FDM Quality Process

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Mission

Oak Ridge National Laboratory missioned NMSU's capstone team to improve the reliability of fused deposition modeling (FDM) by developing a predictive quality model using real-time sensing and mechanical testing.

Project Scope Of Work:

- Predict print quality through in-line sensing and data acquisition
  - Sensors: Accelerometers, thermocouples, and infrared (IR) cameras
  - Record temperature, vibration, and thermal distribution during printing
- Fabricate mechanical test specimens using variable print parameters
  - Parameters include orientation, size, and infill pattern
  - All specimens printed using industry standard PLA material
  - Tensile strength testing
- Analyze results and correlate sensor data with mechanical performance

Focal Areas

Software:

- Raspberry Pi is a compact, single-board computer
- Integrates essential components like a CPU, RAM, and a HDMI port onto a single circuit board
- Python has allowed us to obtain the coordinate data

Extrusion Parameters:

- *Temperatures*
- *Speed (or Flow Rate)*
- *Layer Height*
- *Nozzle Diameter*
- *Infill Density*
- *Print Speed*

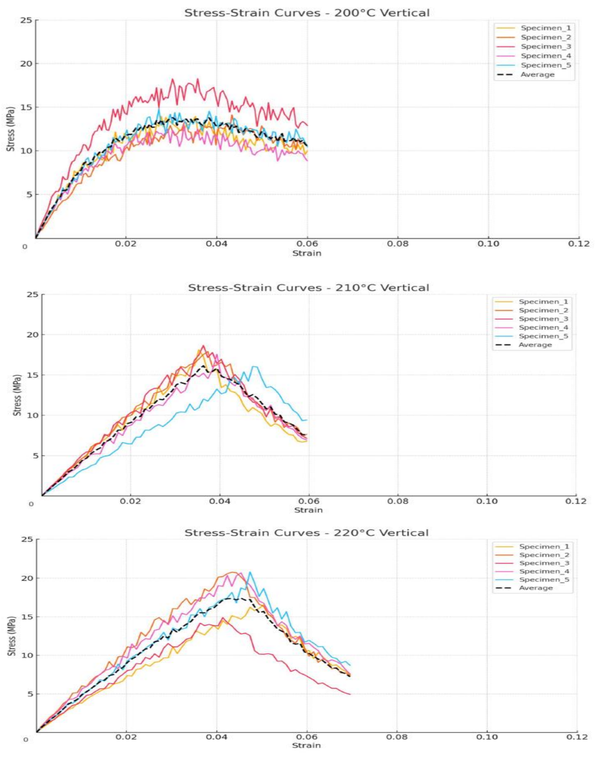
Porosity and Anisotropy:

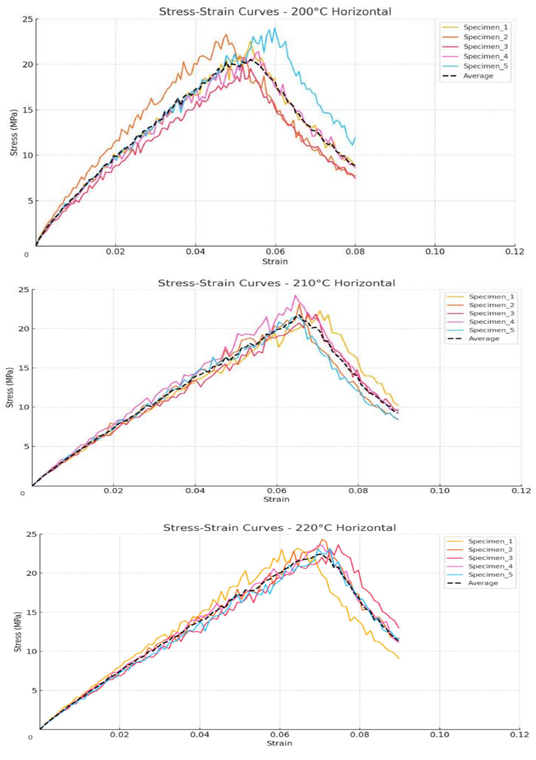
- Porosity refers to inadvertent gaps within a material, while anisotropy describes direction-dependent properties such as varying strength or stiffness.

Special Thanks

- Our clients, Madhura Limaye and Segun Isaac Talabi
- Brooke Montgomery and Luke Nogales
- Aggie Innovation Machine Shop

Final Design





Phase 1: *Calibration & Baseline Data Collection*

- Ensure the FDM printer is properly calibrated (nozzle height, bed leveling, and extrusion settings)
- Print a standard test specimen under controlled conditions without any modifications

Phase 2: *Controlled Printing Experiments*

- Change nozzle temperatures (e.g., 200°C, 210°C, 220°C)

Phase 3: *Post-Printing Quality Analysis*

- Test specimens are sent to the NMSU Machine Shop to get cut into dog bones by a waterjet
- Mechanical property testing using an Instron

Phase 4: *Correlation Analysis*

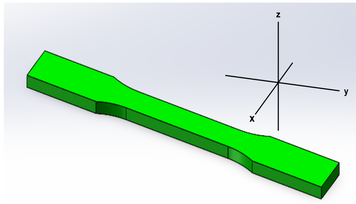
- Data collected from the sensors during printing will be analyzed alongside post-printing mechanical and surface quality results
- The graphs of the Instron will be compared to one another to find out the best parameters for the strongest outcome with PLA
- The raspberry pi data will be analyzed to understand how temperatures affect the final prints

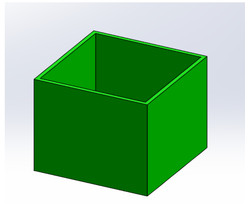
Concept Development

Cube and Dog Bone

The design of the cubes and dog bones needed purposeful geometry that would suit the tensile testing requirements we were looking to analyze.

- 9 cubes with dimensions of *140 mm x 140 mm x 140 mm*
- 70 dog bones, with dimensions of *6.5 mm x 0.75 mm x 0.20 mm*





Results

Temperature (°C)	Orientation	Tensile Strength	Strain at Break	Notes
220	Horizontal	Highest	Highest	Best adhesion, stable
220	Vertical	30-40% lower	Lower	Brittle, weaker
210	Horizontal	Moderate	Moderate	Slight decline from 220°C
210	Vertical	Lower	Lower	Brittle, like 220°C
200	Horizontal	Lowest	Early failure	Poor performance
200	Vertical	Weakest	Weakest	Pronounced degradation

- The best printing parameters for industry standard PLA using the Bambu Lab X1-Carbon is *220 °C at a horizontal orientation*
  - These conditions provide the highest tensile strength and highest strain at break, along with the best adhesion and stability.

References

- "Bambu Lab X1-Carbon Combo 3D Printer," MatterHackers. [Online]. Available: https://www.matterhackers.com/store/l/bambu-lab-x1-carbon-combo-3d-printer/sk/MG70U3XH.
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