Development and Validation of 2D Finite Difference Modeling of Heat Transfer, Degree of Healing, and Stress Development in FFF Printing

Macromolecules Innovation Institute
At the intersection of science, engineering, and society

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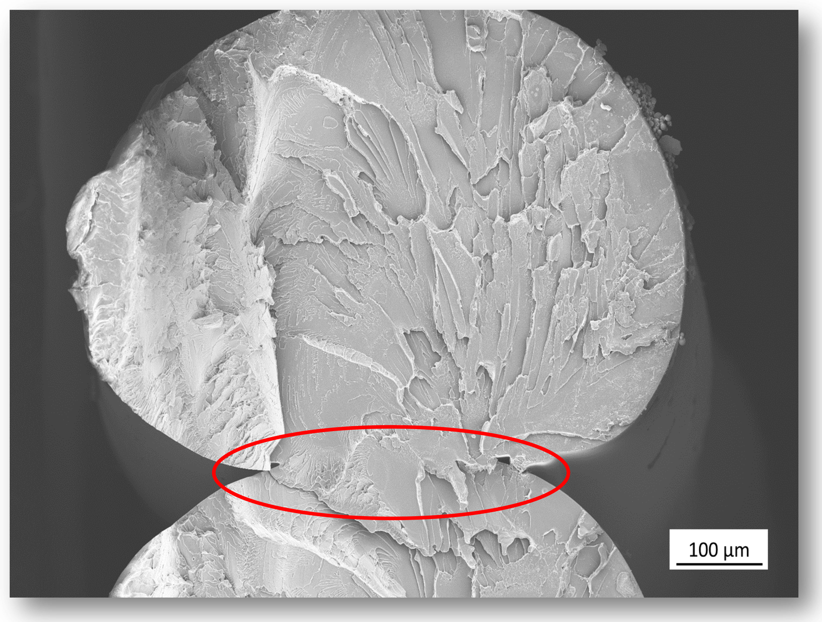
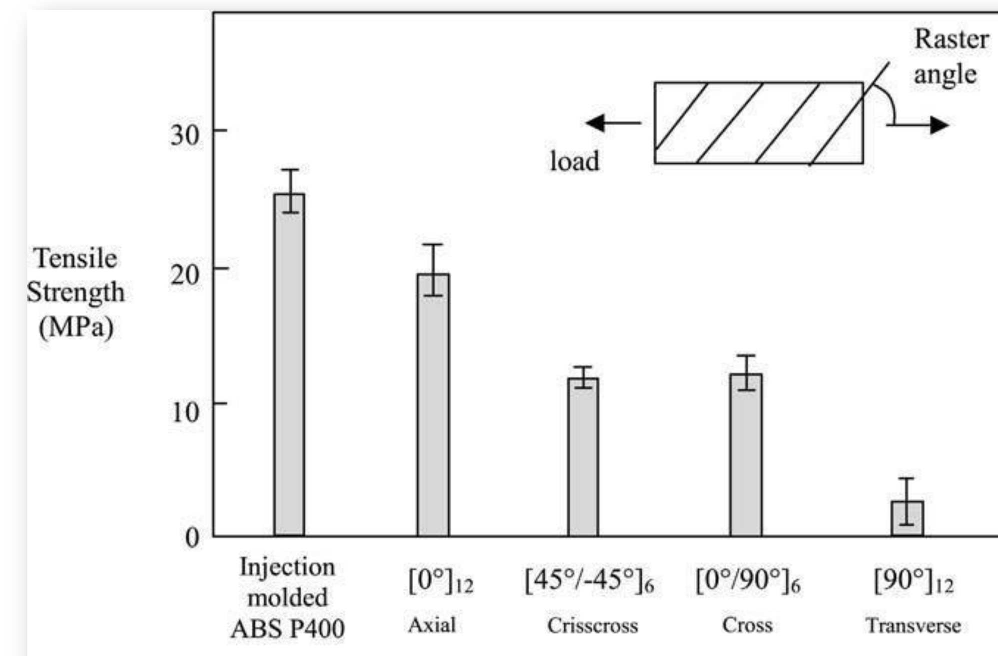
VIRGINIA TECH

Background/Introduction

- Part strength in fused filament fabrication (FFF) additive manufacturing depends on interlayer (z-axis) adhesion
- Interface is an inherent point of weakness due to fast cooling rates and limited diffusion time
- Thermal model will improve understanding and prediction of bonding characteristics

