MODELING THE EFFECT OF FIBER CLUSTERING & RESIN BLEEDING ON VOID FORMATION DURING ADDITIVE MANUFACTURING OF CONTINUOUS CARBON FIBER THERMOSET COMPOSITES

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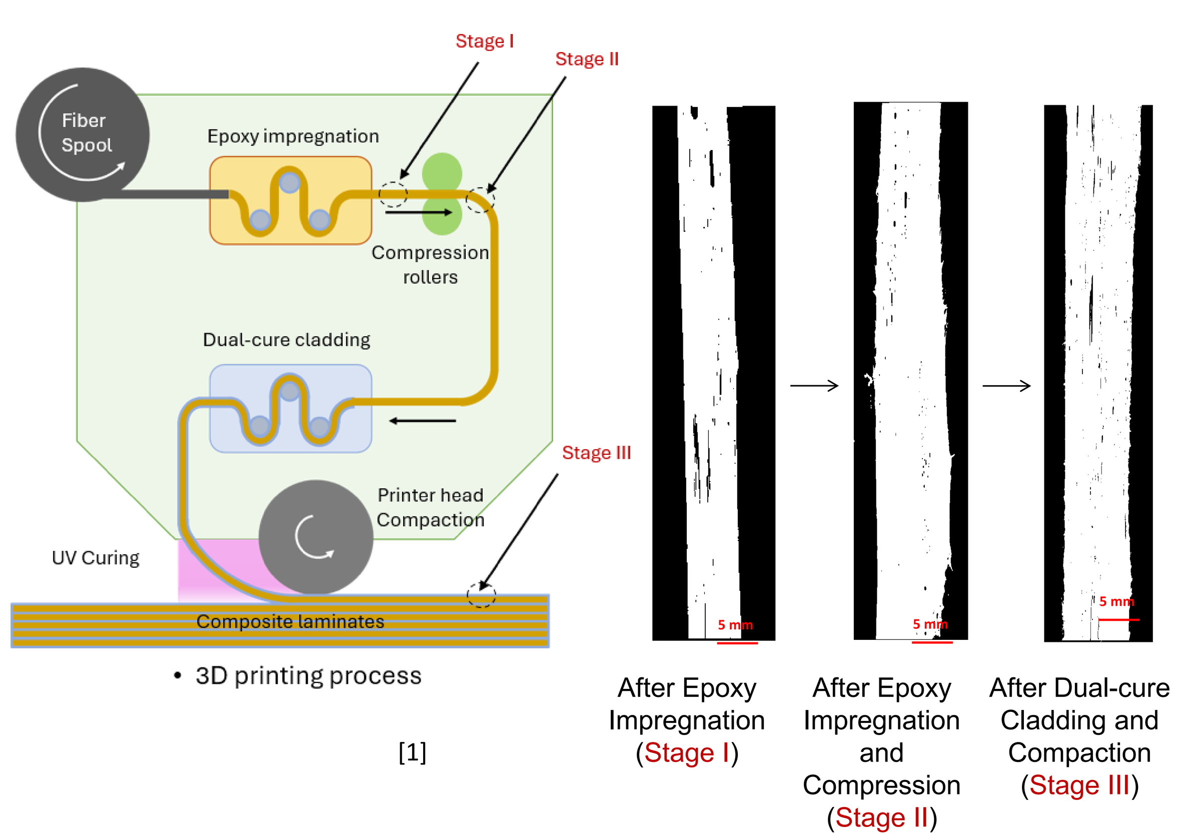
Introduction

- Additive manufacturing of continuous carbon fiber thermoset composites has led to the achievement of in-situ resin impregnation with a wide range of thermoset resins saving processing time and storage consumptions of prepregs without affecting the mechanical properties.
- But voids inside the final 3d printed parts due to improper impregnation can significantly affect the final part quality which is highly undesirable.
- To understand the void formation at various stages, we printed samples at multiple stages (i.e., **Stage I** after first epoxy impregnation, **Stage II** after compression rollers and **Stage III** after the final compaction at the printer head). The samples were cured to conduct micro-CT analysis and characterize the void content. Average void percentages after stage I, II and III were found to be 8%, 4% and 6% respectively.



