Project #50: Polymer Hybrid Manufacturing

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Objective

To integrate an Ambit Polymer Extrusion System with an existing Haas CNC Mini Mill and demonstrate the advantages and limitations of hybrid manufacturing by producing a large-scale test article.

Background

Hybrid manufacturing utilizes both subtractive and additive manufacturing in a single system to incorporate the benefits of both processes. The Ambit is a prototype product designed to retrofit CNCs with these advanced capabilities.

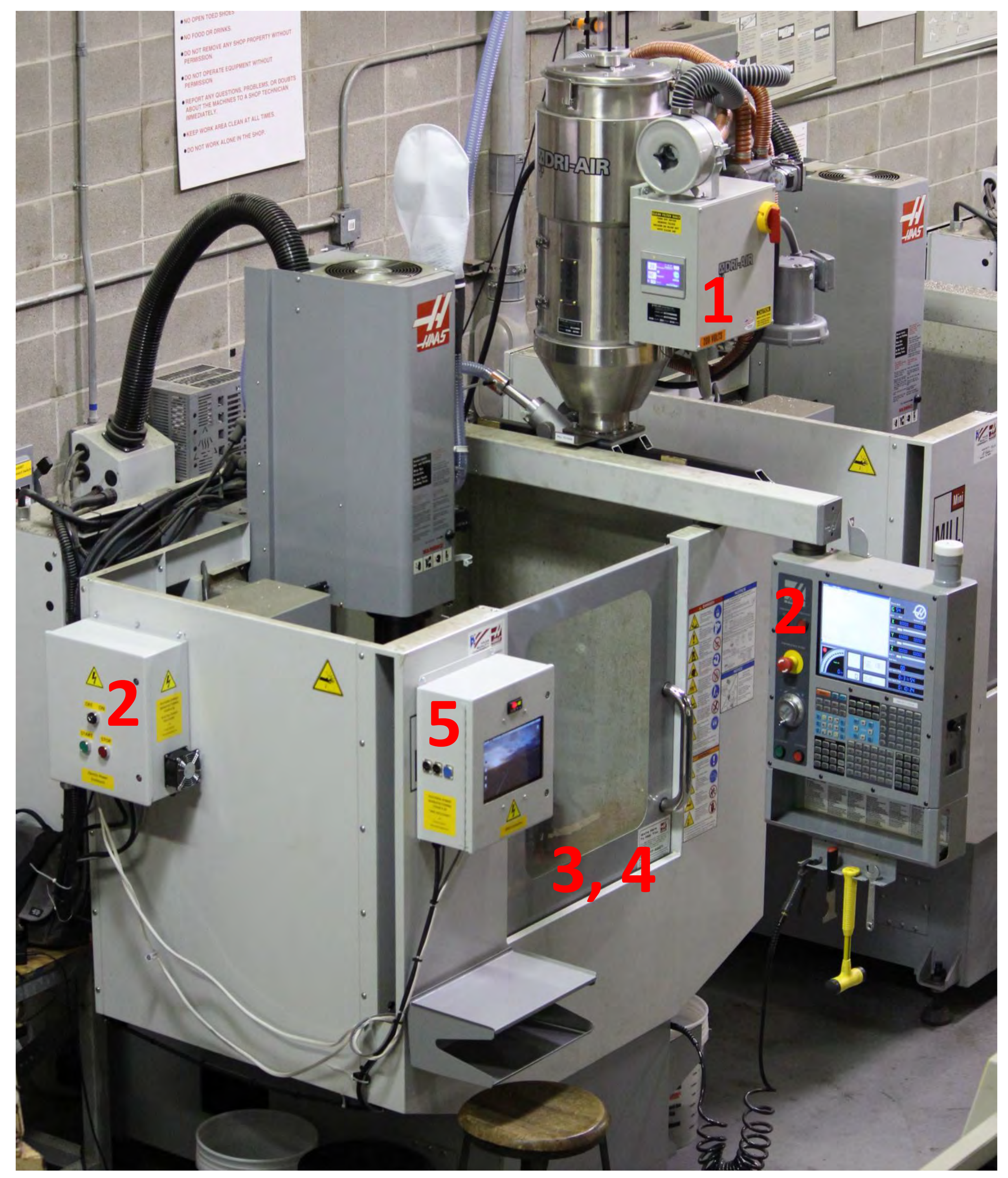
Engineering Specifications

Specification	Target Values	Measured Values
Build Plate Temperature	20 °C – 135 °C	90 °C
Extruder Temperature	220 °C	220 °C
Layer Height	< 0.15 inches	.05 inches
Spindle Speed	35 - 200 RPM	50 - 97.5 RPM
Extrusion Rate	70% - 130%	70% - 130%
Feed Rate	24 - 150 IPM	24, 80 - 149 IPM

