IMPROVING DAMAGE TOLERANCE OF EPOXY RESIN-BASED COMPOSITES VIA INTERLAYER TOUGHENING STRATEGIES

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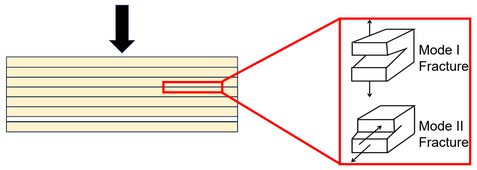
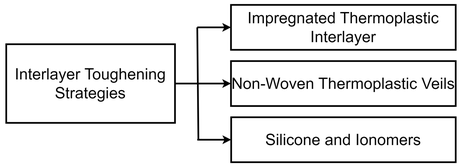
Introduction

Epoxy resin-based composites are used due to their low weight, high strength, and resistance to environmental conditions.

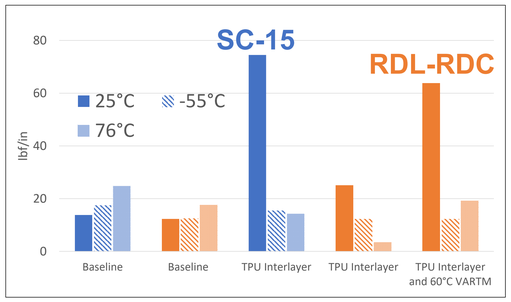
What happens during impaction?



To improve resistance to interlaminar failures in the composite, interlayer toughening is utilized to reduce shear stresses through decoupling of plies increasing delamination resistance.



SC-15 vs RDL-RDC: Peel Strength

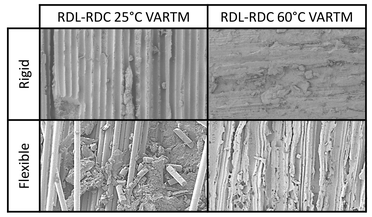


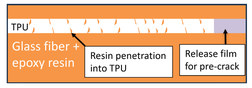
At 25°C	At 60°C
SC-15 showed more Mode I fracture toughness than **RDL-RDC**	**RDL-RDC** showed comparable results to **SC-15** at 25°C

How can we improve fracture toughness of these composites at all operating temperatures (-55°C to 76°C)?

Resin-TPU Bonding Mechanism

Key bonding mechanism: Resin diffusion into TPU interlayer



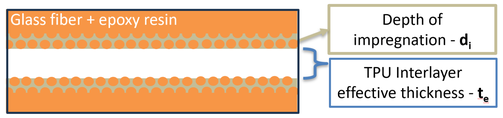


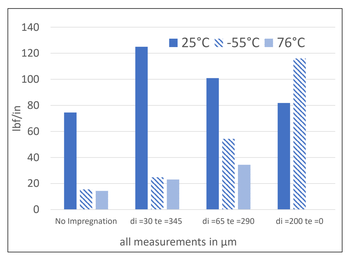
Hypothesis: **RDL-RDC** resin properties change at elevated temperature to allow more diffusion, comparable to that of **SC-15** Resin at room temperature.

-55°C and 76°C Challenges

TPU interlayer fails at extreme temperatures

- At -55°C the TPU is too stiff due to being below it's T_g of -25°C
- At 76°C the TPU is less stiff, due to softening while approaching T_{melt}





TPU Impregnation can

- ☑ Improve fracture toughness
- ☐ Affect Mode II toughness
- ☐ Affect stiffness of the composite

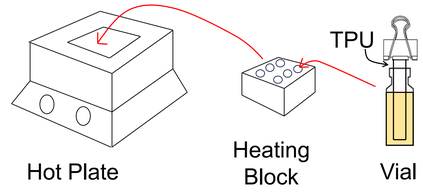
How is TPU impregnation affecting stiffness? Are there other interlayer materials that can replace TPU?

