Enhanced composite T-joint energy dissipation using laser patterning strategy

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Introduction

Internal aircraft structures such as ribs, spars and stringers are required to be connected and must be able to transfer loads to the skin. Metallic joints require bolts and rivets which cause weight penalties and stress concentration. Composite T-joints allows the connection of structural components while maintaining low weight and high toughness.

Objectives

- Investigate the efficacy of a novel CO_2 laser pre-treatment on the toughness of CFRP T-joints.
- Understand the failure mechanisms in toughened CFRP T-joints considering different surface ply orientations.

Methods

CFRP T-joints were manufactured by using unidirectional carbon fiber prepregs composed of toughened epoxy resin and carbon fibers. After a general peel-ply treatment, the adherents experienced CO_2 laser treatment. We applied laser treatment with two different energy, low and high, to create laser pattern of cleaning, LC, and ablation, LA, treatment as shown in Fig. 1. Upon the laser treatments the stiffeners and skins were secondary bonded using an Araldite 420 A/B adhesive and mechanical tested using pull-off tests.

The baseline joint, where peel ply treatment was applied is nominated as "**PP**". The laser patterned joint, where the alternative high and low laser power was applied, is nominated as "**B5G5**".

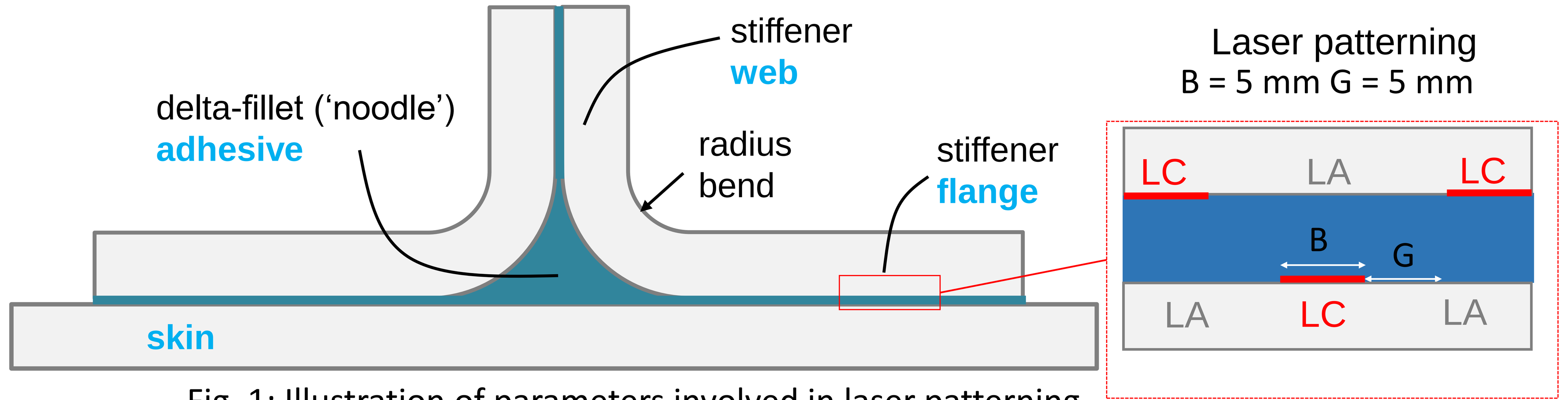

Fig. 1: Illustration of parameters involved in laser patterning

Results

High surface roughness profile fluctuations were noticed at LC treated regimes, but low profiles were observed at LA regimes.

SEM shows how the high fluence LA treatment exposed fully the fibers as compared to LC which minorly removed contaminants from the surface.

