GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF AEROSPACE AND MECHANICAL ENGINEERING
The UNIVERSITY *of* OKLAHOMA

Development of a CFRP Print Head and Quality Monitoring System



Faculty Advisor:
Dr. David Baldwin



Faculty Sponsor:
Dr. Arif Abdullah



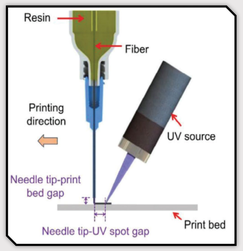
Team Members (Left to Right): Lauren Robinowitz, Gregory O'Loughlin, Drew Busch, Sean Freudenberger

Overview

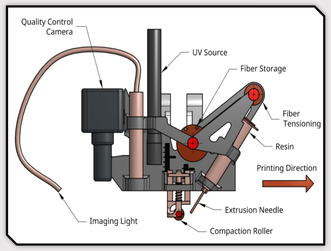
Background
- Carbon Fiber Reinforced Polymers (CFRPs) are lightweight composite structures consisting of carbon fiber imbedded within a polymer matrix
- High tensile strength which excels at directional strength reinforcement
- Applications in aerospace, automotive, infrastructure, and more
- Manual manufacturing introduces inconsistencies and additional costs

Problem Statement
- Develop an integrated gantry-system capable of automated printing, inspection, and scanning of continuous fiber composite structures

Prior Research

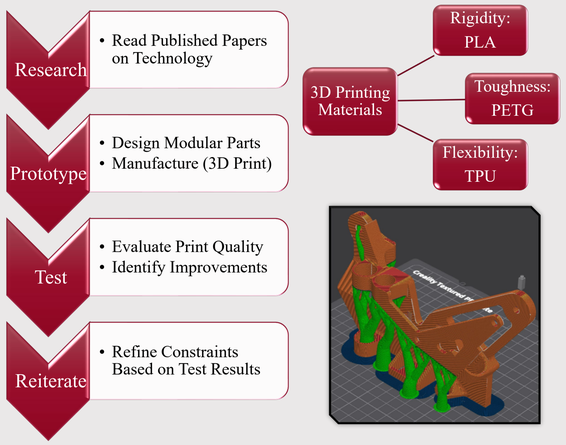


Design Improvements



Constraints
- Must perform resin infusion, fiber compaction, UV curing, and real time analysis
- Able to securely mount to future robotic systems without impacting functionality
- Capable of multiple fiber sizes, printing speeds, and printing surfaces for research
- Evaluate resin-fiber ratio, air bubble count, and printed fiber geometry

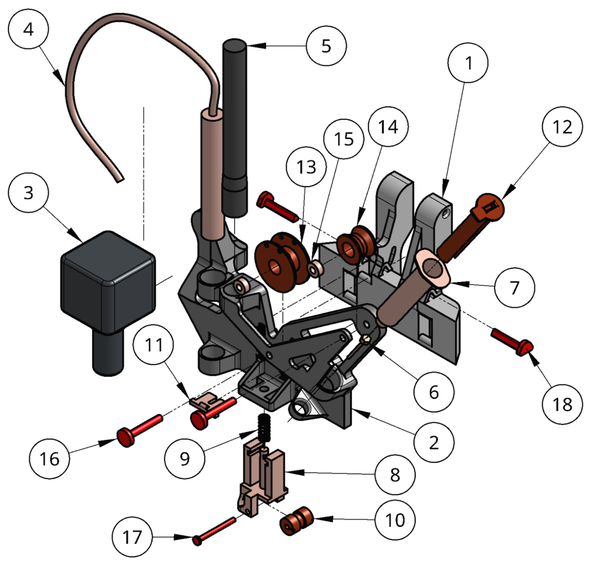
Design Process



Codes and Standards

- ISO/ASTM 52900:2021, Additive Manufacturing—General Principles—Fundamentals
- ISO/ASTM 52901: Additive Manufacturing—General Principles—Requirements for AM
- ISO 12100: Safety of Machinery — General Principles for Design — Risk Assessment and Risk Reduction

