Through Thickness Thermal Conductivity Enhancement for 3-D Fiber Composites

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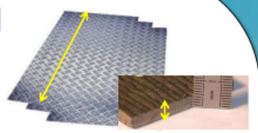
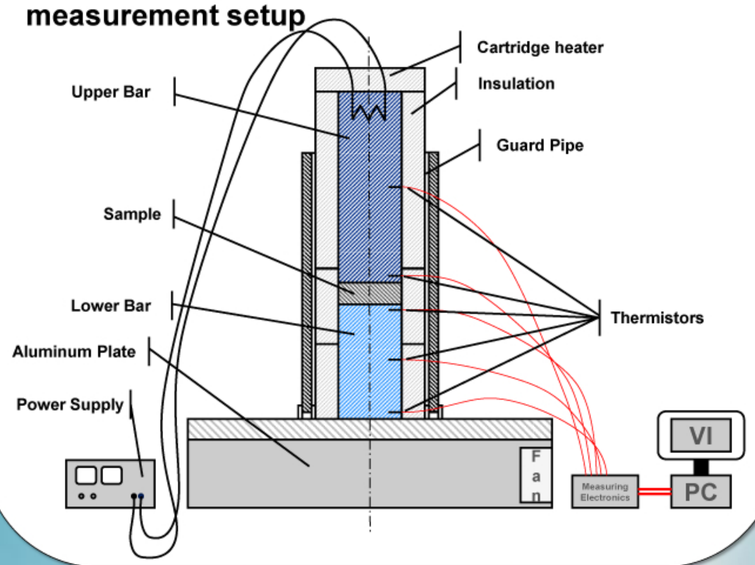
INTRODUCTION



- **Motivation**
  - The low through-thickness thermal conductivity of laminated fiber composites restricts their applications in practical systems where heat needs to be removed efficiently.
  - Small thickness implies the best way to extract heat from a composite enclosure is through its thickness direction.
- **Objectives**
  - Understand fundamental limitations of thermal conductivity in existing composites and propose novel approaches.
  - Address measurement issues for heterogeneous samples.

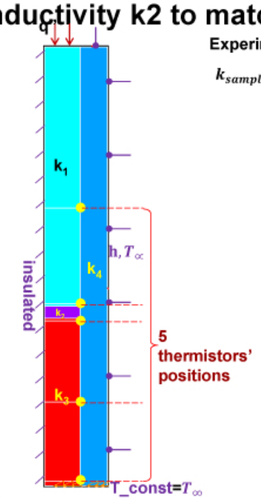
EXPERIMENTAL METHOD AND SETUP

- **Fourier's Law based thermal conductivity (TC) measurement setup**



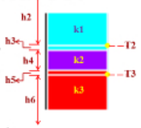
SETUP VALIDATION FE MODEL

- **Axisymmetric FE Model**
- **Modeling approach: Allow for heat loss in radial direction and incrementally change sample conductivity k2 to match T1~T5 temperatures.**

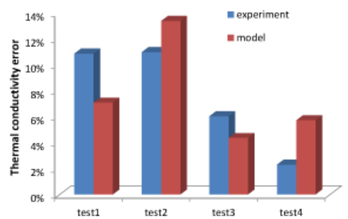


Experimental calculation:

$$k_{sample} = \frac{h_4}{k_3\frac{\Delta T_{23}}{\Delta T_{34}} - \frac{h_3}{k_1} - \frac{h_5}{k_3} - R_{grease}}$$



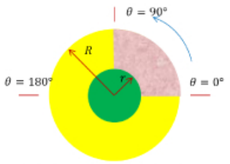
Validation showcase*



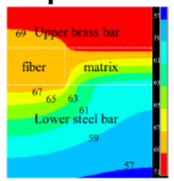
* 3tex17alpha sample(fiber-epoxy matrix composite sample of k = 3.66 W/mK, made of 28% E-glass as warp, 18.3% E-glass as fill, and 3.7% Copper Z fibers)

HEAT TRANSPORT IN HETEROGENEOUS SAMPLES

- **Z- fiber composite samples**

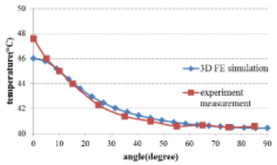


Single fiber embedded model



Temperature field around the single-fiber model tested in the setup

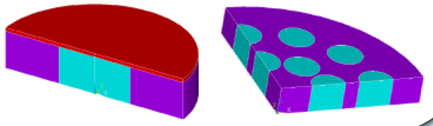
Two copper-rod model



Angle dependent temperature comparison validation

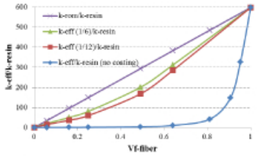
TC ENHANCEMENT APPROACHES AND MODELS

- **Approaches**
  - Embed Z fibers
  - Create a conductive coating
- **Models investigated**
  - Conductive fiber in thickness direction with/without conductive coating
  - Fiber distribution effect
  - Combined effect of conductive coating and fiber distribution

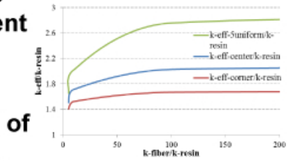


TC ENHANCEMENT RESULTS

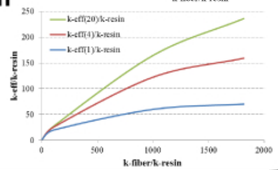
- **Single-fiber unit cell model**



- **Fixed fiber volume fraction but different fiber distributions**



- **Combined models of fiber distribution with coating**



FUTURE WORK

- **Improve the validity of the model of conductive coated composite samples by manufacturing optimization, and experimental test with the TC measurement setup.**
- **Characterize and validate models of composites with different fibers of different TC, placement and structures.**

ACKNOWLEDGEMENTS

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