• 3D printing process [1]

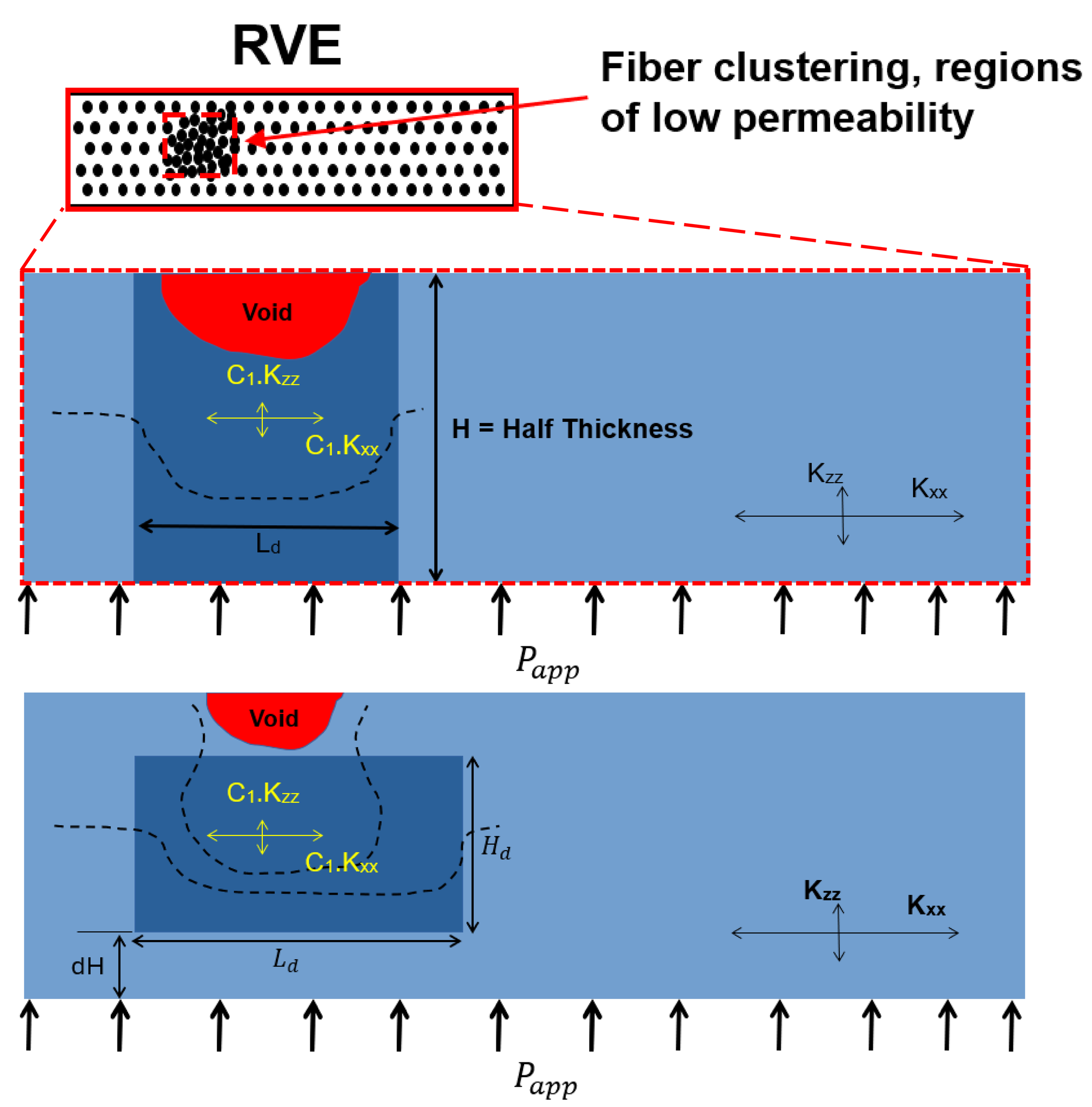
Objectives

- Identify reasons for void formation.
- Develop models to uncover important material and process parameters that influence void formation
  - **Model 1:** Fiber clustering effect on void formation
  - **Model 2:** Resin bleeding effect on void formation
- Validate the models with experimental results.

