Additive Manufacturing of Continuous Fiber Reinforced Polymer Composites

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Introduction

Composite 3d printing is the printing of parts (usually plastic) with the inclusion of a secondary material such as carbon fiber, metal powder, or another plastic. One such type of composite 3d printing is Continuous Fiber Printing which is the subject of this research project.

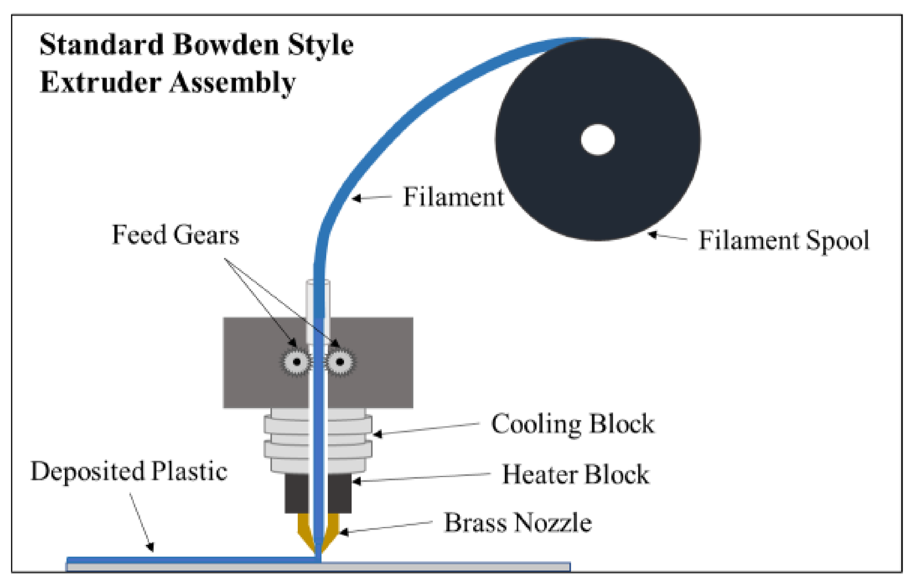
Continuous fiber printing deposits a continuous string of a fine fiber (such as carbon fiber or Kevlar) in matrix with the primary plastic. This process can significantly increase the tensile strength and rigidity of plastic parts making them much more suitable for engineering applications.

Purpose

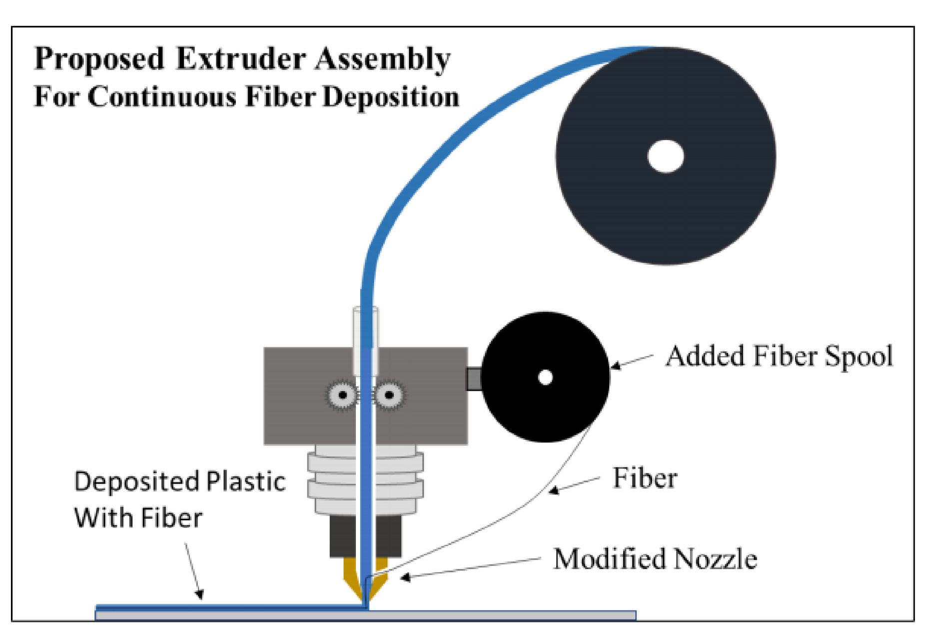
The purpose of this research project is to develop a repeatable process for converting a consumer model 3d printer into one capable of continuous fiber printing and composite part production.

