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Fracture of pressure-sensitive adhesives through interfacial failure characterized by DCB and peel testing

BD Simões (INEGI, Portugal) | VCMB Rodrigues | EAS Marques |

RJC Carbas | S Maul | P Stihler | P Weißgraeber | Lucas F.M. da Silva

Introduction

The durability of bonded joints using pressure-sensitive adhesives (PSAs) depends on interfacial failure mechanisms. This work investigates fracture behaviour through Double Cantilever Beam (DCB) and peel tests performed on acrylic PSAs under controlled conditions. The objective is to assess the transferability of the fracture characterization between DCB and peel geometries.

Materials & Methods

- Adhesive C: acrylic, , h = 0.3 mm, vacuum-bonded;
- Adhesive D: rubber-based, h = 0.5 mm, high-pressure bonded;
- Peel tests conducted (PSA C) at 30°, 60°, 90°, 120°, 150°, 180°;
- DCB tests performed to extract Mode I cohesive law via direct method;
- Peel tests at 30°, 60°, 90° (PSA C & D) to capture mixed-mode and plastic dissipation effects; FEM models developed for each geometry.

Experimental Results

Peel average force vs. loading angle

- Both adhesives follow identical trends: max. at 30°, min. at 90°;
- Adhesive D consistently higher loads than Adhesive C across all angles;
- Slight load recovery observed at 180° for Adhesive C.

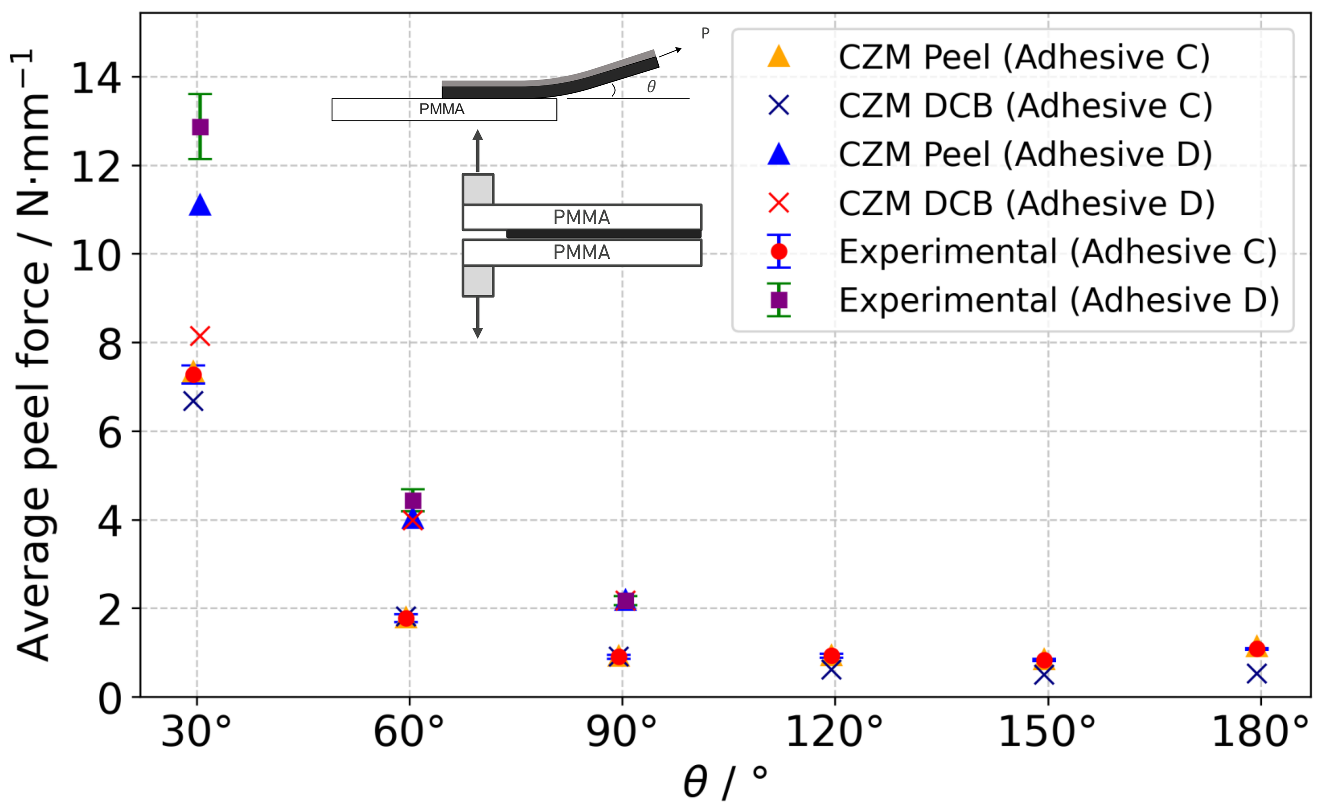

Figure 1– Peel load per width (Nmm[-1]) as a function of the peel angle for experimental data and numerical models using both peel and DCB cohesive laws.

Additional energy analysis

Peel angle governs mode mixity, controlling energy partition between plastic dissipation and true fracture.