Model Formulations

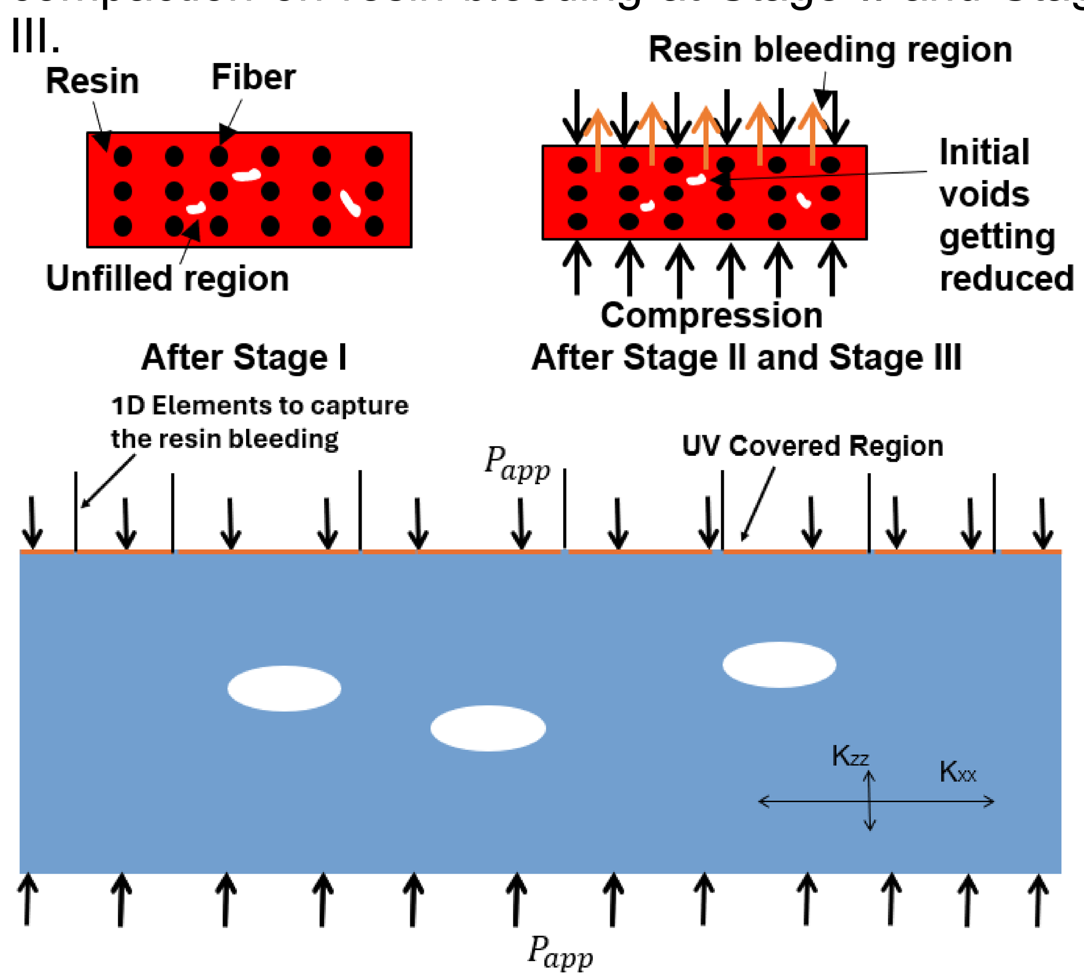
Model 1. Fiber clustering effect on void formation

A model is developed to study the effect of fiber clustering (due to variation in geometry by applied tension and pulling speed) by introducing regions/windows of low permeability inside the fiber tow. The simulations were done using LIMS [2].



Model 2. Resin bleeding effect on void formation

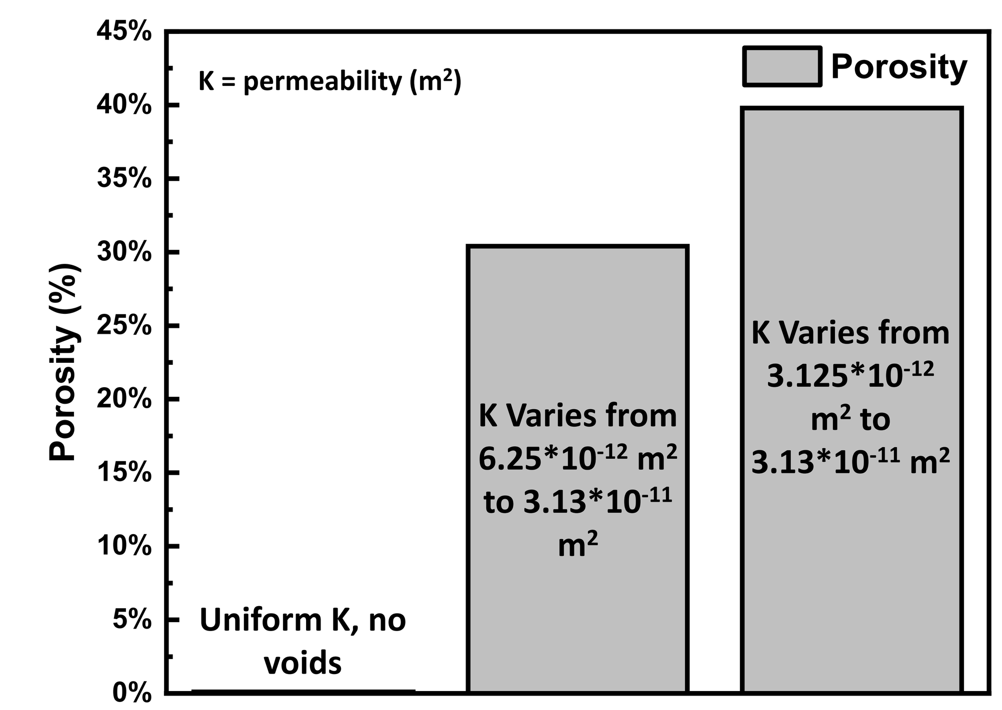
To investigate the effect of compression and compaction on resin bleeding at Stage II and Stage III.