Functional and Process Requirements

Requirement	Satisfied
Perform Additive Manufacturing	✓
Perform Subtractive Manufacturing	✓
Variable Control	✓
Be Safe	✓
Be Easy to Use	✓
Perform Testing	✓
Process Refinement	✓

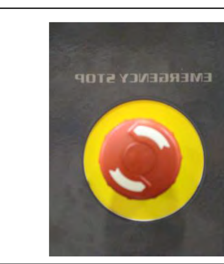
Polymer Hybrid Manufacturing System



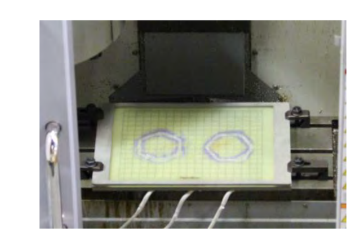
Polymer Hybrid Manufacturing System Located at LSU Additive Manufacturing and Machining Facility

1. Dryer and Hopper
Closed loop system used to dry, store, and supply polymer pellets at desired temperatures

2. Emergency Stop
Shut down electric power to all moving and heated subsystems connected through the power enclosure

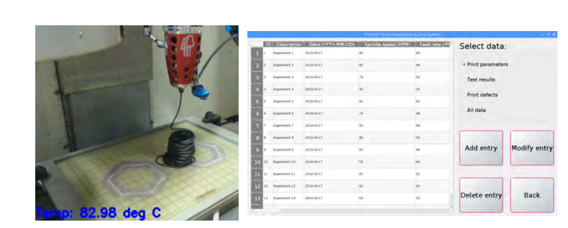


3. Heated Build Plate
Adheres printed part's first layer to the heated surface for additive and subtractive processes



4. Ambit PE-1
Prototype polymer extrusion head compatible subtractive manufacturing systems

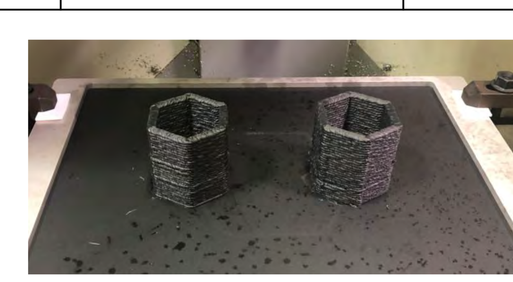
5. User Interface
Process monitoring via temperature sensors and camera, data collection



Parameter and Quality Evaluation

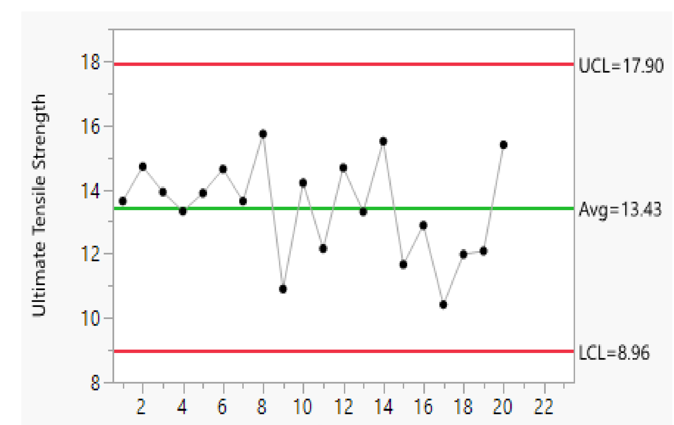
Pilot Test – Center Point Run
Goal: Find the distribution and variance of data recorded based on parameters below.

Test	Spindle Speed	Feed Rate
1 - 5	50 RPM	24 IPM



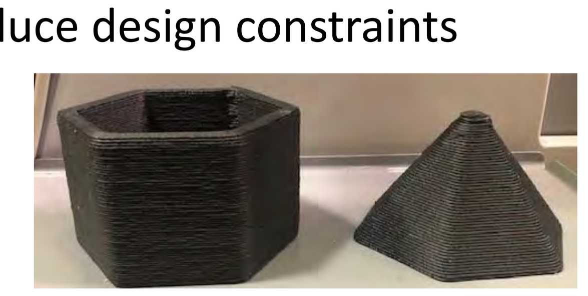
Pilot Test Print Specimen

Shapiro-Wilk test fails to reject H_0 so data is normally distributed and all samples are within control limits shown by control chart.



