Experimental challenges in DCB testing of thin composite laminates

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Online Workshop 'Mode I interlaminar fracture toughness and the factors affecting it'
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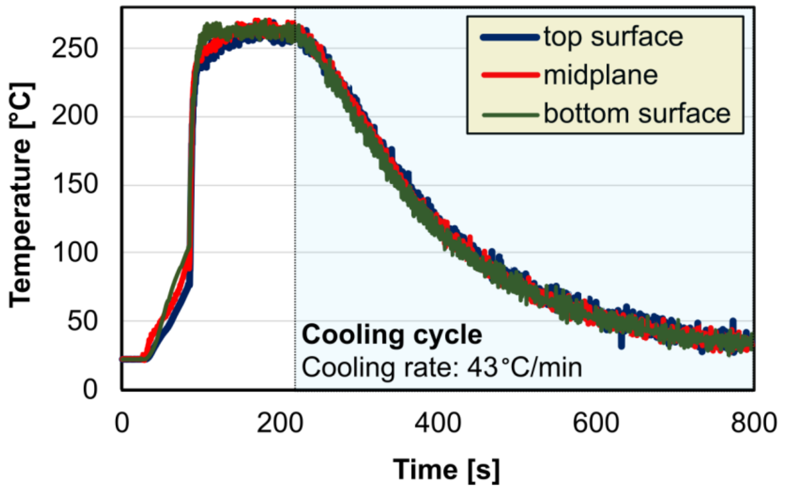
KU LEUVEN
MATERIALS ENGINEERING

Composite materials group

Thin composite laminates

Need for thin laminates

- Material savings
- Manufacturing thermal history that can be assumed isothermal through the thickness, which is essential for semi-crystalline polymers, whose material crystallinity is crucial in mechanical and interlaminar properties.



Reasons to test thin laminates (and not following the ASTM thickness)

- Make sure about uniform cooling rate across the thickness
- Representativeness for those applications where thin laminates are needed