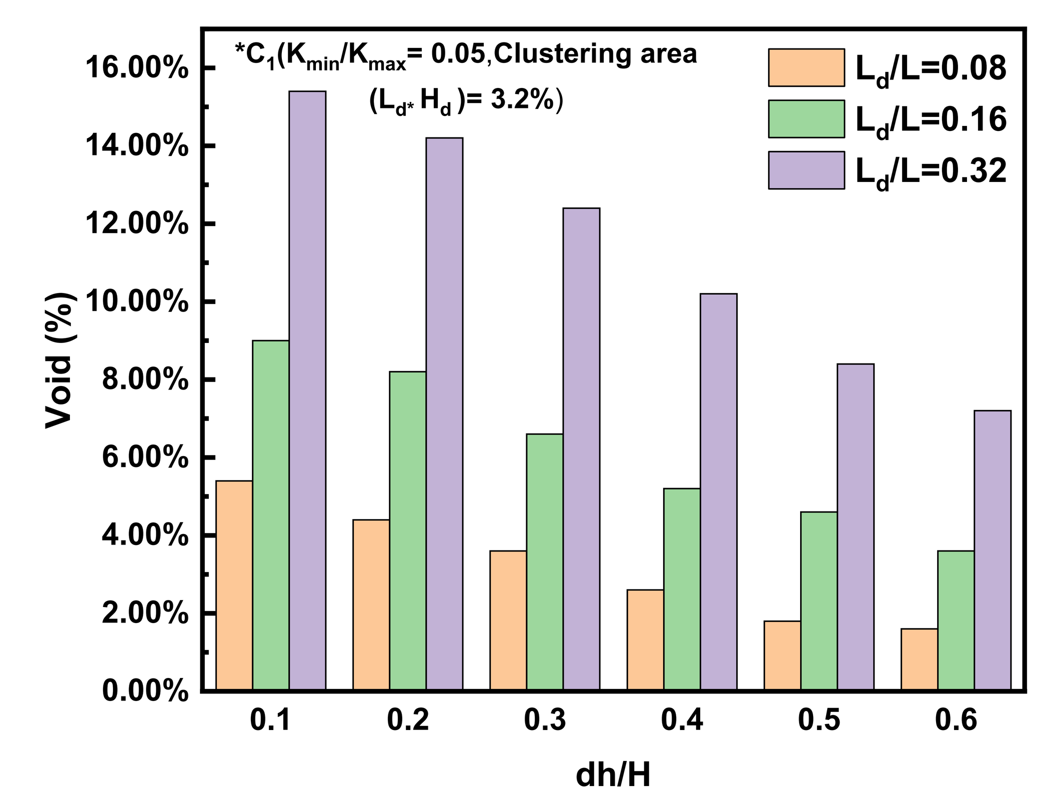
C_1 = Permeability variation factor $=\frac{k_{low}}{k_{bulk}}$, L_d = length of the low permeability region (mm), dH = distance between the injection point and the low permeability region (mm), K = permeability (m^2), P = Applied pressure (Pa)

