Curved Layer Carbon Fiber 3D Printing

fiber orientation control - lighter parts - increased strength

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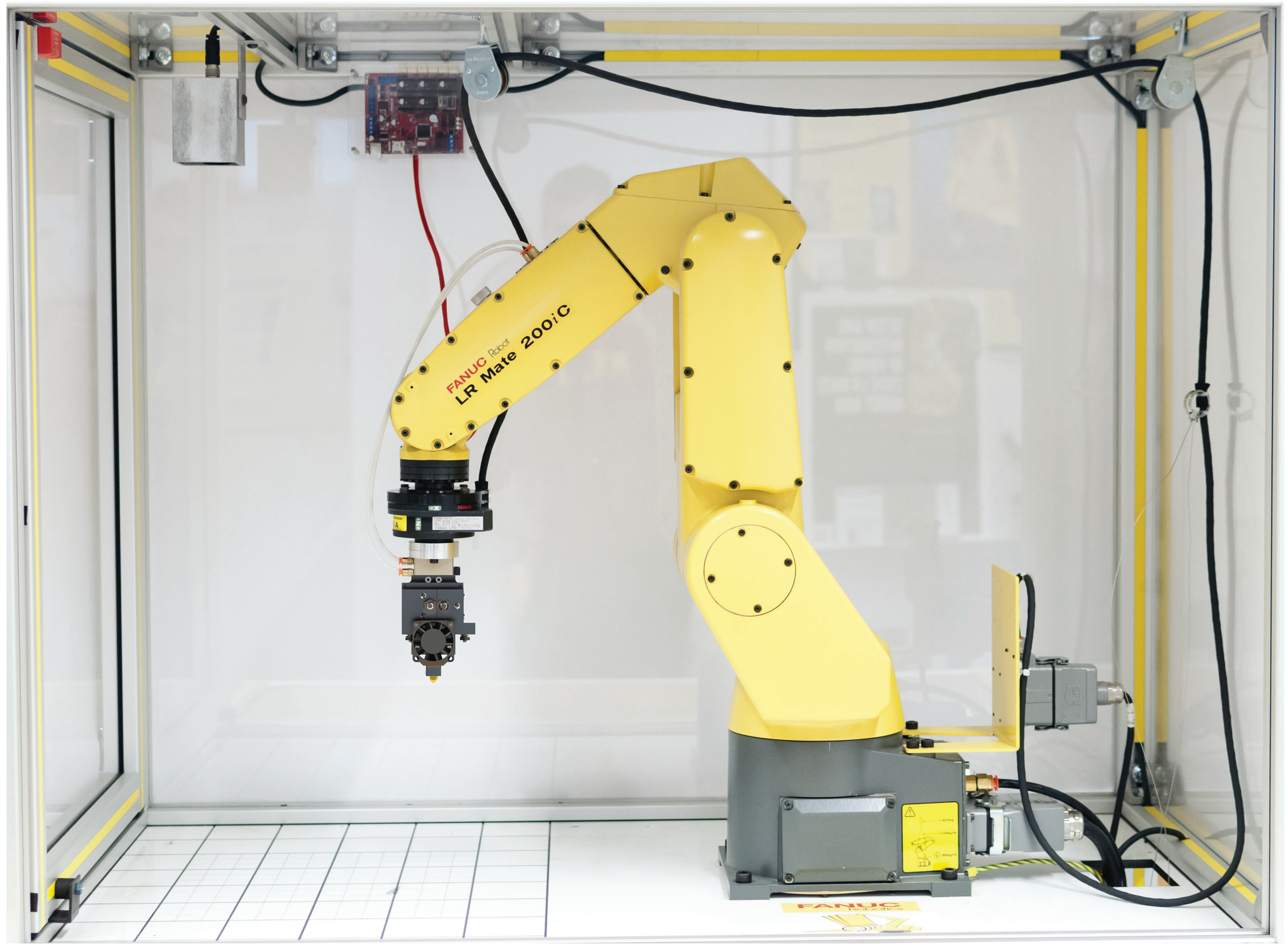
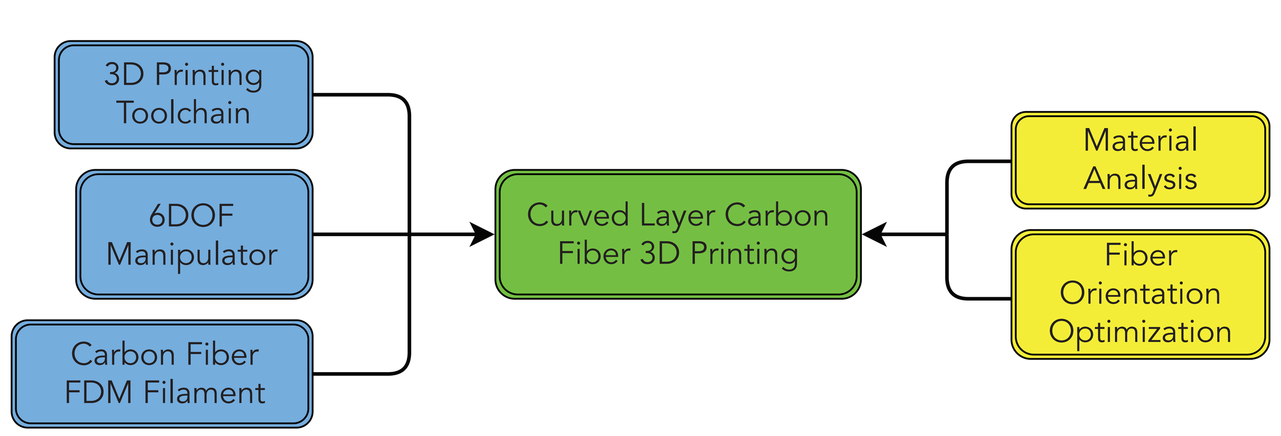