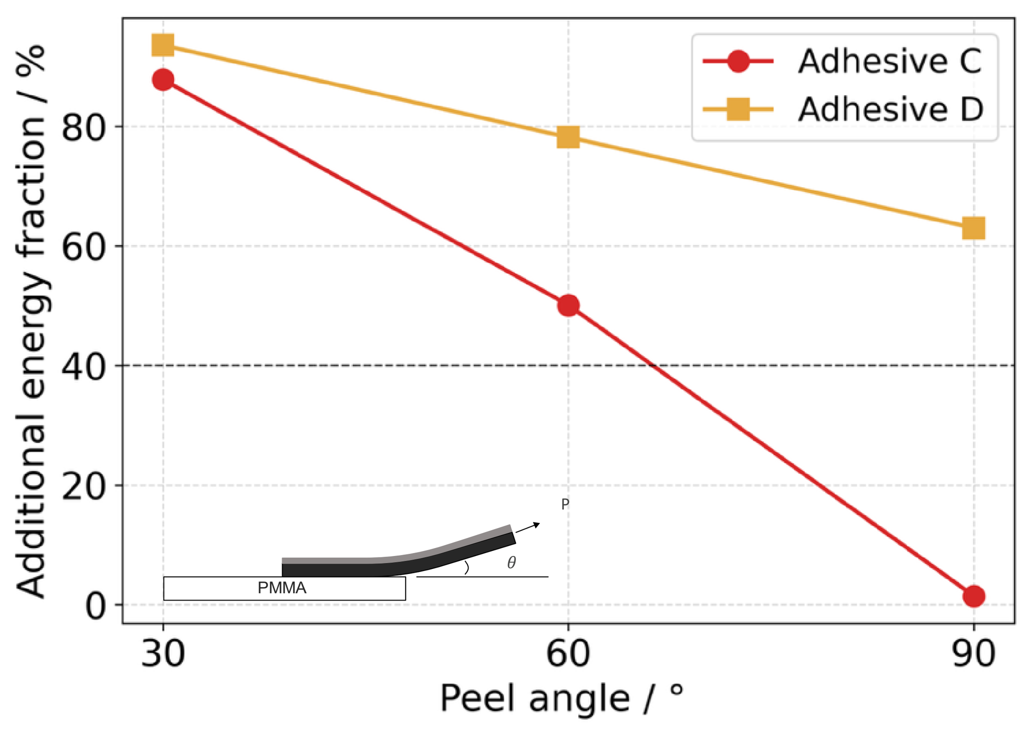

Figure 2 – Additional energy fraction (G_{eff} – G_c)/G_{eff}) as a function of peel angle, for Adhesive C (red) and Adhesive D (yellow).

- **Adhesive C:** additional energy fraction drops to ~0% at 90°;
- **Adhesive D:** retains ~60% at 90°, reflecting higher energy dissipation;

Numerical results and validation

Numerical results

The CZM model reproduced experimental trends with good agreement in overall load and deformation values (Fig. 3).

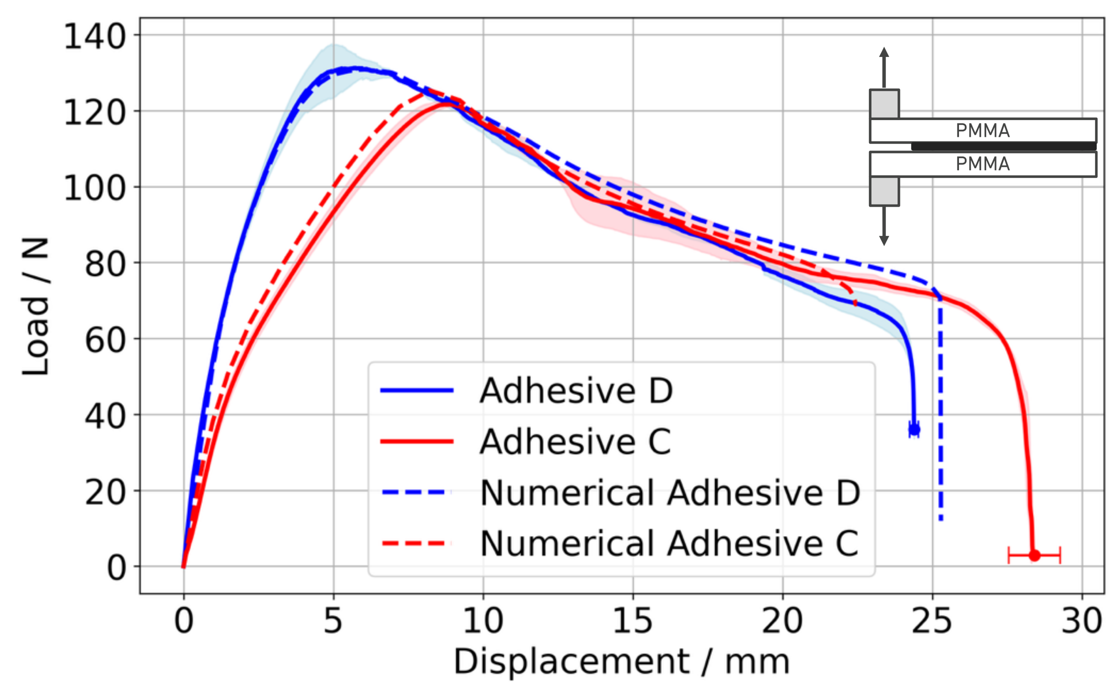

Figure 3 – Numerical vs. experimental load-displacement curves for DCB specimens that were used to assess the transferability of the model.