Methodology

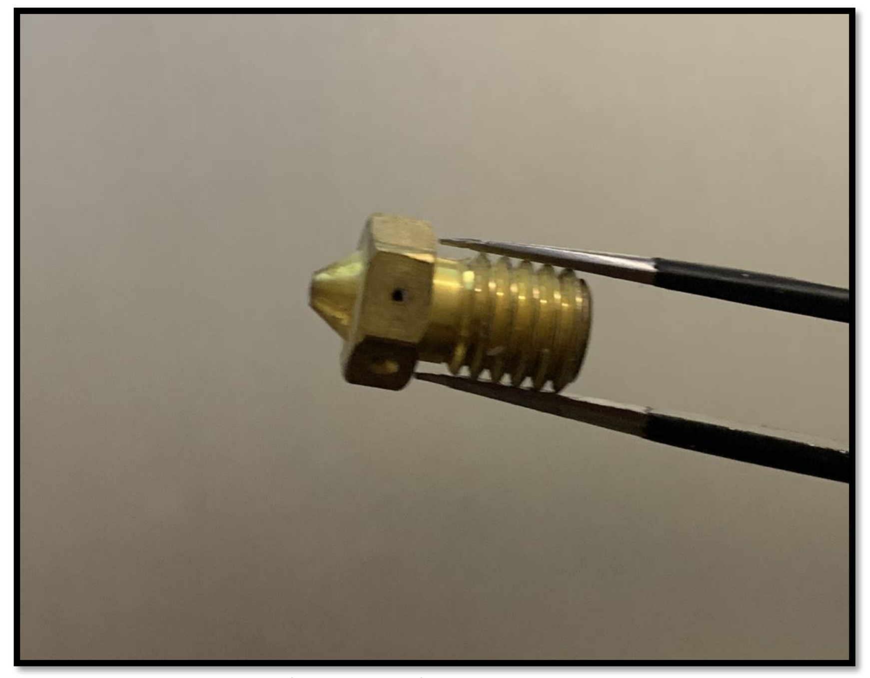
A standard Bowden Style extruder assembly (the most common type among 3d printers) consists mainly of a heater block, feed gears connected to the extruder's own stepper motor, an inlet for the filament, and a brass nozzle. During operation, the feed gears are rotated by the motor which pulls filament off a spool and feeds it through the heater block before pushing it out of the nozzle.