Problem Definition and Project Goals

Current desktop 3D printers build parts with thermoplastics like ABS and PLA using Fused Deposition Modeling (FDM). A plastic filament is heated and extruded as a thin line, creating a stack of flat layers until the part is built up. Parts made this way have poor mechanical properties due to the low strength of the plastics and the poor adhesion between layers. Thin vertical features suffer most from layer separation under loading, due to the small inter-layer contact area.

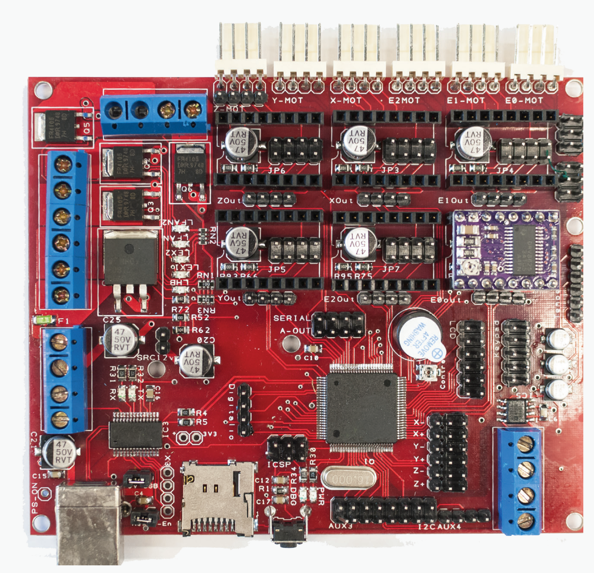


We are solving the material and the print geometry problems by building a 3D printer that will print a carbon fiber composite in curved layers. Carbon fiber reinforced plastics (CFRPs) are an industry-proven alternative to metals. However, the strength of CFRPs depends on the orientation of the fibers with respect to the part geometry and loads. Printing carbon fiber in curved layers allows us to optimize layer geometry for fiber orientation and layer adhesion, yielding stronger, lighter parts.

6-DOF Robot Arm

The LR Mate 200iC, shown at left, manipulates the extruder to create prints. Its 6 degrees of freedom make curved layer printing possible. The robot is programmed using its own built-in language and controller. On the end of the arm, a force sensor provides collision detection as a safety measure.

Control Electronics



All of the extruder control electronics and software is sourced or adapted from the open source RepRap 3D printer project. The Megatronics board, shown at left, controls the extruder motor, heater, and thermistor while tracking the speed and position of the robot arm.