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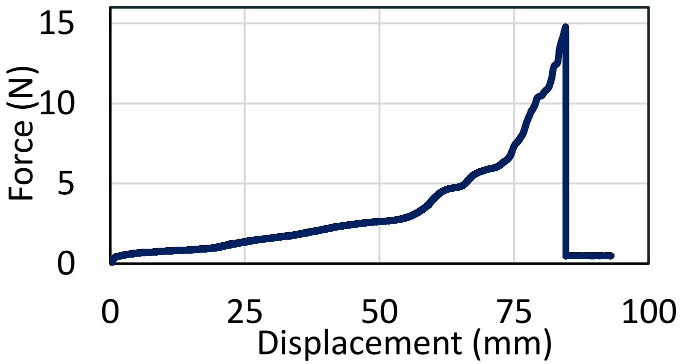
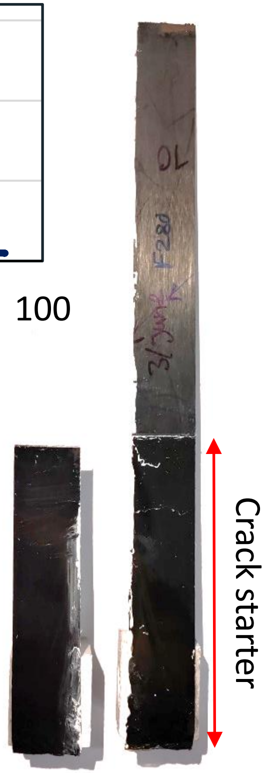
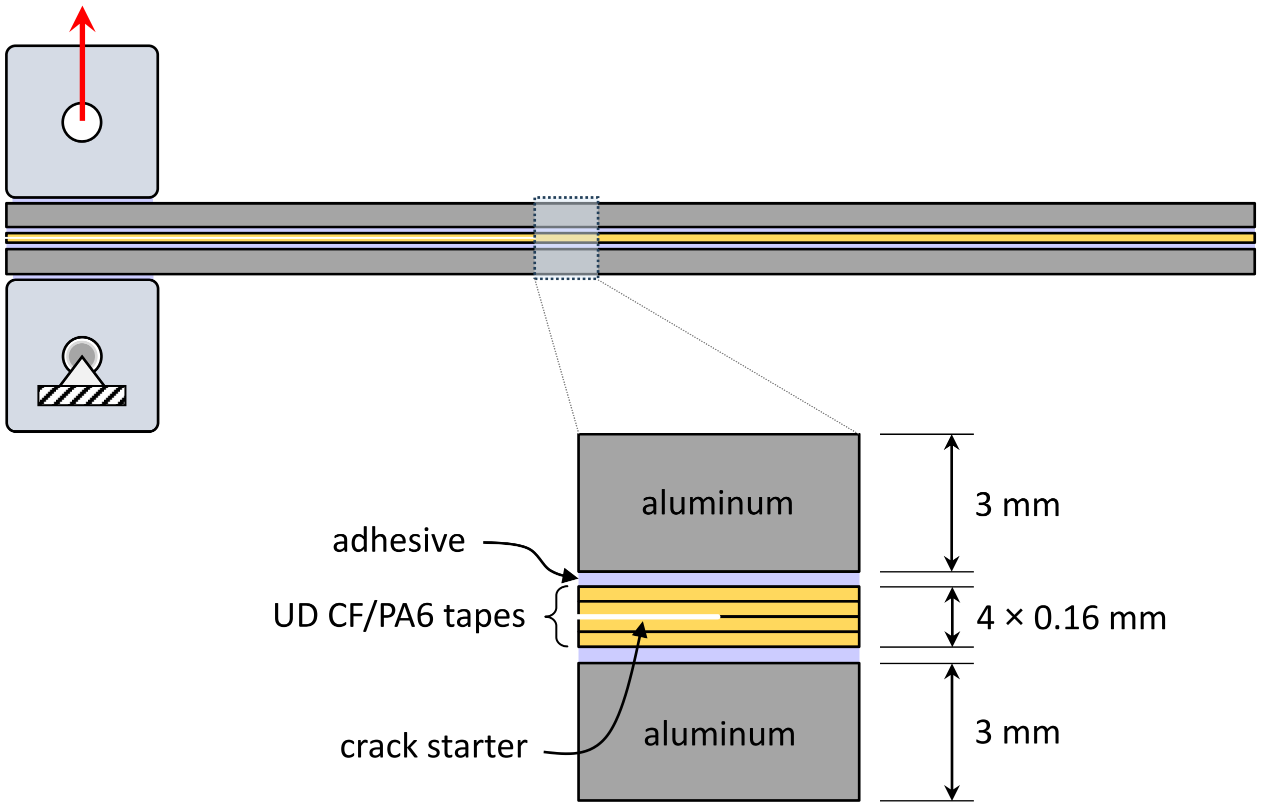
Material yielding or sudden breakage