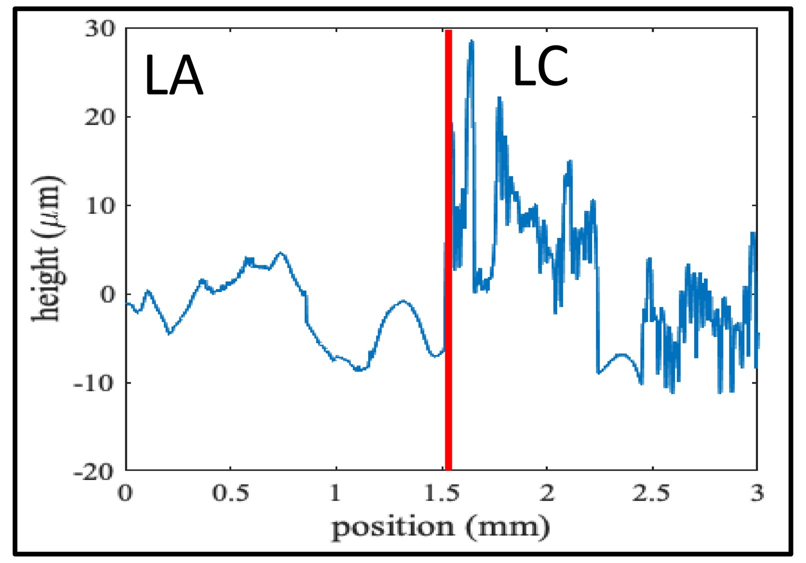

Fig. 2: Surface profilometry result at LA-LC interface

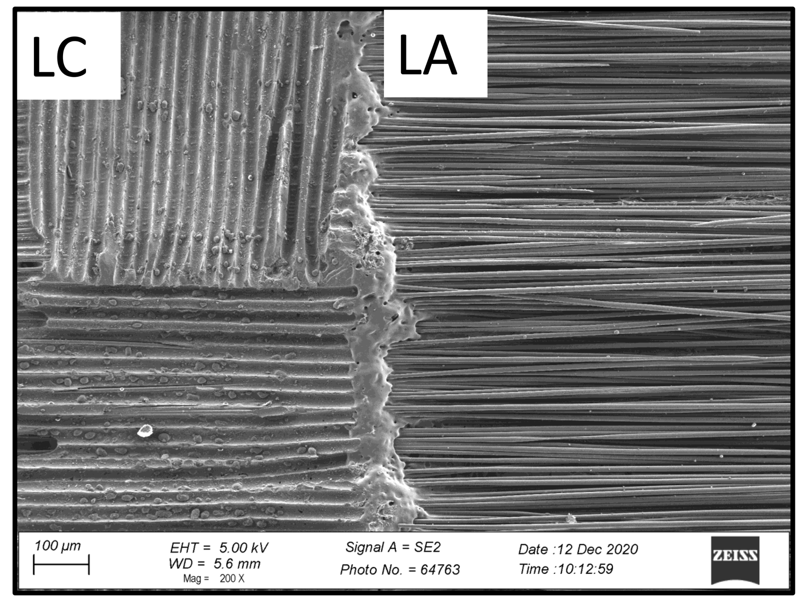

Fig. 3: SEM image taken at LA-LC interface

PP baseline resulted in catastrophic failure at low extensions (4 mm). However, the laser treated T-joints showed progressive failure with improved toughness and extensions. The maximum load and extension for B5G5 joint reach 1712 N and 17.8 mm, respectively, compared to 805 N and 4 mm for PP joint.