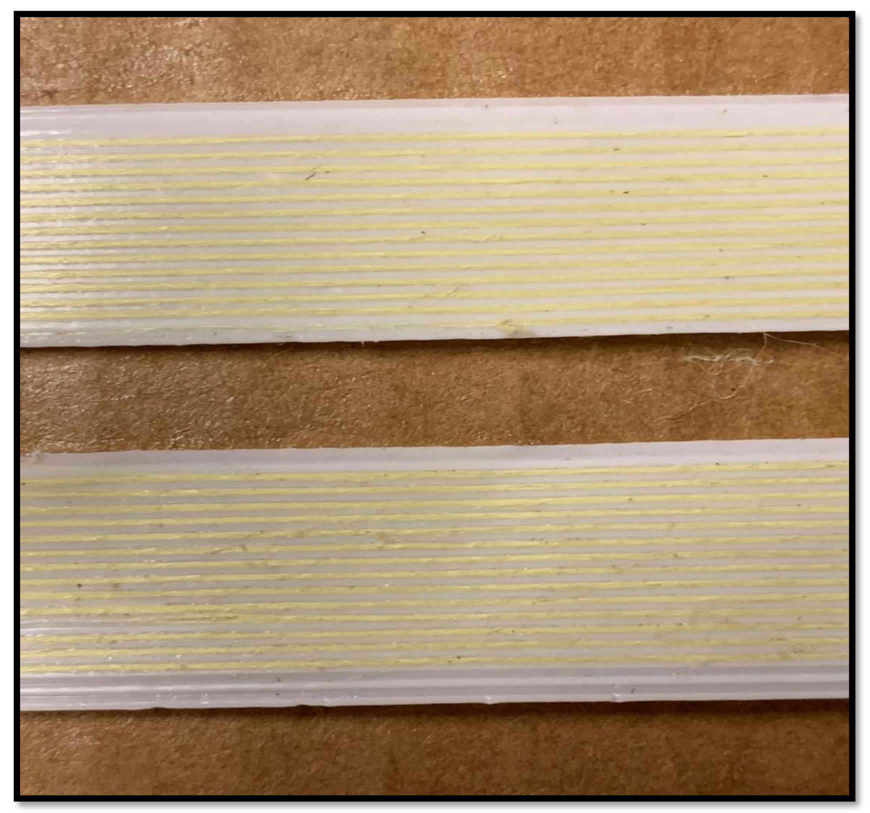


The design process for this project consisted of three main parts. The first was machining of a purchased printer's existing brass nozzle. The nozzle needed to be drilled with a very small hole (approximately 0.5 mm in diameter) at an angle sloping towards the direction of flow. This drilled inlet would allow fiber to be inserted into it and extruded out with the plastic from the main outlet. The second modification was the addition of a rotating spool to hold and allow the feeding of fiber into the nozzle. Lastly, a mount needed to be constructed to affix the spool to the printer.