80 mm extension, no crack initiation →
sudden arm break occurred

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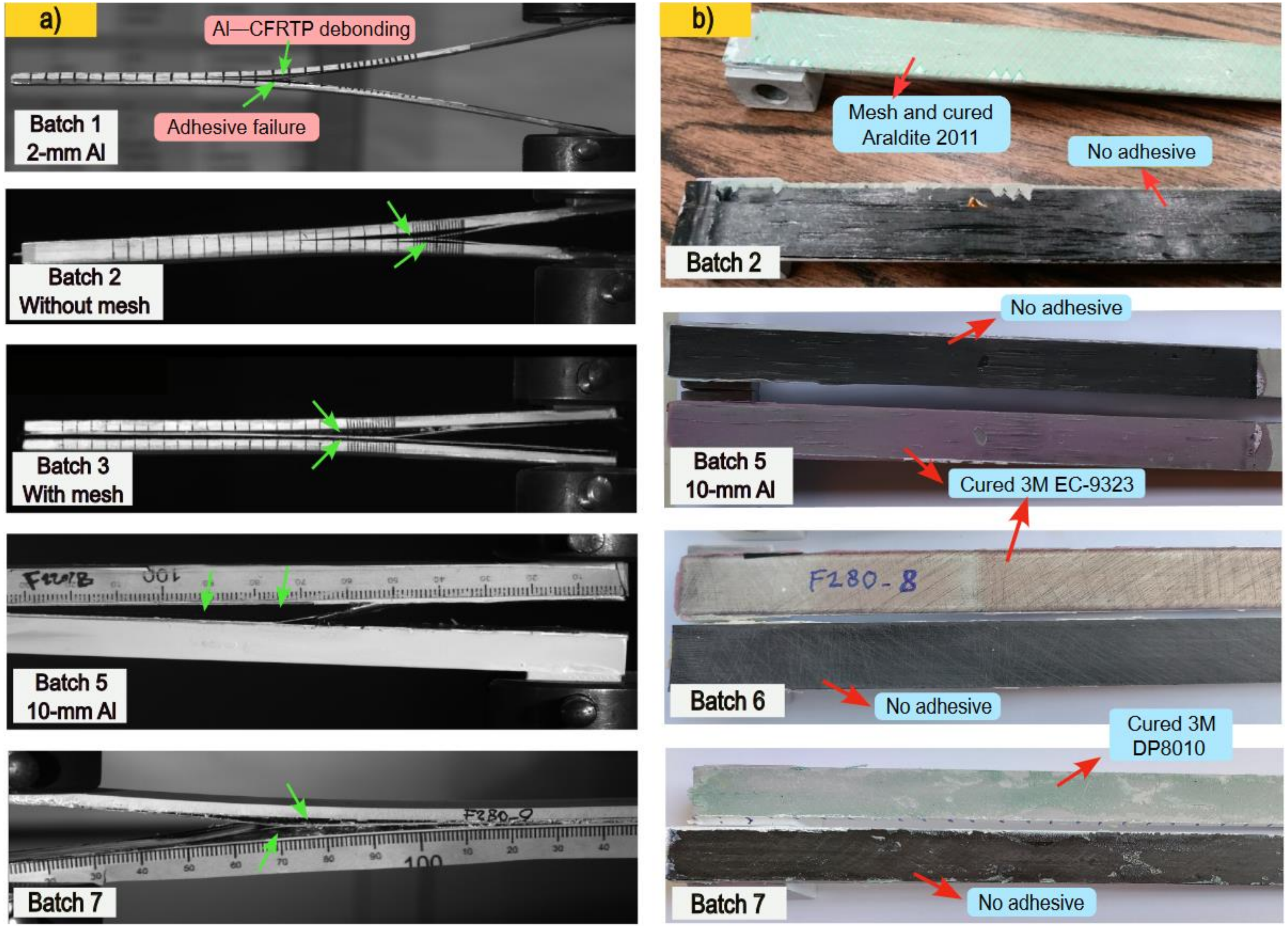
Adhesion issues to the stiffeners

- Low surface energy and wettability issues
- CF/PA6 thermoplastic fracture toughness is higher than most of the (thermoset-based) adhesives, and crack initiation at the Al–CFRTP interface is inevitable