Results and Discussion

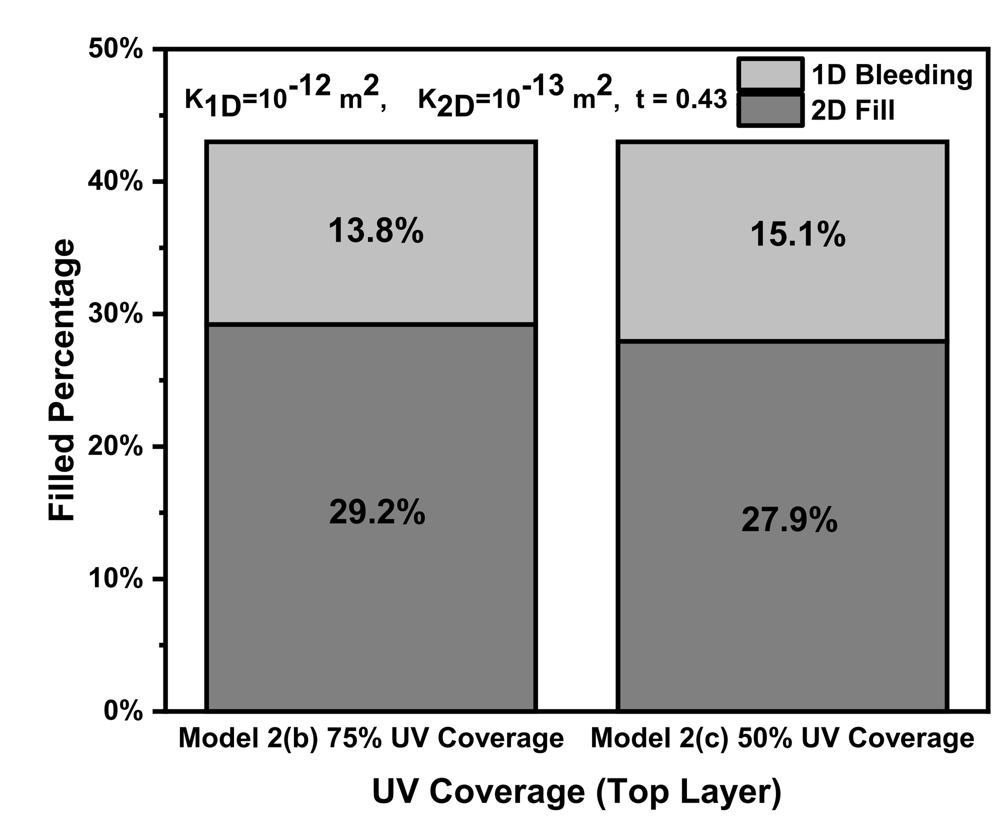
Model 1. Variability in local permeability can significantly influence the void percentages.



Different clustering lengths and location affect the void percentages.

