

Reinforced Nichrome-Tufted CFRP Laminates for Self-Healing Activation

Motivation: The Delamination Challenge

CFRP composites offer exceptional strength-to-weight ratios but suffer from delamination at ply interfaces. In-service repair currently requires external heating equipment, making autonomous self-healing impractical.



Figure 1. Delamination failure in a CFRP laminate.

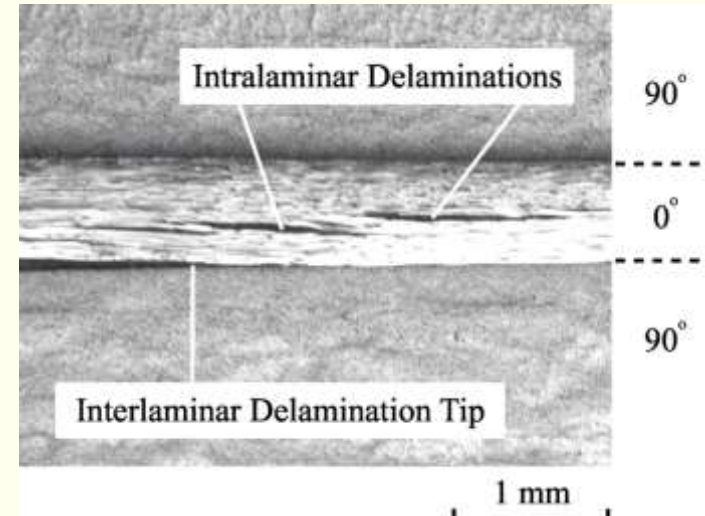
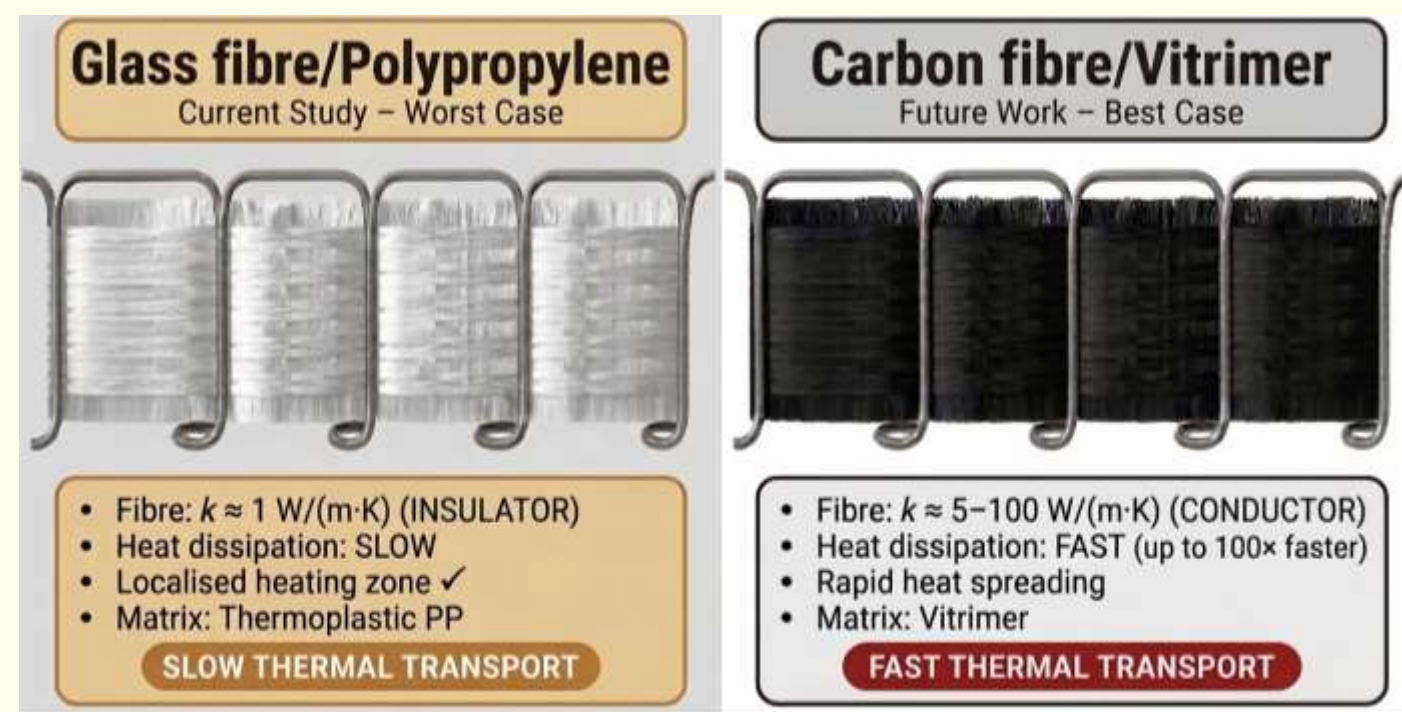


Figure 2. Cross-section micrograph [2].