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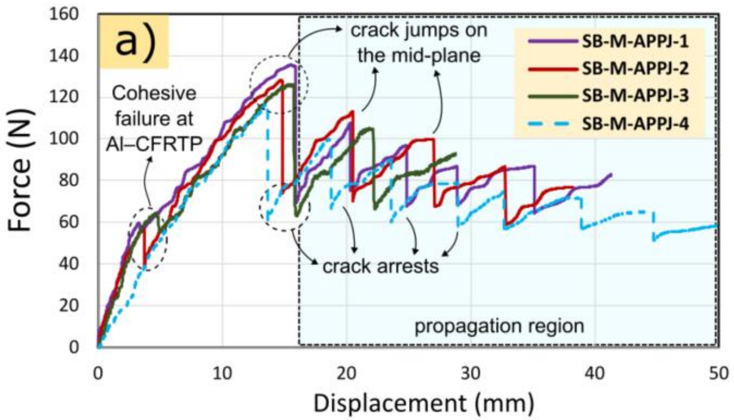
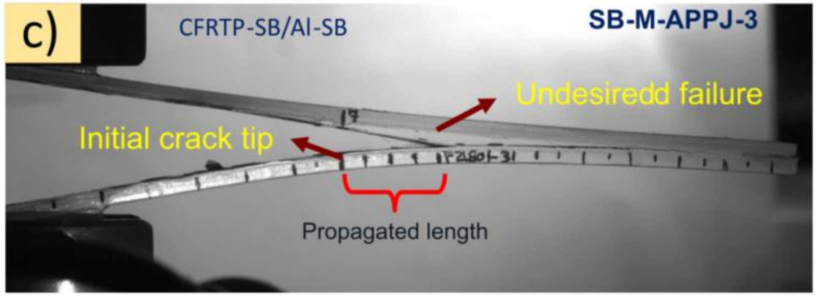
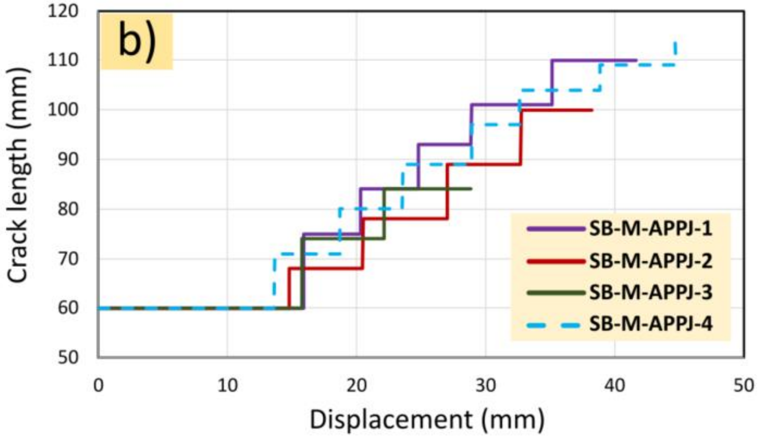
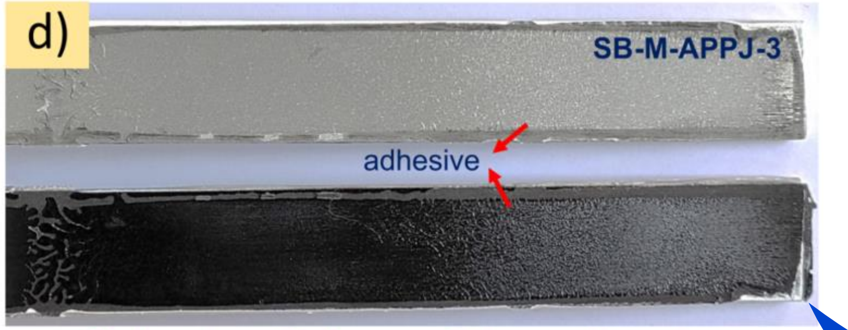
Atmospheric pressure plasma jet (APPJ) treatment