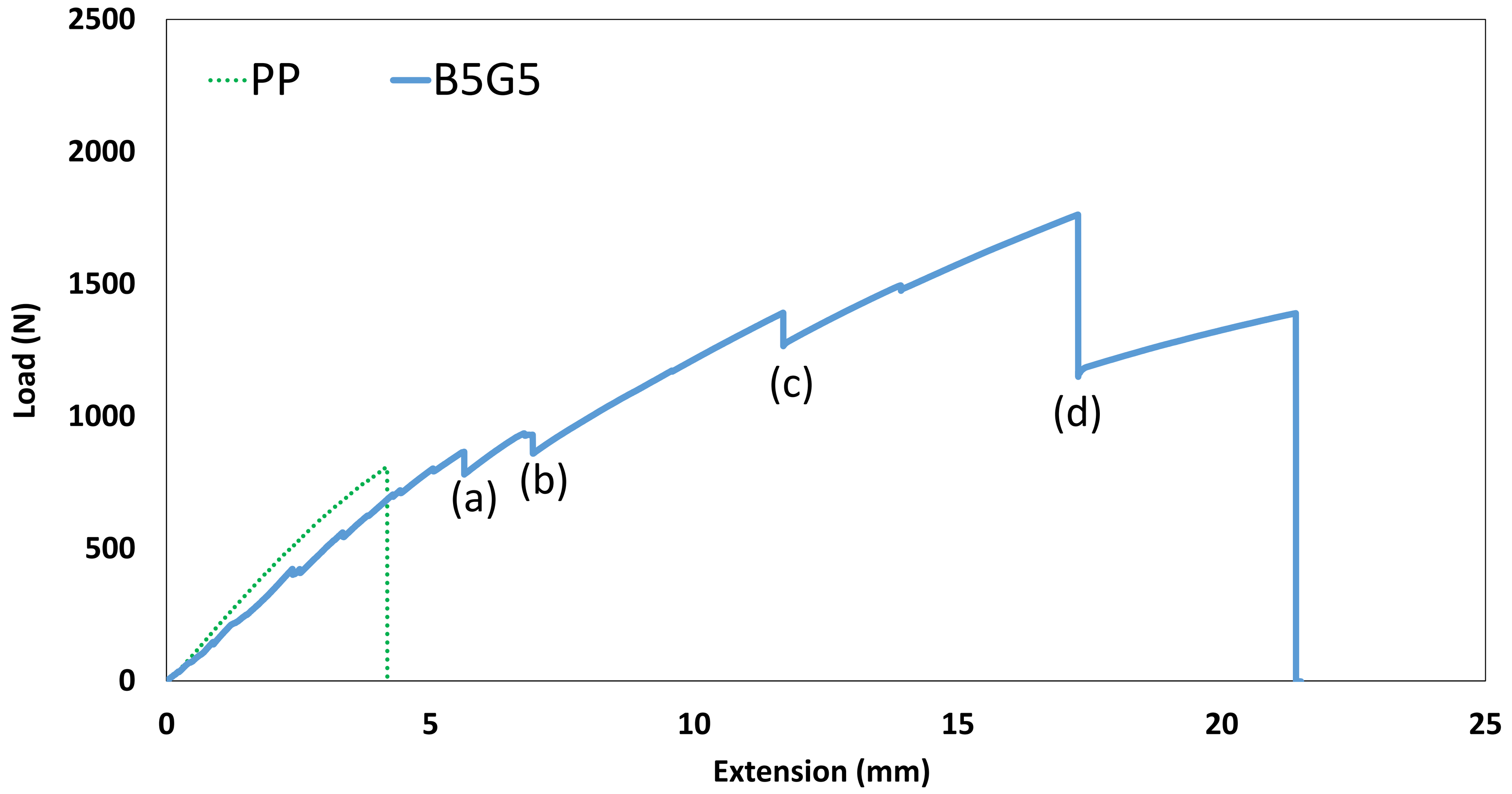

Fig. 4: $P - \delta$ curves of the B5G5 design compared with the baseline PP

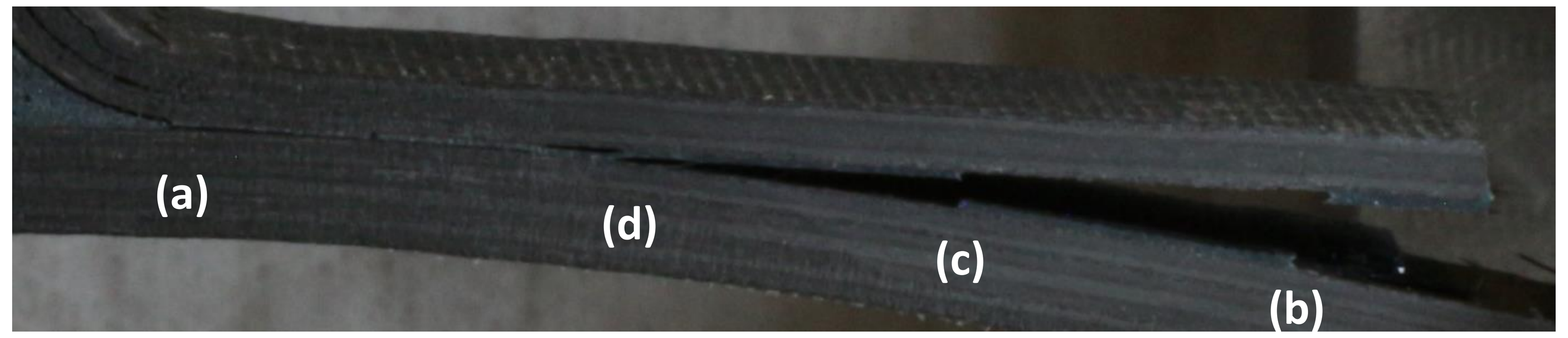

Fig. 5: In situ damage modes in B5G5 joint.

Discussion

The enhancement observed for B5G5 T-joints was related with the creation of adhesive ligaments between the top and bottom adhesive layers (Fig. 5). The adhesive ligaments were generated at the transition between LA and LC treatment due to the difference in roughness between both treatments as shown in Fig. 2, which arrest the crack propagation at one interface allowing crack migration to the other interface. The effect of laser patterning was optimised when a 0° ply fiber direction was placed at the interface.

Owing to the crack migration, the ligament formation and breakage during testing, progressive failure occurred in B5G5 T-joints with larger improvements in the energy dissipation (toughness) reaching 12 times larger than the conventional PP treatment.

Conclusions

- Laser pre-treatment provided enhanced toughness and energy dissipation as compared to PP.
- Laser patterning resulted in up to ~12x enhanced energy dissipation by the activation of non-local damage mechanisms which produced progressive failure indicating safter joints.

Mjed Hashem; Ahmed Wagih; Gilles Lubineau. 'Laser Based Pre-treatment of Secondary Bonded Composite T-joints for Improved Toughness and Energy Dissipation'. To be Submitted

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