Mode mixity governs transferability

- **ψ < 20°:** Prediction error **<2%;** Adhesive D: high energy ratio (2.7×) yet still <2% error;
- **20° > ψ < 40°:** Prediction error **2-15%**
- **ψ > 40°:** Prediction error **>15%;** Mode mixity, not energy ratio, is the governing criterion.

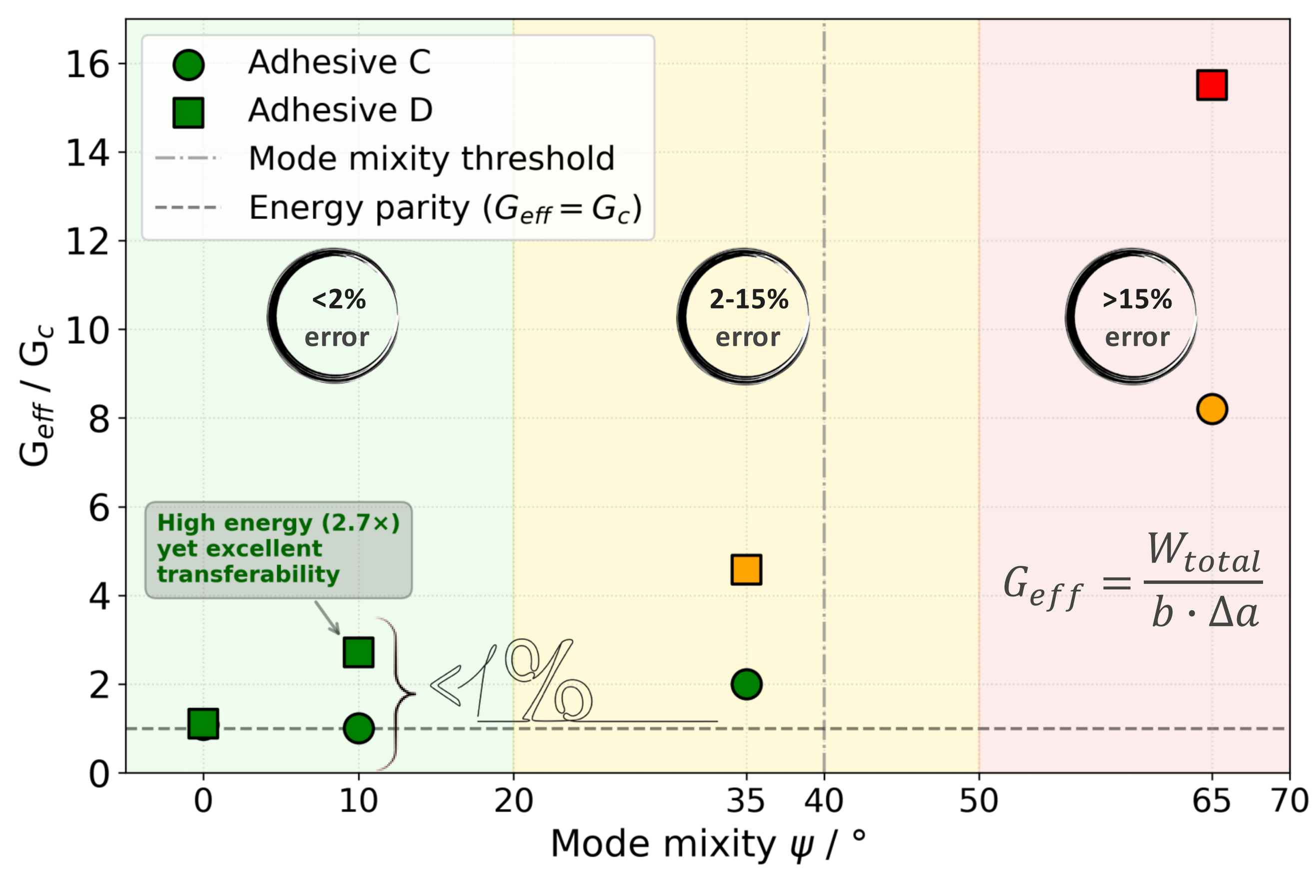

Figure 4 – G_{eff}/G_c vs. mode mixity ψ map for Adhesive C and D. Mode mixity threshold at 40° separates low-error from high-error predictions.

Key findings & Conclusions

✓ DCB and peel tests provide complementary fracture characterization of PSAs.

✓ CZM cohesive laws extracted from DCB can be successfully transferred to peel geometry.

✓ Unified characterization protocol suitable for electronics, medical, and transport industries.

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