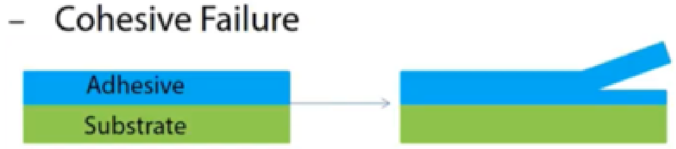








Cohesive failure of the adhesive



The composite interface is tougher than the adhesive

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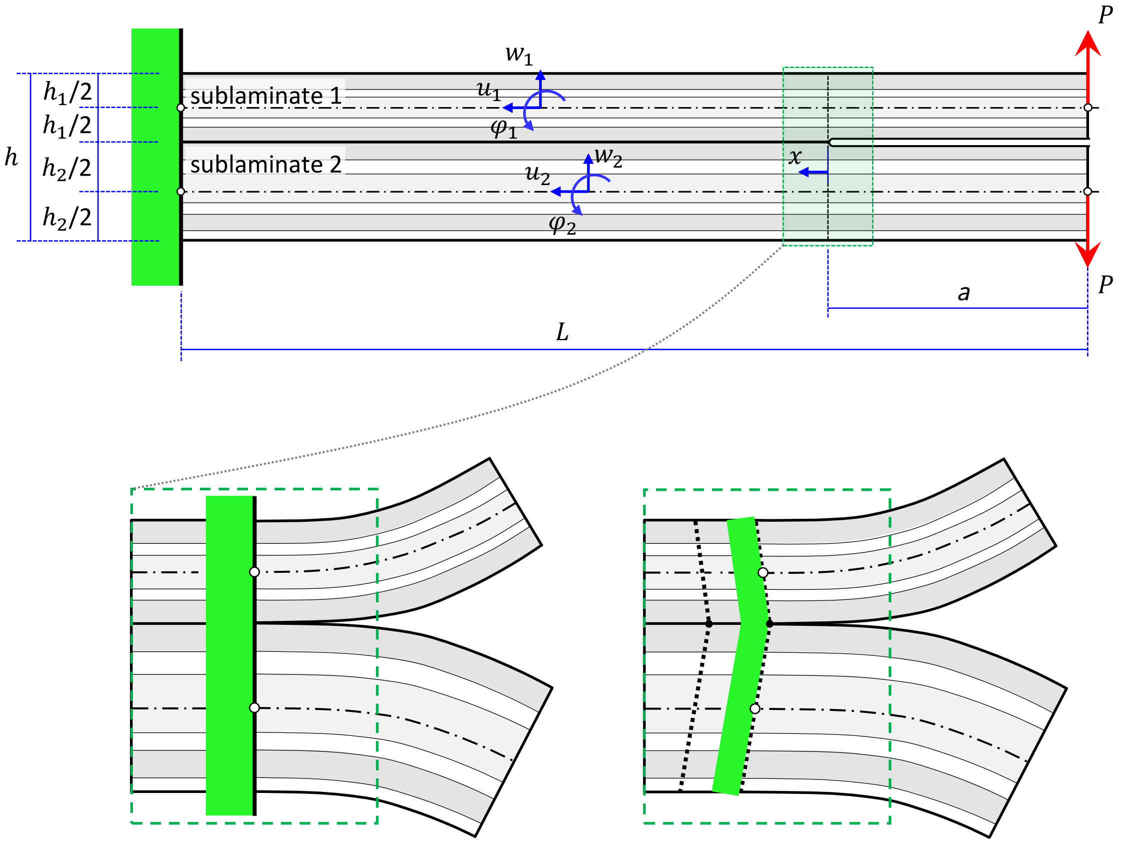
Experimental data reduction



Clamped model

(Valvo, 2016)

Semi-rigid model

(Tsokanas & Loutas, 2019; Tsokanas & Loutas, 2022)

Clamped model (Valvo, 2016)

$$\mathcal{G}_{\mathrm{I}} = \frac{P^2}{2}\left\{\left[d_1 + d_2 - \frac{\left(b_1+b_2+d_1\frac{h_1}{2}-d_2\frac{h_2}{2}\right)^2}{a_1+a_2+b_1h_1-b_2h_2+d_1\frac{h_1^2}{4}+d_2\frac{h_2^2}{4}}\right]a^2 + c_1 + c_2\right\}$$

$$\mathcal{G}_{\mathrm{II}} = \frac{P^2}{2}\frac{\left(b_1+b_2+d_1\frac{h_1}{2}-d_2\frac{h_2}{2}\right)^2}{a_1+a_2+b_1h_1-b_2h_2+d_1\frac{h_1^2}{4}+d_2\frac{h_2^2}{4}}a^2$$

$$\mathcal{G} = \frac{P^2}{2}\left[c_1 + c_2 + (d_1 + d_2)a^2\right]$$

These **data-reduction equations** are function of:

- The **applied load**
- The **geometry** of the specimen (sublaminate thicknesses, crack length)
- The **material properties** (engineering constants and coefficients of thermal and moisture expansion)

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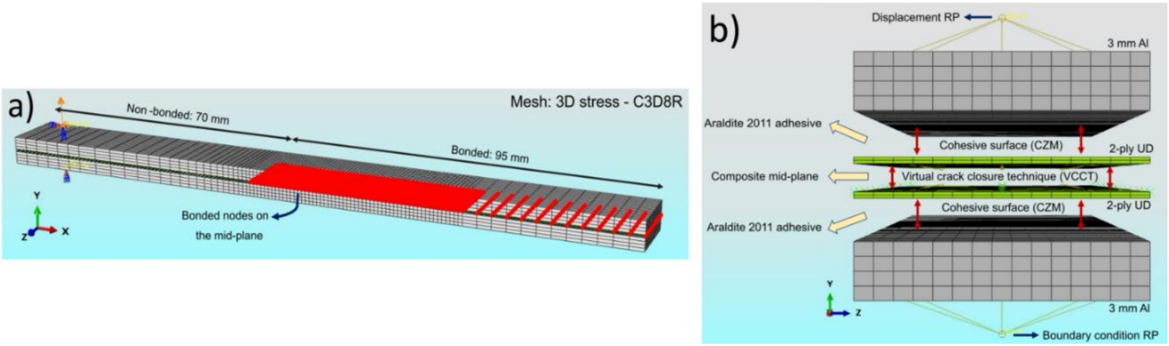