Material Selection & Strategy

We are starting this project with the most challenging laminate possible, where both the matrix and the fibres are thermal and electrical insulators.



Finite Element Analysis Model

A tetrahedral mesh offers a much more refined geometry with a reduced number of nodes compared to a hexahedral mesh.

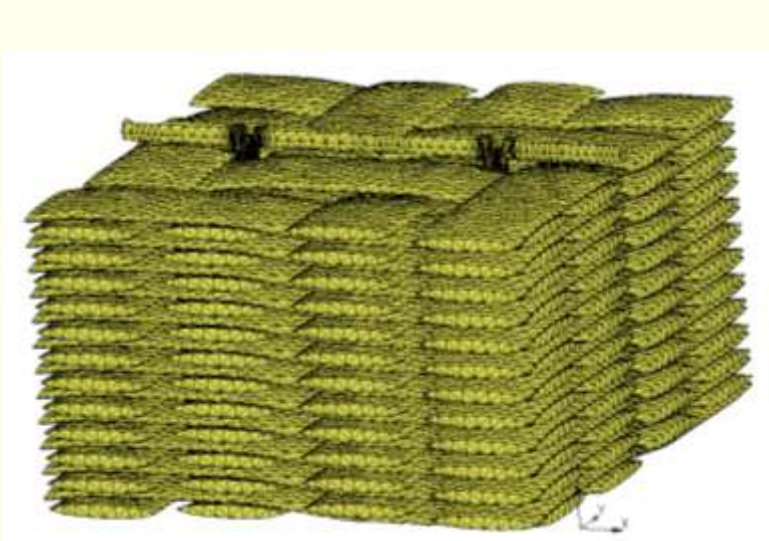


Figure 8. Tetrahedral mesh of the 12-ply RVE.

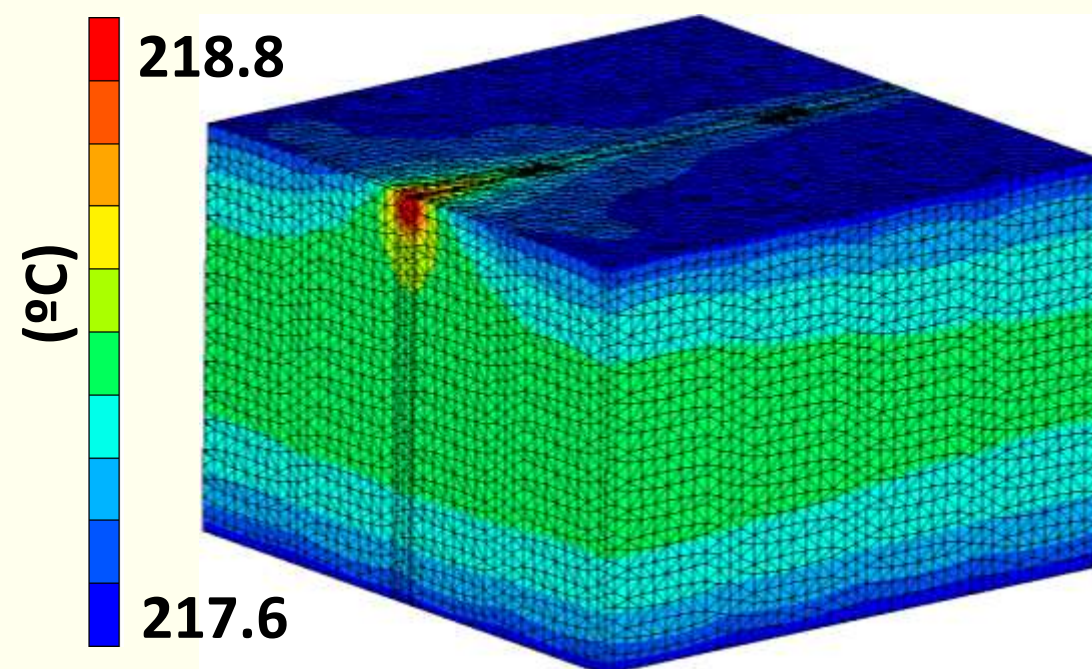


Figure 9. Preliminary simulation showing temperature distribution across the RVE

Conclusions & Next Steps

A 12-ply GF/PP twill 2/2 RVE was successfully built in TexGen and imported into MSC MARC with temperature-dependent material properties derived from TGA experiments and datasheet values.