Control Chart

Response Surface Test
Goal: Identify a list of optimal parameters for future prints that reduce design constraints



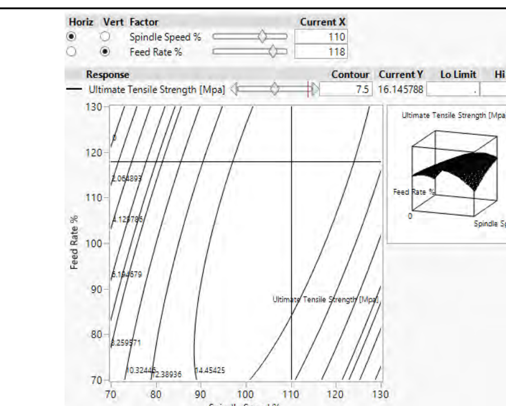
Response Surface Test Print Specimen

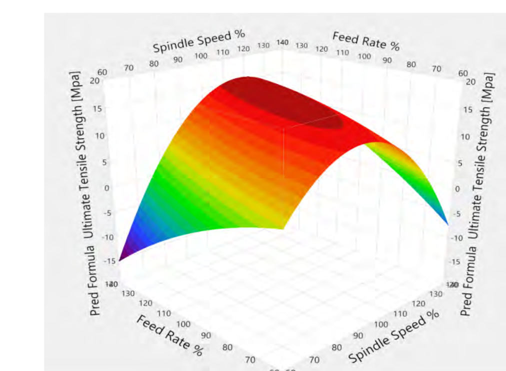
Response Surface Test Print Parameters

Test	Spindle Speed	Feed Rate
1	52 RPM	80 IPM
2	52 RPM	150 IPM
3	52 RPM	115 IPM
4	97 RPM	150 IPM
5	70 RPM	150 IPM
6	97 RPM	115 IPM
7	70 RPM	115 IPM
8	70 RPM	115 IPM
9	97 RPM	80 IPM
10	70 RPM	80 IPM

Outcomes

Optimal Outcomes	Spindle Speed	Feed Rate
% Elongation (1.61%)	111 RPM	115 IPM
Ult. Tensile Strength (16.15 MPa)	110 RPM	118 IPM
Reduced Layer Time (35 s)	75 RPM	124 IPM
Near Net Shape – Width (± 0.06 in)	127 RPM	130 IPM
Near Net Shape – Height (± 0.07 in)	70 RPM	121 IPM





The contour profile and response surface plot were populated using the outcomes of the tensile testing performed (ASTM D638) through response surface methodology

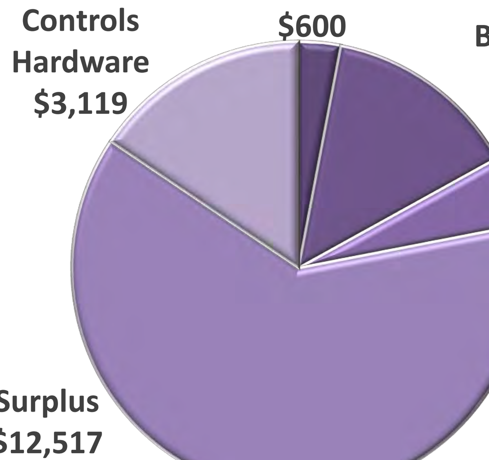
Conclusions

Advantages	Limitations
• 15x faster than a desktop 3D printer • Suited for large build volumes • Direct control during operation including changing layer time to affect layer bonds	• Transition time • High variance throughout prints • Minimal documentation regarding parameters and their effects • Maintenance – difficult, costly • Unreliable system

Recommendations:

- Implement and evaluate a quality control plan
- Scale to larger equipment allowing for increased layer time and decreased operator parameter control

Budget



Total: $20,000

September	October	November	December	January	February	March	April
Research & Concept Generation	Concept Selection & Test Plan Development	Material Selection, Modeling & Analysis	Ambit Installation, Controls Integration & Product Ordering		Manufacturing, Controls Integration & Product Ordering	Testing, Validation and Quality Analysis	

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