AI-Driven Process Control for Resin Injection Molding

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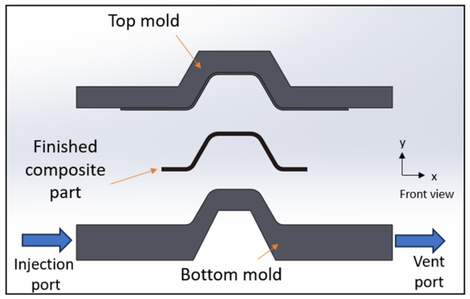
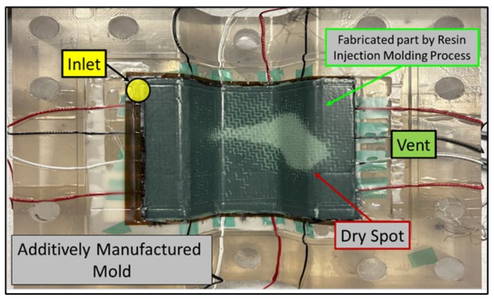
Introduction

- Resin Injection Molding (RTM) Process
  - Infusion of thermoset polymer into a mold filled with dry fabric reinforcement.

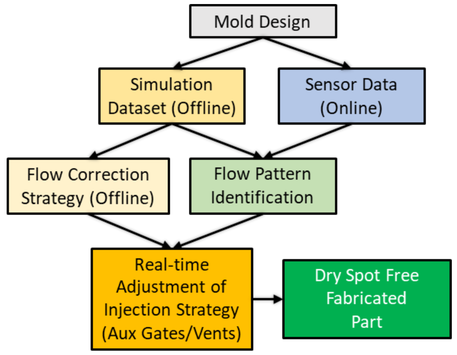


- Challenges
  - Imperfections in fabric placement lead to flow disturbances in high-permeability channels (resin racetracking), resulting in incomplete impregnation and dry spots, ultimately causing defects.



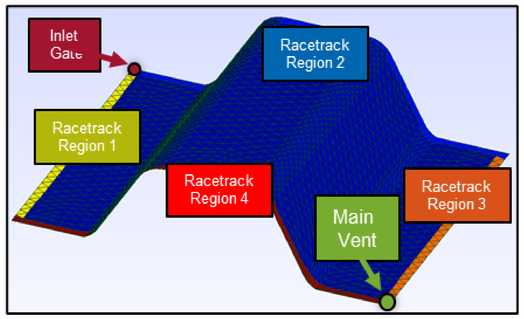
- Motivations
  - Automated detection and mitigation of flow disturbances in RTM.
  - Ensured full fabric impregnation for quality and efficiency in high-volume production.
- Approach
  - Process monitoring using embedded sensors in the 3D printed mold.
  - Implementation of AI-driven process control.

AI-Process Control Diagram

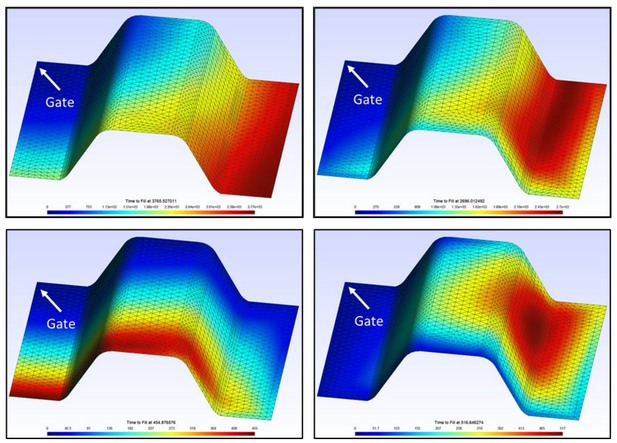


Dataset Development

- Identifying the potential racetrack regions.
- Considering 5 possible permeability for each region.
- Dataset size: $5^4 = 625$ scenarios.



- Resin Fill Time Contour Plots for different scenarios:



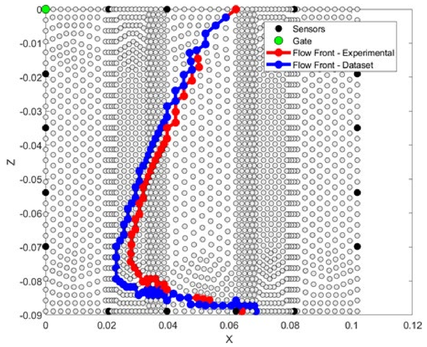
Flow Pattern Identification

1. Defined Sensor Activation Data SAQ vector per scenario.

$$X_{Data} = (S_i\ , t_{S,i})$$

S_i: Sensor ID
$t_{s,i}$: Resin arrival at Sensor i

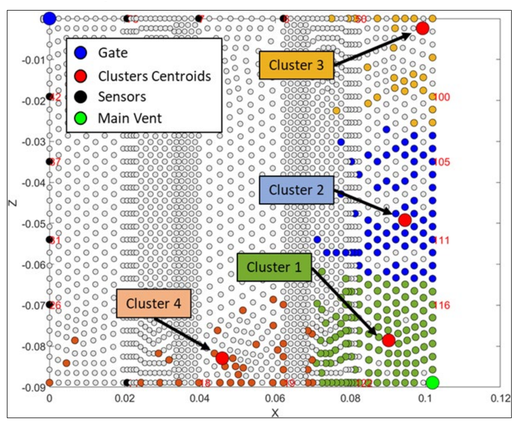
2. Training a model using SAQ comparison between Experimental data and Dataset.
3. Added layer for non-dimensional sensor activation time comparison.
4. Accounted for noise in experimental data.
5. Early stop criteria for making flow correction decisions before resin reaches the main vent.



Flow identification at 390s
(main vent reached at 670s).

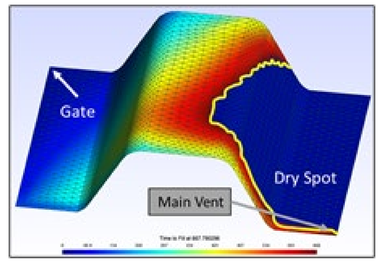
Flow Correction Strategy

- Clustering analysis of the simulation dataset to find optimal locations of auxiliary vents.
- Switching from the main vent to auxiliary vents after flow pattern identification.

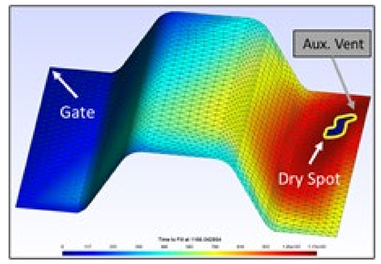


Results and Discussions

- Reduced dry spot volume using an AI-driven process control system.

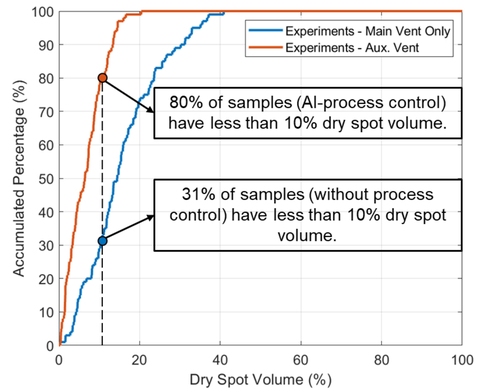


1) Infusion with one Main Vent.



2) Infusion with AI Process Control using 4 Auxiliary Vents.

- Statistical analysis to assess the methodology's success rate.



Acknowledgements

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