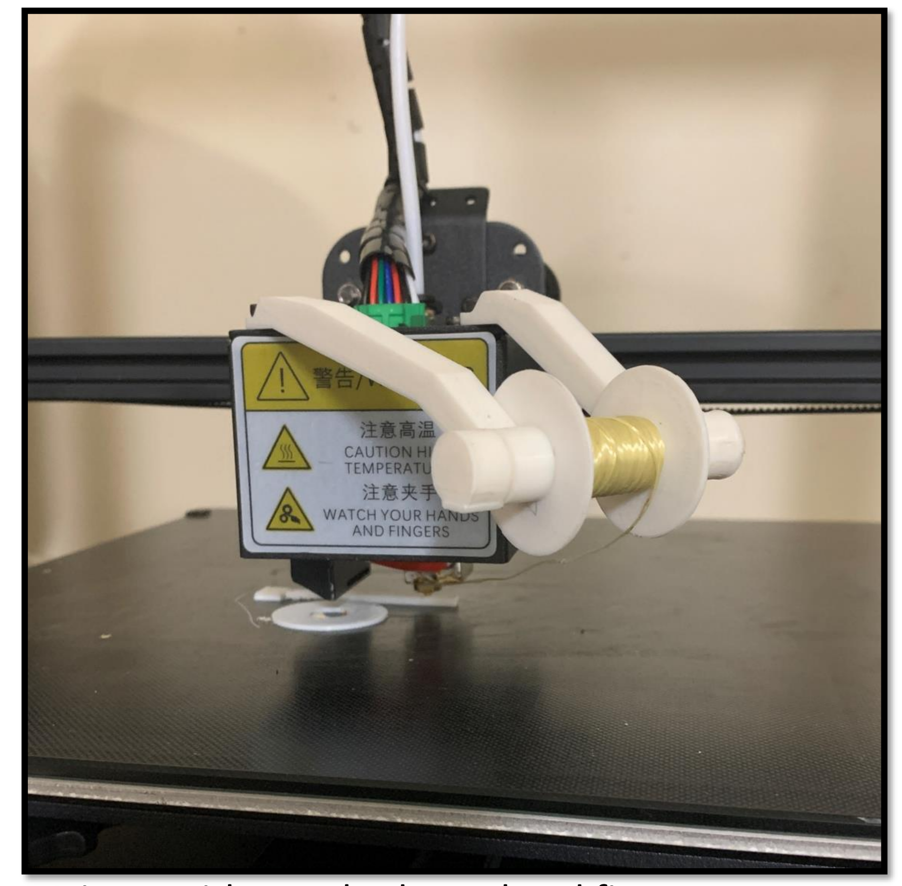


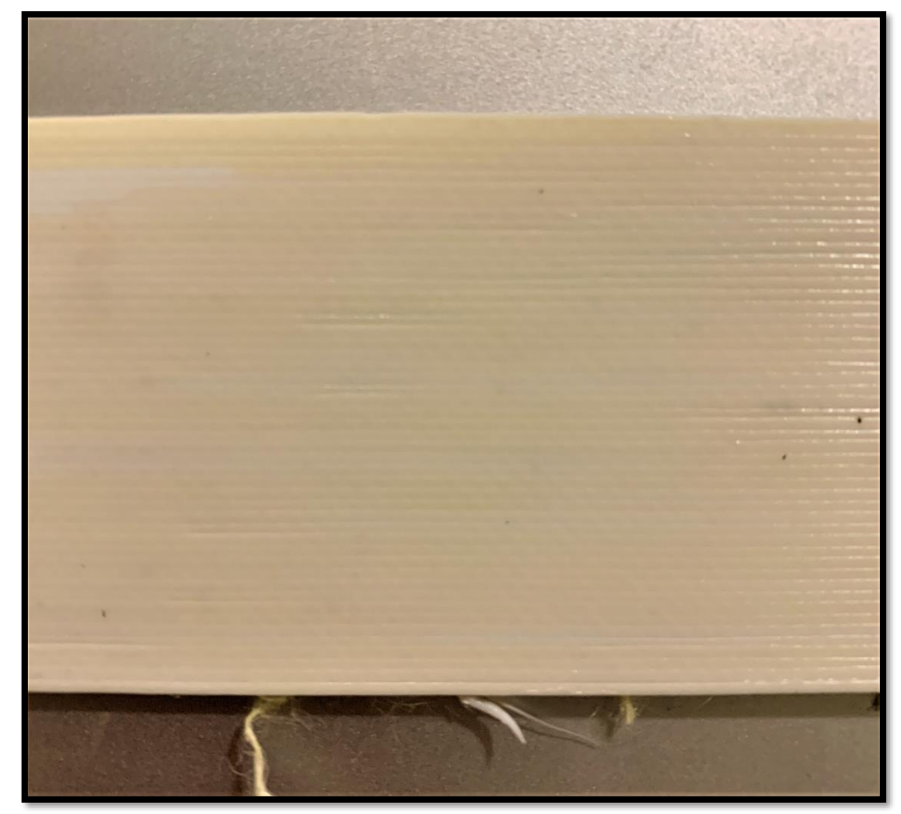
Modifications and Printing Demonstration


Drilled Nozzle (0.5mm)


Rows of printed PLA plastic showing successful deposition of Kevlar strands


Fiber that was pulled out of sync on a sharp corner. This was the primary problem encountered in this research.


Printer with attached spool and fixtures (shown with spooled Kevlar fiber)


A rectangular section of printed plastic showing completely encapsulated fiber

Results

The project was successful in achieving fiber deposition capability from a standard consumer 3d printer. After the machining of the nozzles and fabrication of the fiber feeding system, the printer was successful in depositing defined strands of Kevlar in matrix with the base polymer.

One primary issue encountered however was the tendency of the fiber to fall out of tandem with the polymer while routing sharp corners. This was due to the fact that the fiber did not tend to extrude out with the plastic, but rather was pulled out by the movement of the print head. When the direction was reversed on sharp geometry it caused a lack of tension in the fiber, and subsequently resulted in poor deposition.

Several types of fiber were tested in this system including Kevlar, carbon fiber, cotton, silk, and wool. The greatest amount of success was achieved with Kevlar. It maintains good thermal resistance while being tough and pliable.

Success with carbon fiber was limited due to the fact that it is inherently more brittle and less flexible than Kevlar. When fed into the nozzle it tended to fray and break before any meaningful printing could be achieved. In future research this could likely be alleviated by using fiber that has been pre-bonded to a secondary polymer.

Future Research

In future research it would be desirable to incorporate the use of fibers pre-bonded in a polymer matrix. These pre-bonded fibers become rigid and could be driven through a separate extruder in much the same way as the base material. With many dual extruder printers on the market, one could likely be modified to accommodate the use of this rigid fiber. This change would also accommodate the use of natural and renewable fibers to a greater extent.

Acknowledgements

This research project and its accomplishments would not have been possible without the generous funding and support given by the IUPUC Office Of Student Research.

My faculty mentor, Dr. M. Noor-A-Alam was also a huge part of my success, his counsel, expertise, and assistance was invaluable to the project.

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