Next steps include:

- Optimisation of the system to achieve the shortest healing time possible
- Validation of the FE model against infrared camera temperature measurements
- Extension of the framework to a CF/Vitrimer system as the target application

Dual-Function Nichrome-Tufted TTR

I. MECHANICAL: Through-thickness Reinforcement (TTR) increases delamination resistance.

II. THERMAL: Nichrome wire serves as a resistive heating element ($Q = I^2R$) that heals by melting the composite's matrix when current is applied.



Figure 3. Cracked composite matrix prior to healing activation.



Figure 4. Resistive heating via electrical current through the nichrome tuft.



Figure 5. Re-solidified matrix following thermal activation.

Representative Volume Element (RVE)

The laminate geometry for the simulation consists in a 4x4 yarn repeat, 5.33 x 5.33 x 3.48 mm unit cell. These geometry complies with the volume of glass fibre measured through TGA experiments ($V_f = 38.5\%$).

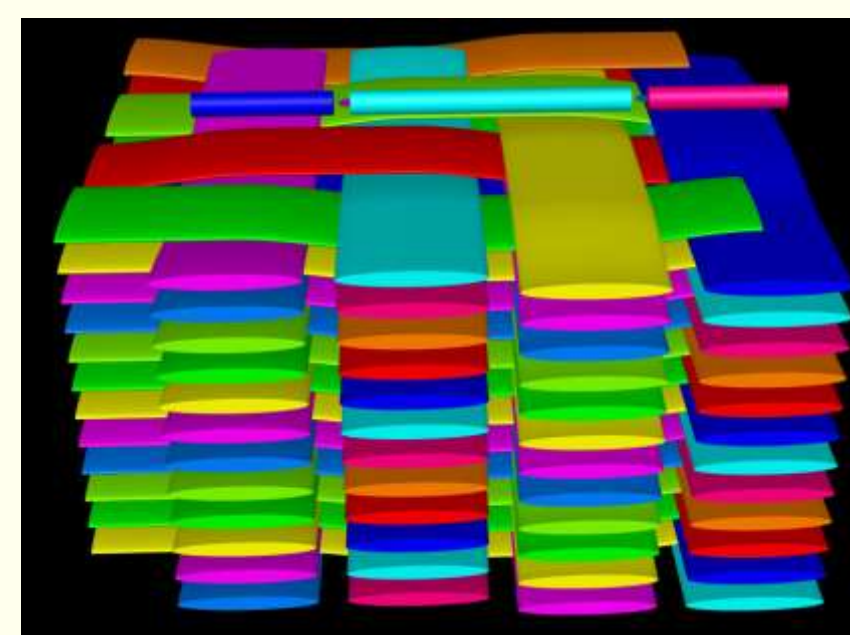


Figure 6. 12-ply GF/PP RVE geometry developed in TexGen.