Final Design



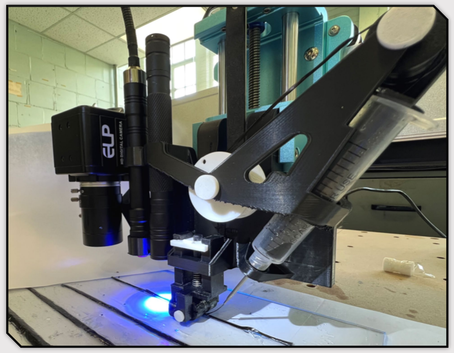
Number	Name
1	Gantry Mount
2	Main Body
3	Camera
4	Imaging Light
5	UV Light
6	Needle
7	Syringe
8	Compaction Guide
9	Compaction Spring
10	Compaction Roller
11	Compaction Guide Lock
12	Ladder
13	Fiber Spool
14	Feeding Roller
15	Bearing
16	Feeding Pin
17	Compaction Roller Pin
18	Mounting Pin

Modularity
- All parts are easily exchangeable to expedite the research process
- Mounting scheme is generalized to allow different robotic systems

Feeding and Infusion
- Fiber tow is pulled through guides in a resin-filled syringe
- Spool and guiding rollers allow fiber length and size flexibility

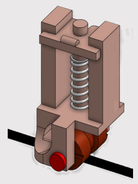
Roller
- Slot compacts fiber onto surface without removing resin
- Spring ensures constant force and printing over bumps

Imaging
- Camera provides real-time quality assessment of CFRP lines
- LED light provides high contrast for defect detection



Roller Mechanism

- Initially PLA, upgraded to TPU.
- Ensures consistency, reduces rippling and waviness
- Central groove to reinforce line geometry.
- Applies 5.4 N of compression force on CFRP line.



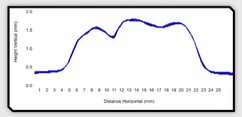
Camera

- Utilizes ImageJ software
- Real time imaging for quality analysis
- 5k resolution and weighs 180g
- Manual zoom, focus, and iris



Scanner

- Utilizes Creality Scan software.
- Provides 0.02 mm scanning resolution
- Allows for quantification of the printed lines geometry and object geometry for prints



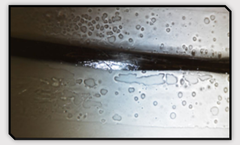
Scanned Height Map of Printed CFRP Lines



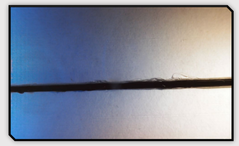
Quality Control

Optimal line quality includes:
- Negligible air bubbles
- No ripples in fiber surface
- Maintains a straight geometric profile

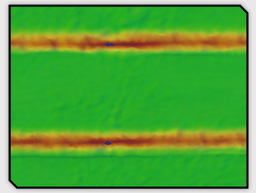
Changes made to improve line quality:
- Increased print speed from 2.5 to 10 mm/s in the G-Code
- Crimped a 10-gauge needle, reducing the cross-sectional area to 0.4mm²



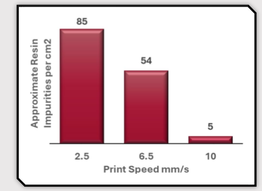
Slower Speed



Faster Speed



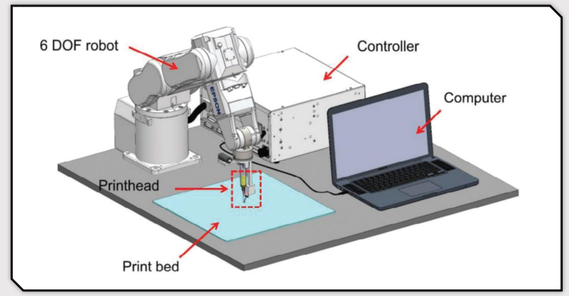
Surface Roughness Scan of Printed Lines



Print Speed vs Resin Impurities

Added Value

- Accelerated the development of the print head system to be used in the full 6 DOF robotic arm system as seen below
- 480 man hours of research and system development ready to be handed off to Dr. Abdullah for continued research
- Developed a quality control workflow utilizing a 3D scanner for the evaluation of further research conducted by the composite materials manufacturing lab



Future Implementation of CFRP Print Head into Integrated Workstation

References

- Abdullah, A. M., Dunn, M. L., and Yu, K., 2024, "Robotic 3D printing of continuous fiber reinforced thermoset composites," Advanced Materials Technologies, 9(24).
- Dojan, C.F., Ziaee, M., Masoumipour, A. et al. Additive manufacturing of carbon fiber-reinforced thermoset composites via in-situ thermal curing. Nat Commun 16, 4691
- 3k Carbon Fiber Tow, 100 ft. pkg.," Carbon fiber tow (fibers/bundle) - CST the composites store, inc.. [Online]. Available: https://www.cstsales.com/a-carbon-fiber-tow.html.