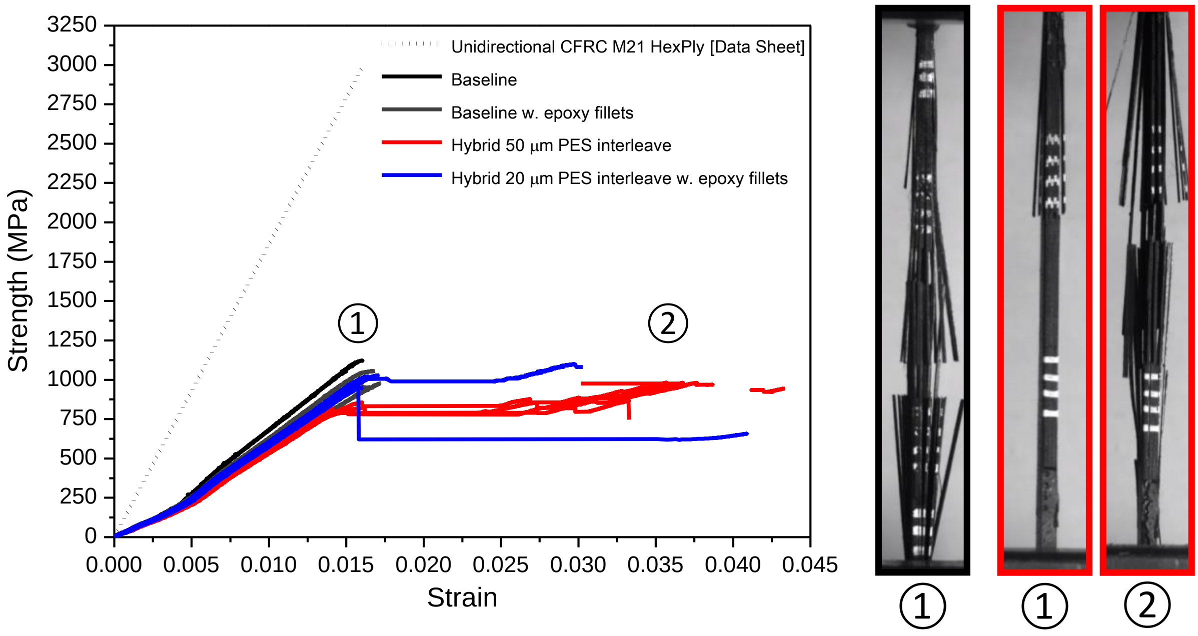

Figure 4: Tensile tests with a comparison to unidirectional CFRC (uncut, data sheet value). ① and ② indicate the points on the stress-strain curves shown in the adjacent photographs for baseline (black) and hybrid 50 µm PES interleave (red) samples.

4 CONCLUSIONS

The use of thermoplastic polyethersulfone as an interleave in finger jointed composites has shown to arrest cracks and improve the toughness (area under stress-strain curve) in addition to improving strain-to-failures above 3.2%. The specific use of this embodiment could be to toughen regions in composites which require the overlap of prepregs and with further developments, for example, multiple/modified overlapped regions, or alternative interleave materials, the approach could be exploited to yield a high performance yet (pseudo)ductile response under tension.

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