Objectives

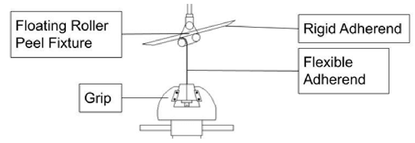
1. Understand resin diffusion mechanism in thermoplastic interlayer composites
2. Investigate additional interlayer materials
3. Observe toughening strategies' effect on stiffness and Mode II fracture toughness

Procedures

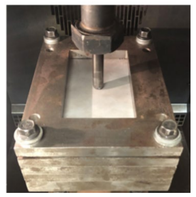
Resin Diffusion



Floating Roller Peel Test

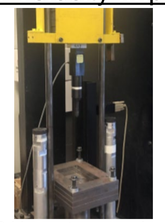


Stiffness Test



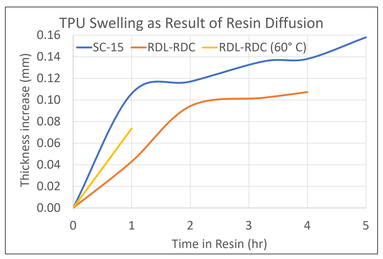
Force per displacement up over 1mm

Low Velocity Impact



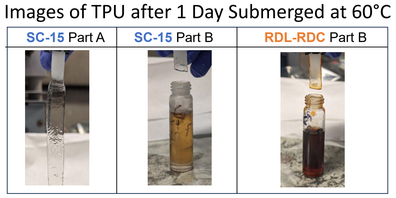
40J impact on specimen

Resin-TPU Bonding Results



- First linear region models mixed but unreacted resin
- **SC-15** diffuses in TPU quicker than **RDL-RDC** at 25°C
- The initial rate of diffusion of **RDL-RDC** at 60°C matches that of **SC-15**
- **SC-15** parts at 60°C causes TPU to dissolve

Images of TPU after 1 Day Submerged at 60°C



Ongoing and Future Work

$$\chi = \frac{V_{Resin}}{RT}(\delta_{TPU} - \delta_{Resin})^2$$

$$\delta_i = \left(\frac{\Delta E_i}{V_i}\right)^{1/2} = \left(\frac{\Delta H_i^V - RT}{V_i}\right)^{1/2}$$

χ = *Flory Interaction Parameter*
δ_i = *Solubility Parameter*
ΔE_i = *Energy of Vaporization*
ΔH_i^V = *Enthalpy of Vaporization*

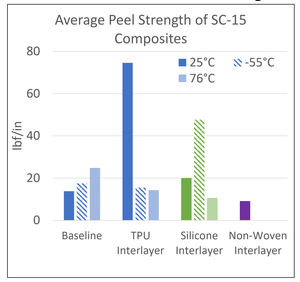
How can we model and quantify the diffusion?

Fracture Toughening Results

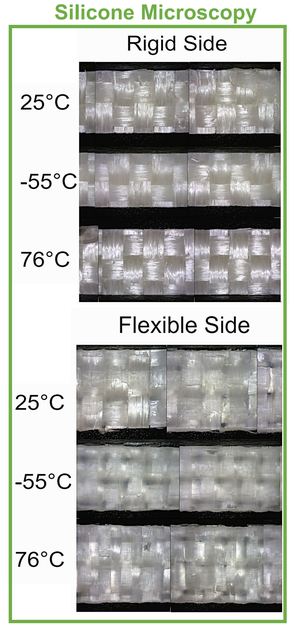
Ongoing Floating Roller Peel Test

Different interlayers are being tested as replacements for TPU

- **Silicone:** Chemically bonds to the glass fiber and resin in the composite
- **Nonwoven Veils:** High T_m and has shown to improve baseline results
- **Polysulfone:** Polymer with high $T_g \approx 230°C$ but ideal properties under its T_g

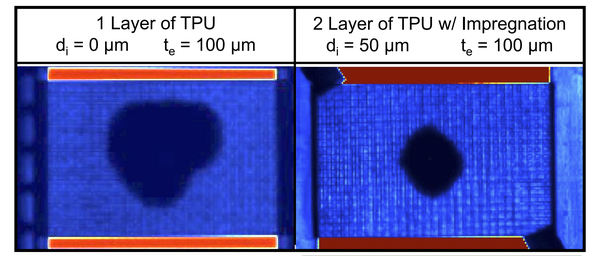


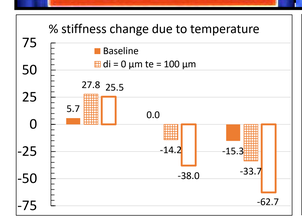
Silicone Microscopy

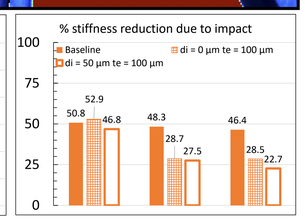


Stiffness and LVI Test

RDL-RDC panels tested at -55°C and C-Scans performed







Acknowledgements

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