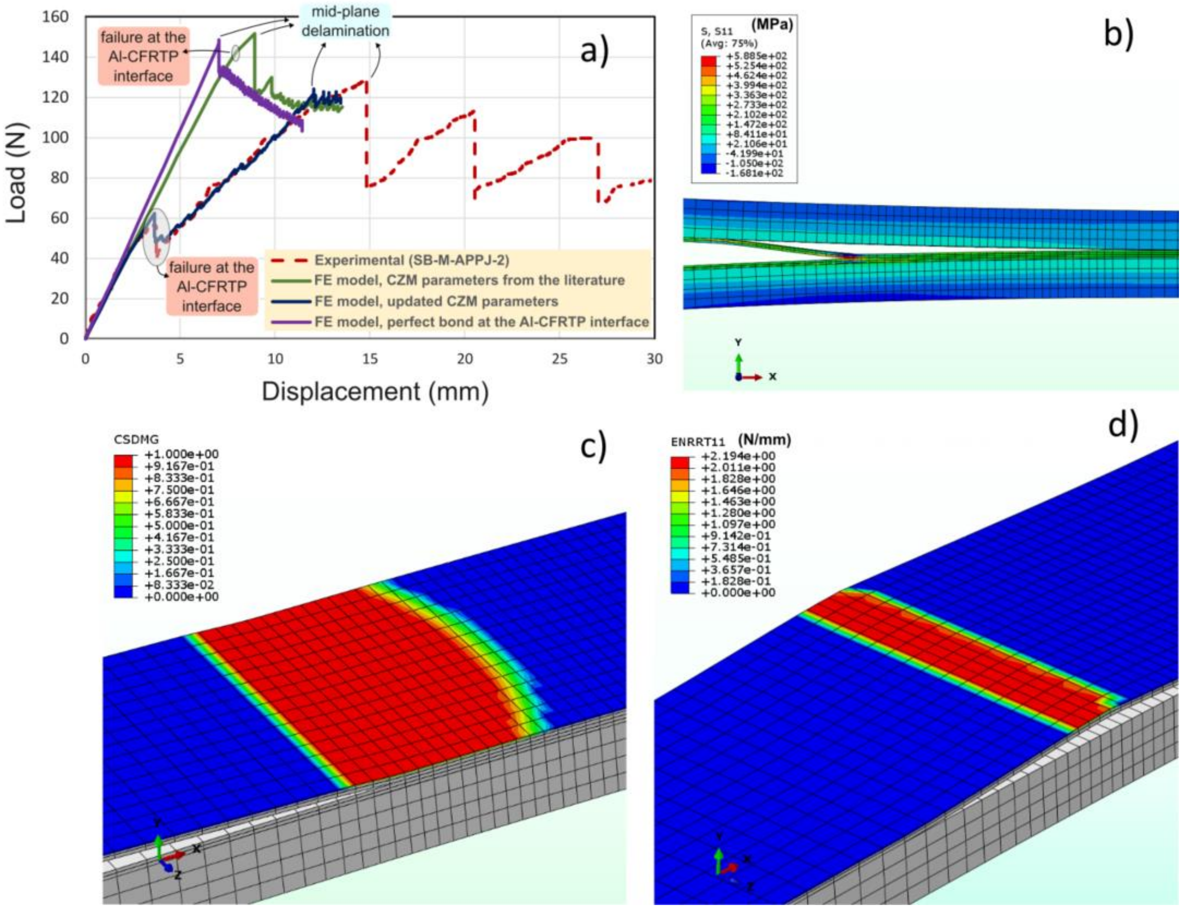

	FE, undesired failure	FE, perfect bond
$G_{Ic,ini}$ (kJ/m2)	**2.140**	**2.110**
$G_{IIc,ini}$ (kJ/m2)	0.009	0.001
$G_{IIIc,ini}$ (kJ/m2)	0.0002	0.0002

Pure mode I and insignificant contribution of cohesive failure of the adhesive on the mid-plane ERR

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