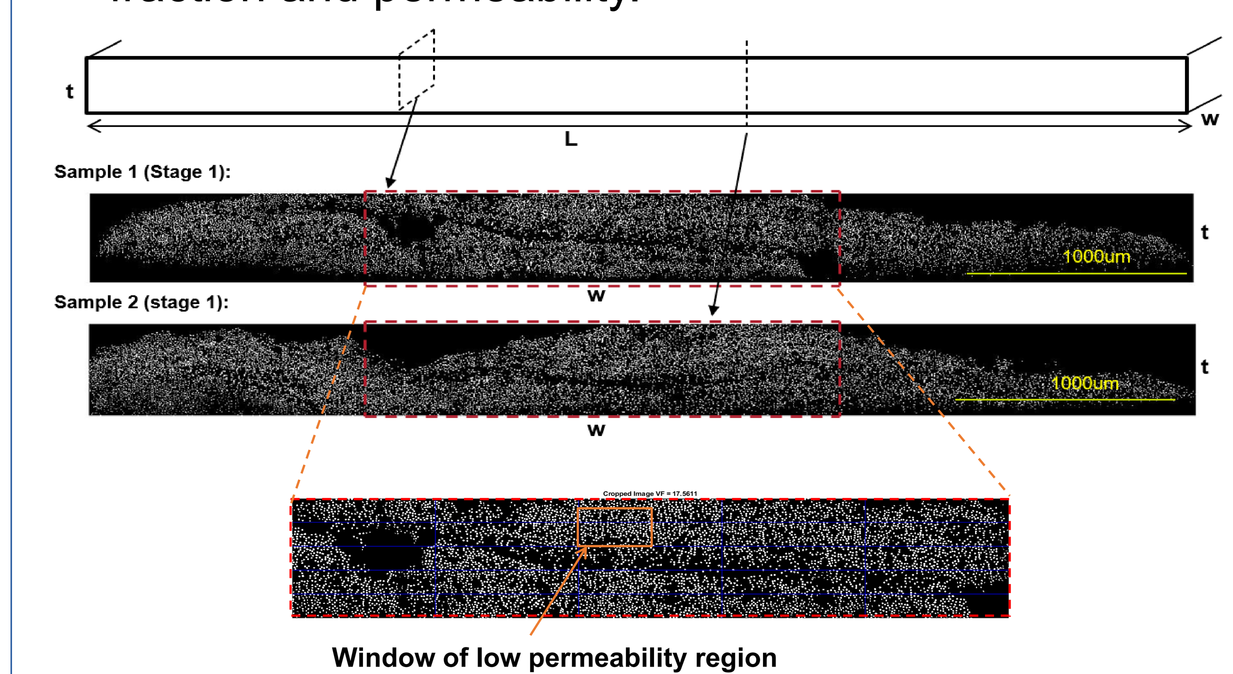


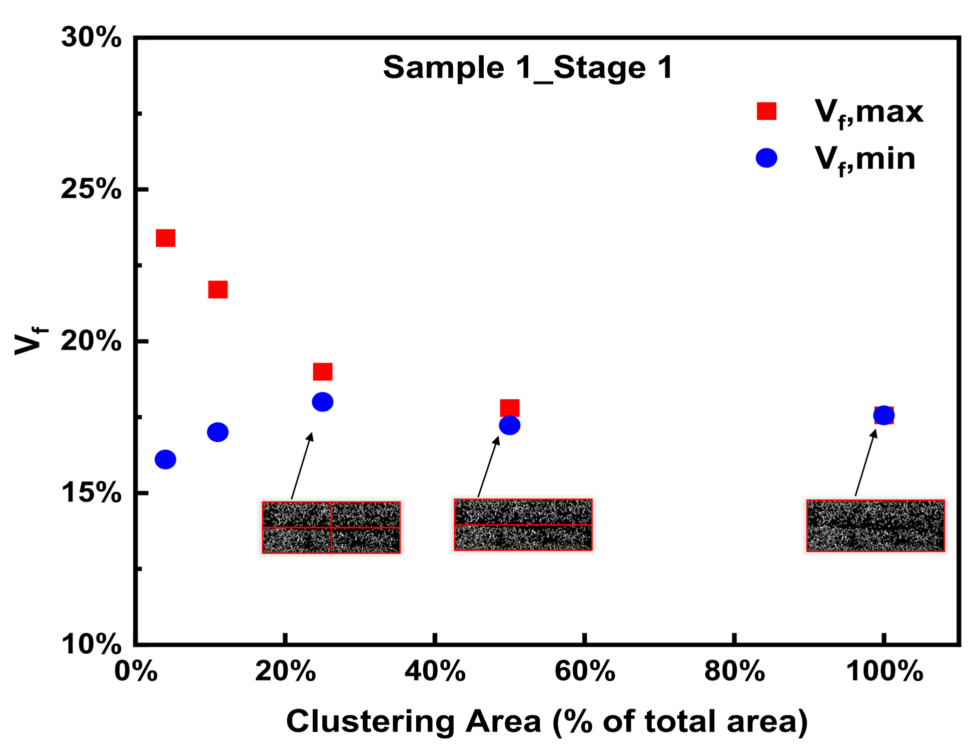
Model 2. Based on different pulling speeds, the degree of UV curing vary on the surface, which can lead to different amounts of resin bleeding. The void regions were filled to a higher extent with higher degree of UV curing.



Experimental Validation

Model 1. Identifying the variation in fiber volume fraction and permeability.





Learnings from the Models

- Larger variability in permeability, fiber clustering length and clustering closer to injection leads to higher void content.
- Larger dry regions take more time to fill increasing the probability of resin bleeding.
- Pulling speed dictates the amount of UV curing and void entrapment.
- High aspect ratio voids take less time to fill.

References

[1] Kaiyue Deng, Soyeon Park, Chunyan Zhang, Ying Peng, Amit Chadhauri, Kelvin Fu, "Core-shell structured tow-pregs enabled additive manufacturing of continuously reinforced thermoset composites"

[2] P. Simacek, S.G. Advani, C. Binetruy, "Liquid Injection Molding Simulation (LIMS) A Comprehensive Tool to Design, Optimize and Control the Filling Process in Liquid Composite Molding," JEC – Composites, n 8, 2004

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