# Data-driven multiscale modeling and experimental framework to reveal the PSP linkage of filler reinforced polymer composites, PSED Cluster 2019-2020

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Academic Disciplines: THEORETICAL AND APPLIED MECHANICS, MECHANICAL ENGINEERING

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## Objective

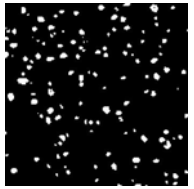
To develop a modeling framework for assessing and linking process to structure to property relationship in particle reinforced polymer composites.

## Motivation

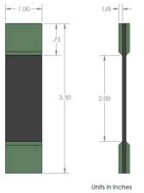
- Predictive numerical techniques are vital for increased design and implementation of composite materials.
- Implementation of curing process to modeling increases the design space and allows for more optimal composite structures.

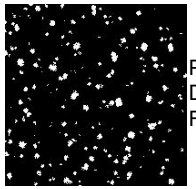
## Experimental Curing and Reconstruction

•Spherical Ti-6Al-4V metallic powder of different mass fractions were mixed with epoxy resin and cured.
•Images are inputted to Nanomine for a physical descriptor-based reconstruction.
•Tensile specimens are cured in a high-throughput experimental set up for model validation.



Target Image





Physical Descriptor Reconstruction

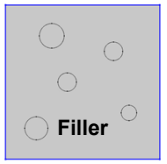
Tensile specimens manufactured using ASTM-D3039 standards.

## Future works

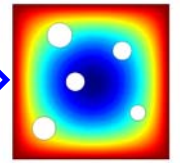
•3D cure model with experimental microstructures input
•Expand cure database with more microstructure and process cycles
•Tensile coupon preparation following optimized cure cycles and testing
•Optimization of curing time

## Modeling and simulation of curing process

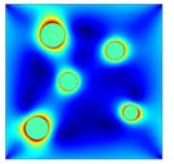
**Physics considered**
- Heat transfer
- Cure kinetics
- Viscoelasticity



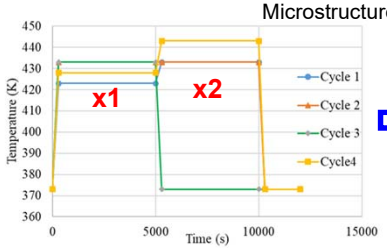

Microstructure



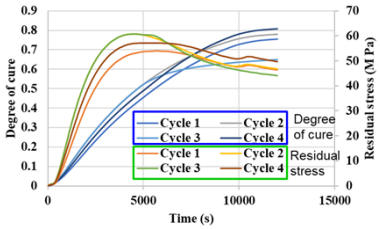
Curing conversion



Residual stress



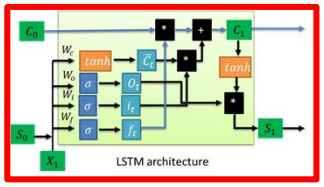

Curing process cycle



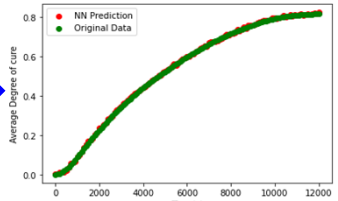

Cured properties

## Predictive modeling and optimization

Curing database from simulation




Recurrent neural network

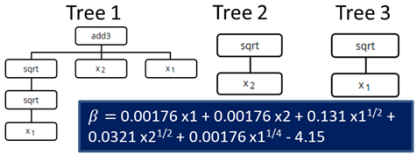



Degree of cure with time

**Input data**
Process variables, Holding temperature (x1, x2)

**Output data**
Properties (degree of cure, $\beta(x_1, x_2)$)

**Genetic programming**




$\beta = 0.00176\,x1 + 0.00176\,x2 + 0.131\,x1^{1/2} + 0.0321\,x2^{1/2} + 0.00176\,x1^{1/4} - 4.15$

Functions:'times','minus','plus','sqrt','square','sin','cos','exp','add3','mult3'

**Multiobjective Optimization**

$max\ f_1(x_1, x_2)$
$\min f2\,(x_1, x_2)$
$Subject\ to\ 410 \leq x_1, x_2 \leq 443$

Pareto front of optimized cure cycle

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