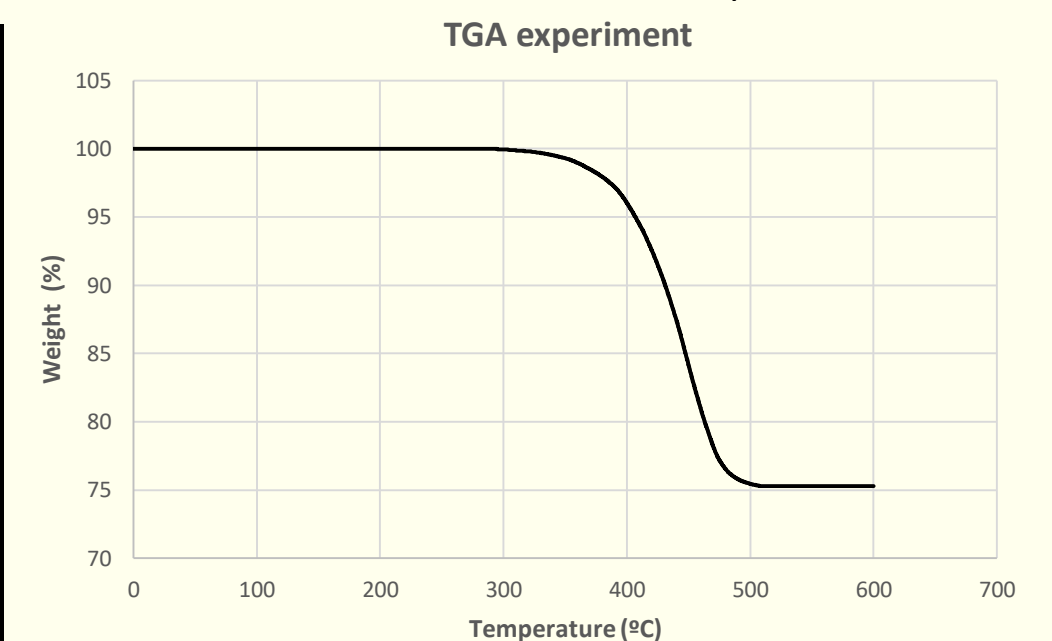
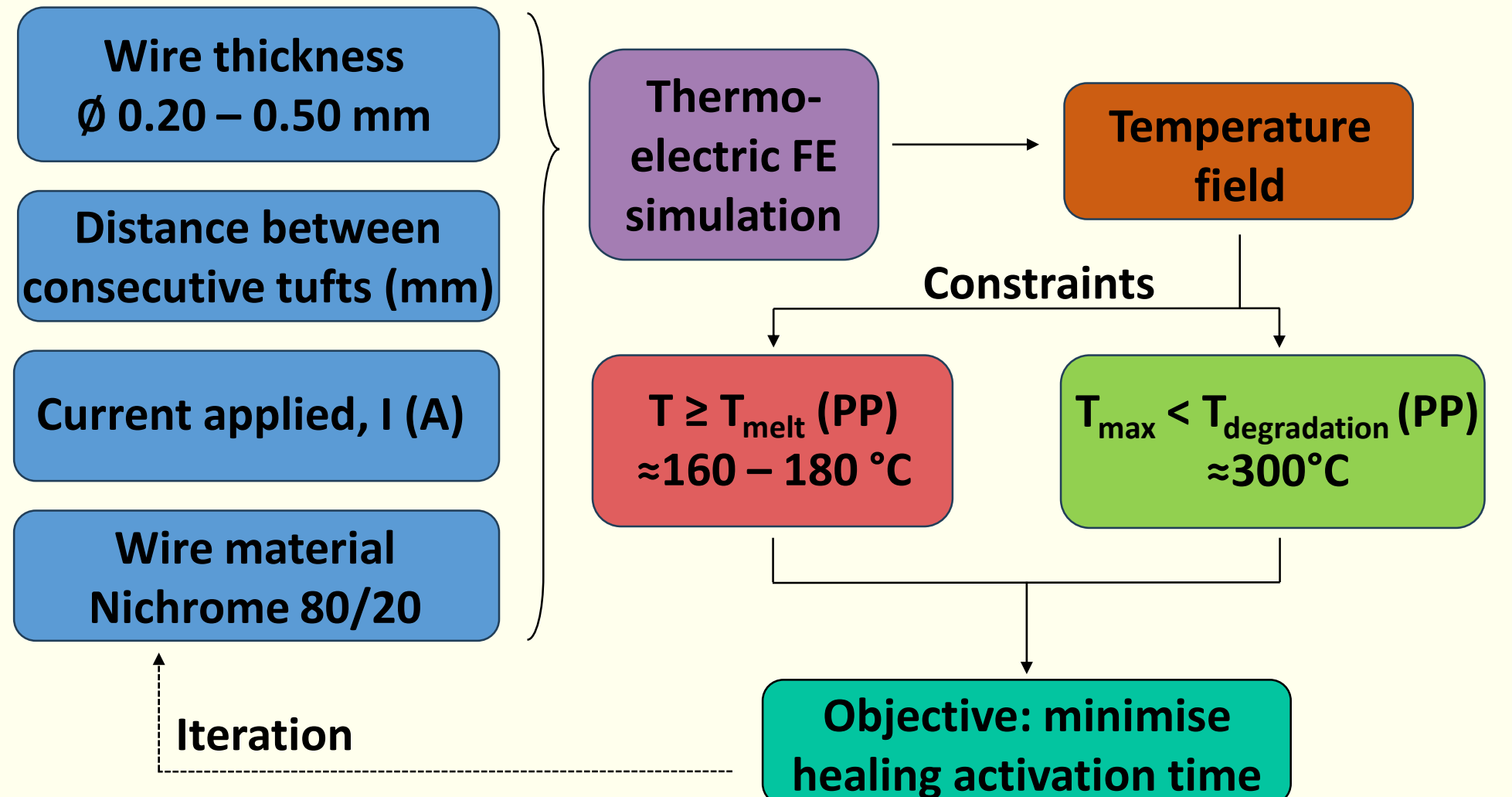


Figure 7. TGA weight loss curve for GF/PP laminate, yielding $V_f = 38.5\%$.

Optimisation Framework

Design variables



References

- [1] Hayes, S.A., Jones, F.R., Marshiya, K., & Zhang, W. (2007). A self-healing thermosetting composite material. *Composites Part A*, 38(4), 1116-1120.
- [2] Wool, R.P., & O'Connor, K.M. (1981). A theory of crack healing in polymers. *Journal of Applied Physics*, 52(10), 5953-5963.



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