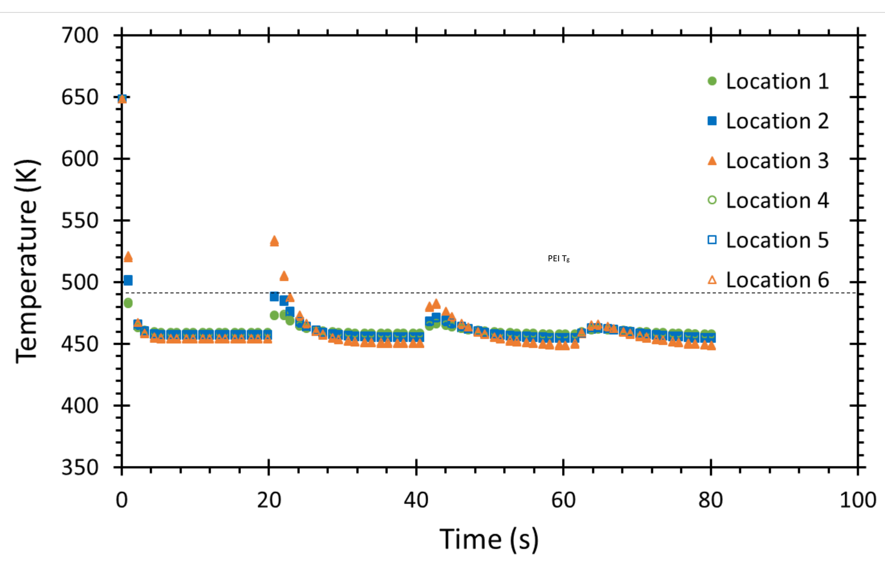


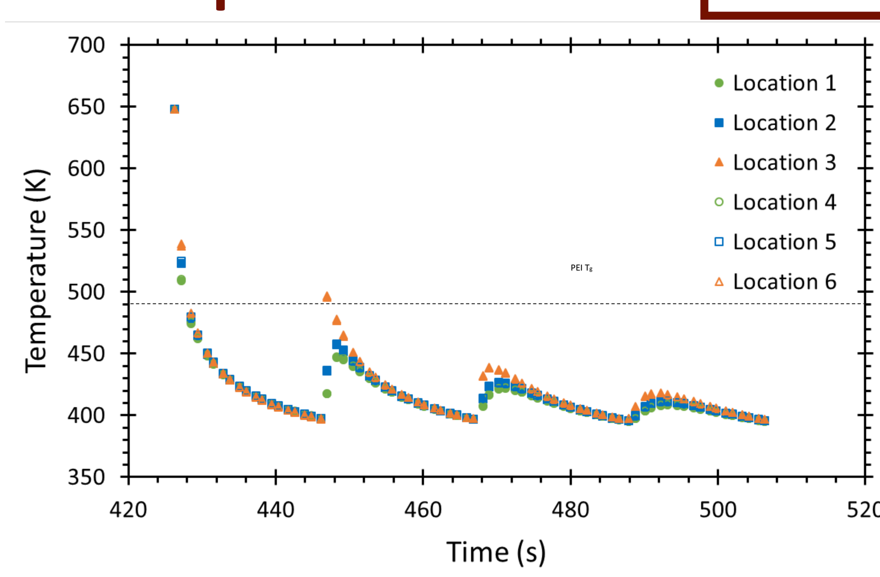
- Interlayer bonding and print orientation leads to anisotropic properties[1]
- Insufficient bonding stems primarily from lack of time above T_g