Filament Development

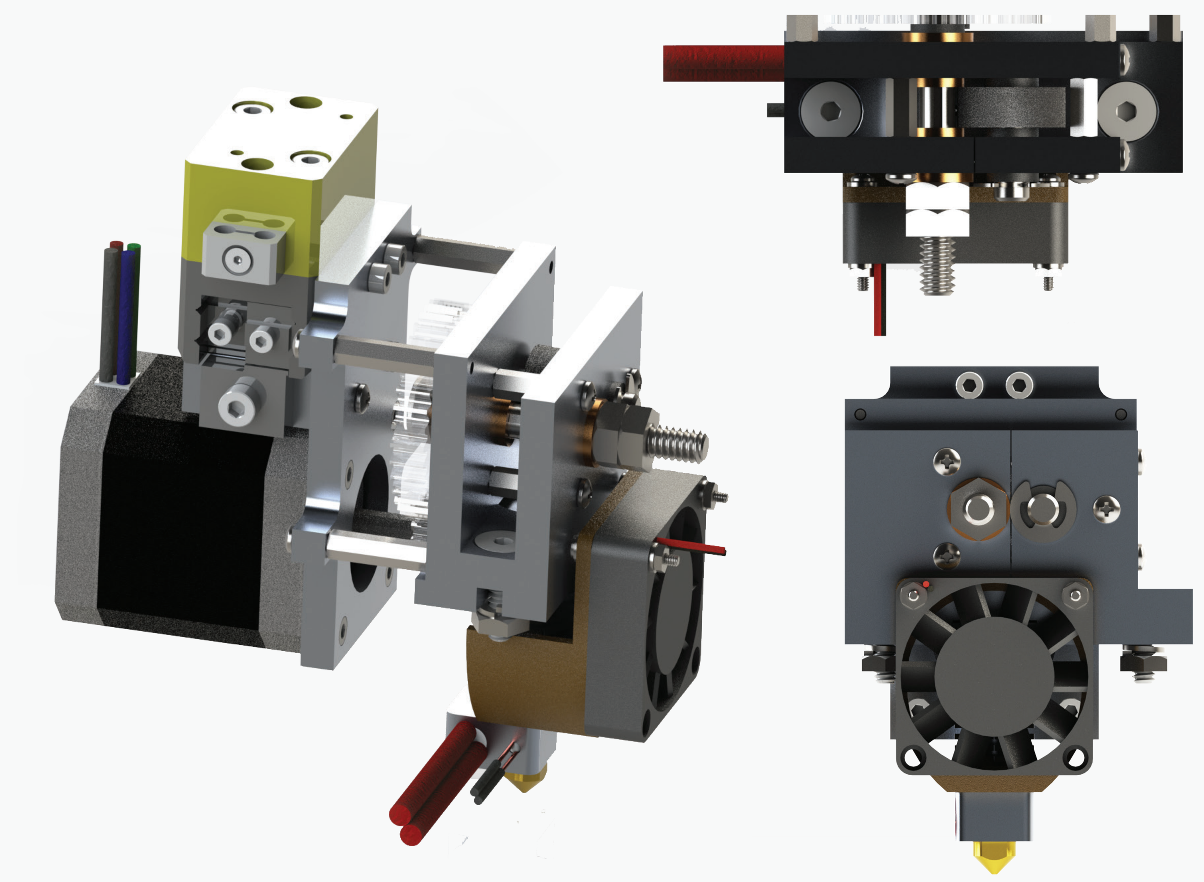
Pultrusion and slurry coating methods are being used to develop a CFRP filament. Pultrusion uses a 3Doodler to fuse carbon fiber with ABS as it is pulled through the nozzle. Coating involved dipping carbon fibers in an ABS-Acetone slurry. Tensile tests were used to tabulate the mechanical properties of each CFRP specimen. These processes will be refined and used in conjunction with more tensile tests and ANSYS modeling to create a usable CFRP filament.

Material	Ultimate Tensile Strength (MPa)	Stiffness (GPa)	Density (kg/m^3)
ABS	53	2.3	1040
Carbon Fiber	3750	231	1750
Aluminum (6061)	310	68.9	2700
Pultruded Filament *	313	13.4	1354
Dipped Filament *	690	19.6	1567

* *Preliminary results from filament tensile tests*

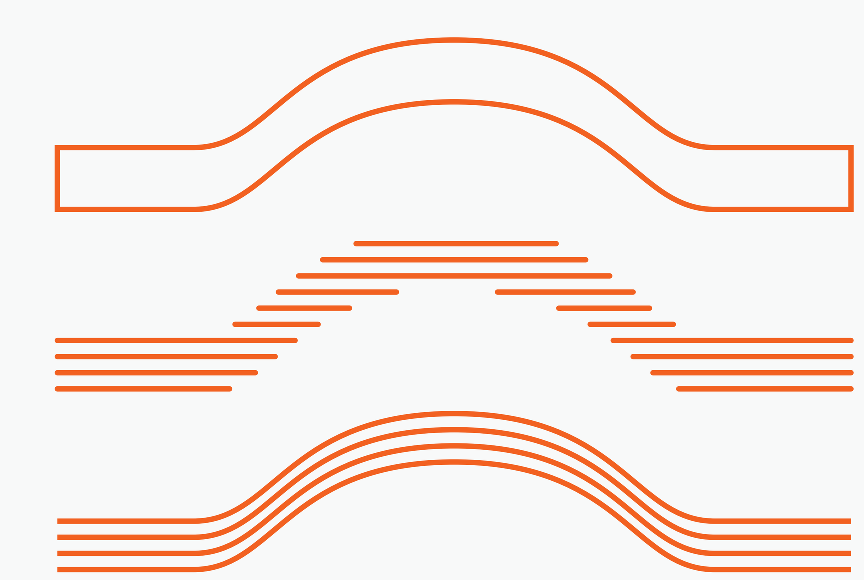
Extruder Design

The extruder, which is constructed using RepRap hardware and machined aluminum, deposits a CFRP filament to create printed parts. The extruder is driven by a stepper motor that rotates a notched screw, which grips and pushes the filament. A bearing opposite the screw provides counter pressure and helps guide the filament into the heated nozzle. The Megatronics board controls motor speed and nozzle temperature.



Layer Generation

ANSYS Composite PrepPost will be used to develop and analyze a finite element model of the printed composite. The model will be used to optimize layer shape and fiber orientation within a given part geometry based on expected loading conditions. Once the optimal layer shapes are determined, the ANSYS data will be used to generate the code for controlling the LR Mate 200iC robot and the code that controls the extruder hardware.



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