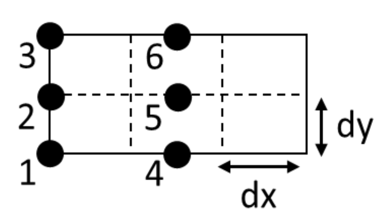
Results

Thermal Transport



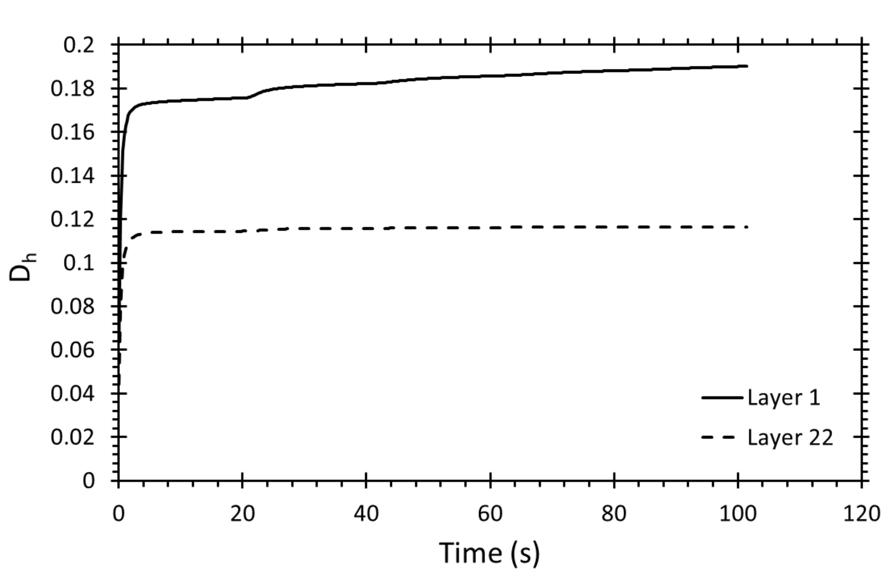


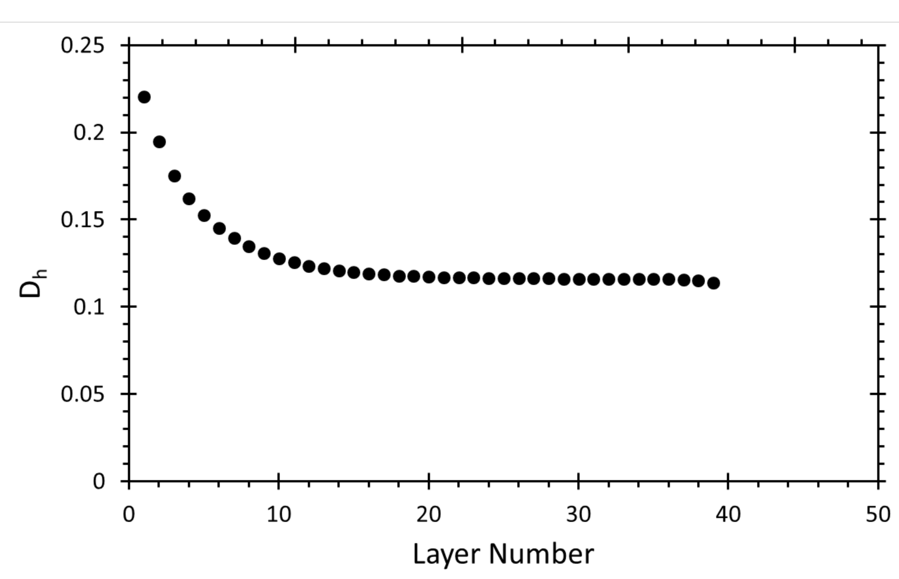
Layer 1



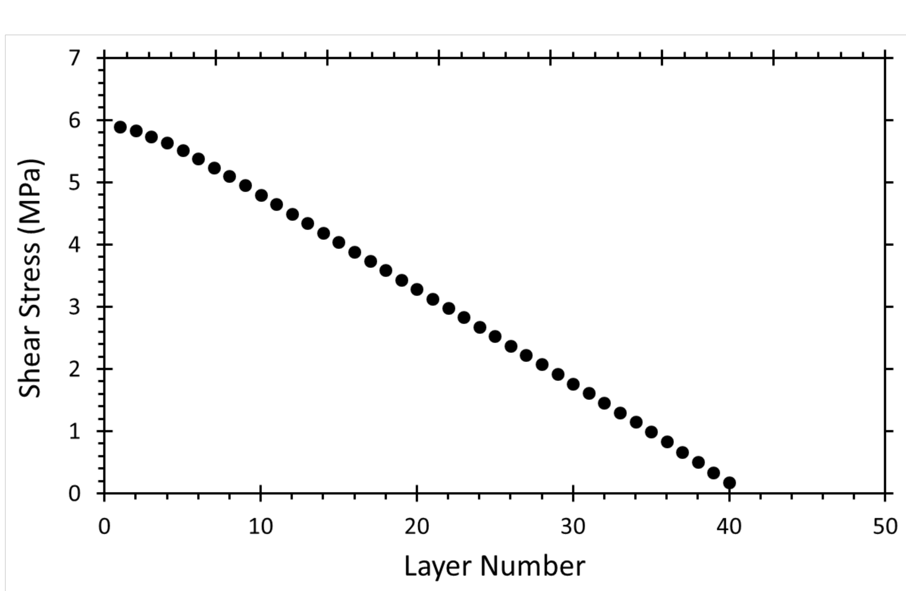
Layer 22

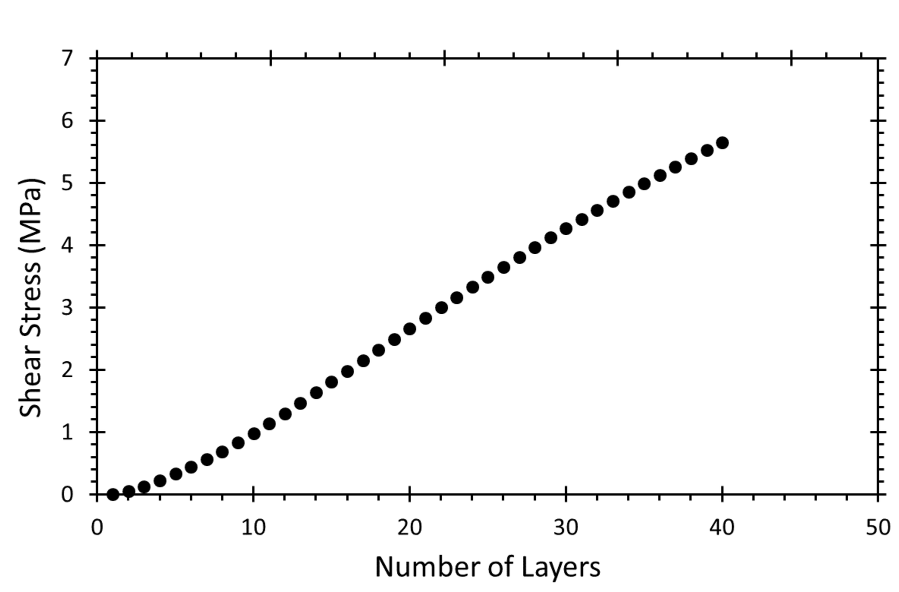
Degree of Healing



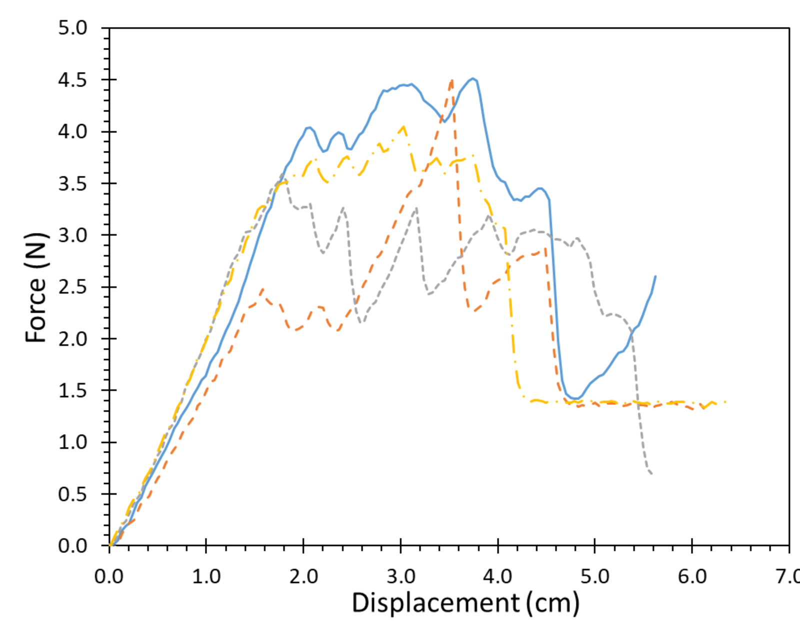


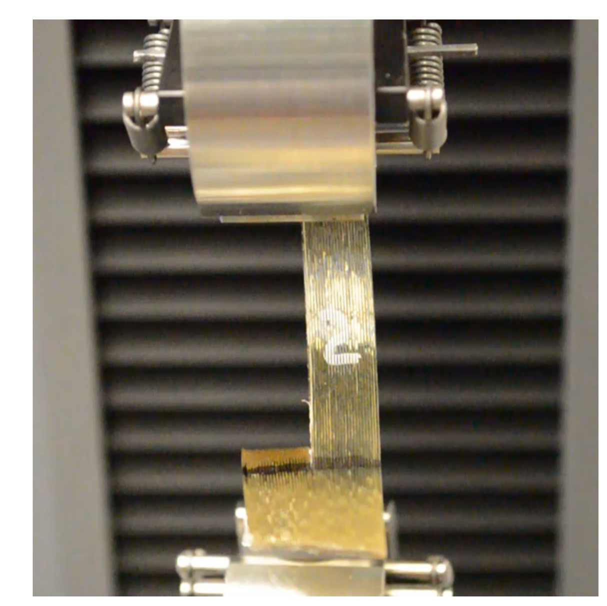
Stress Development



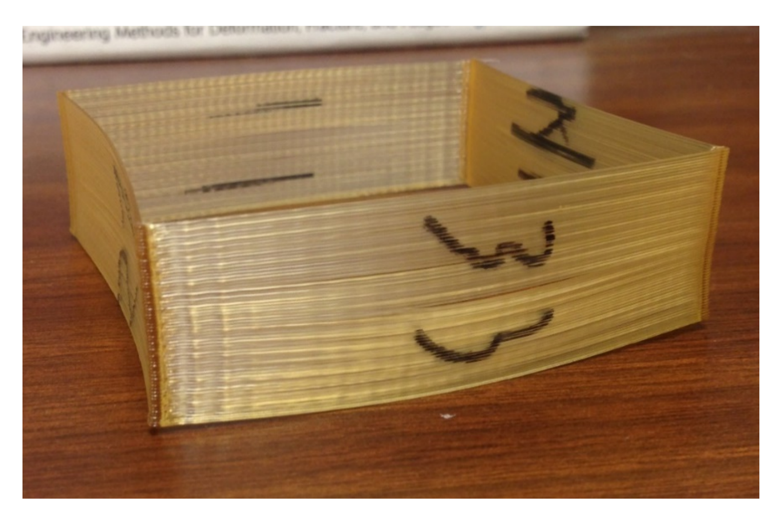


Bond Healing Measurement – Tear Test



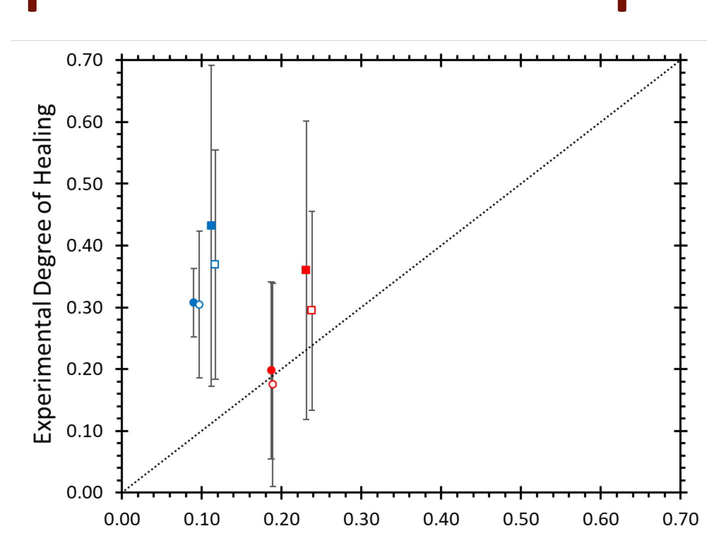


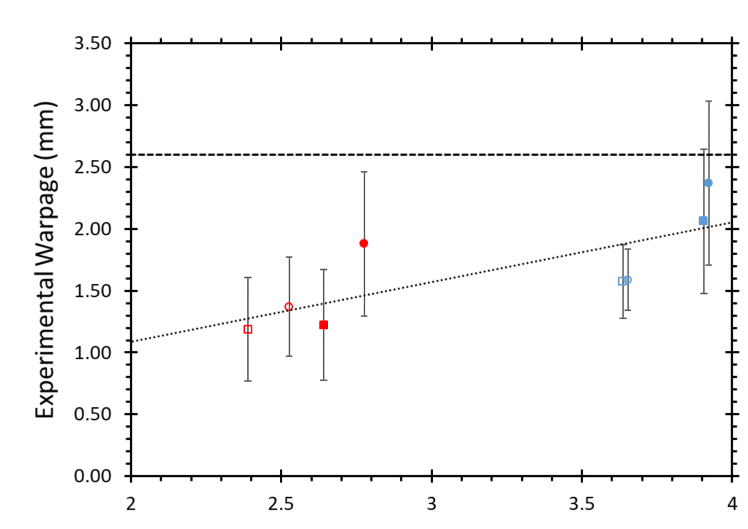
Stress Measurement - Warping



- Warping is driven by residual stress caused by thermal contraction during printing
- Warping can provide estimate of stress in a printed part

Comparison of Empirical and Predicted Results





Deposition Temp	Bed Temp	Print Speed (layer time)
● 345 °	■ 175 °C	■ 15 mm/s (20.3 s)
■ 375 °C	□ 200 °C	■ 60 mm/s (5.1 s) C

Conclusions

- Finite difference models allow the relatively quick prediction of temperature profiles, bond healing, and stress development
- Deposited material drops below T_g in less than one second
- Predictions match empirical values well at slow print speed but deviate at high speed

Acknowledgments

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[1]Jiang, D. Three dimensional topology optimization with orthotropic material orientation design for additive manufacturing structures. Baylor University, 2017.