Additive Manufacturing & Advanced Materials Lab: Spider Web Inspired 3D Printing

SDSU Mechanical Engineering

Team Members: Marc Fuentes, Tasia Gary, Joseph Romero

Project Overview

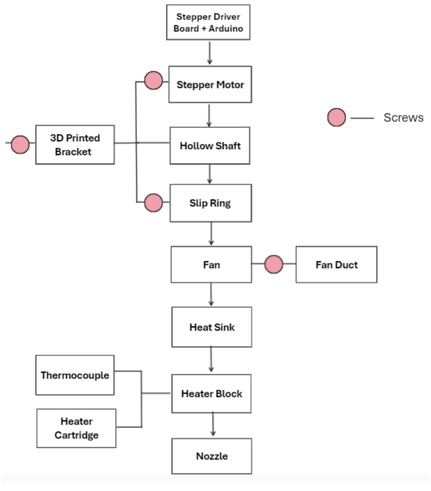
The goal of this research was to create an improved and stronger 3D printing structure than current commercial 3D printers in the market. The project objectives were to analyze the components of a Fused Deposition Modeling (FDM) 3D printer, design and produce a nozzle that mimics the extrusion of a spider web, and study the mechanical behaviors of 3D printed structures produced by the new nozzle. The materials used and tested for this research were silk PLA (polylactic acid) and Carbon Fiber PLA filament.

Methodology

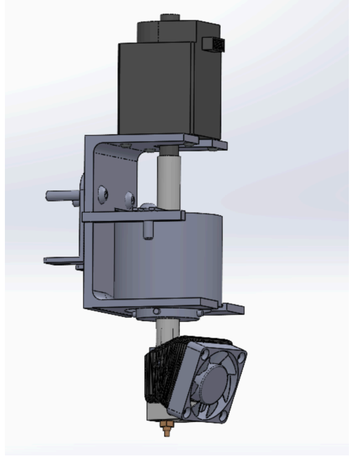
To achieve a spider-web-inspired extrusion of the silk PLA and Carbon Fiber PLA filament, the print head of an Ender 5 Pro 3D printer was disassembled and redesigned to include a stepper motor, a 3D-printed U-Bracket, a 3D-printed hollow shaft, a slip ring, a fan, a 3D-printed fan duct, a hotend, and a custom brass nozzle. The custom nozzle was manufactured using a lathe, and a 0.8 mm drill bit was used to drill three holes into its tip.

To test our hypothesis that the twisted filament strands are stronger than the strands created without a twist, a total of 115 samples of silk PLA and Carbon Fiber PLA were made at the following spin rates: 0, 200, 400, 600, 800, and 1000 (steps per second). Tensile tests were then conducted for each sample.

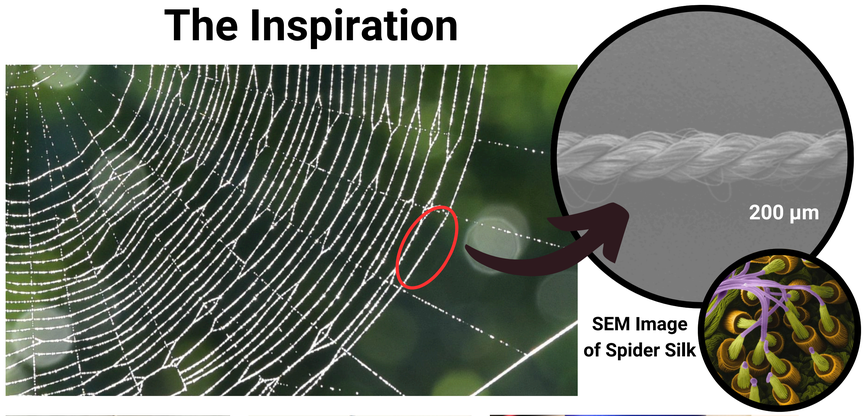
System Level Diagram

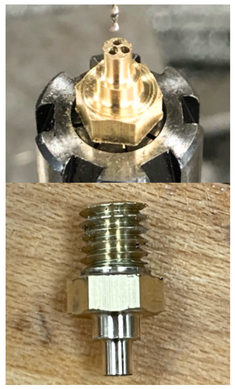


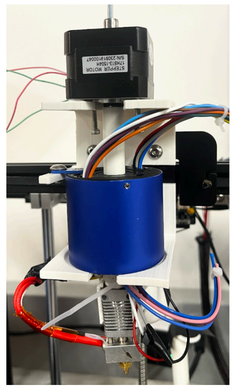
Conceptual Design

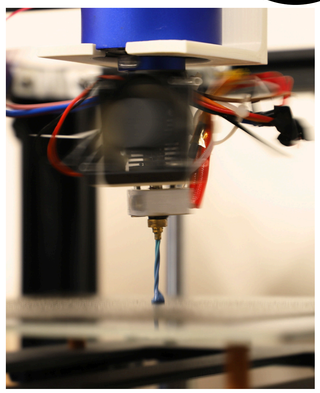


The Inspiration





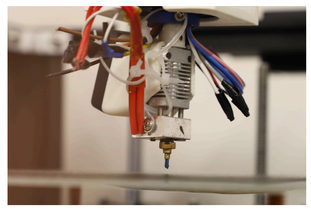




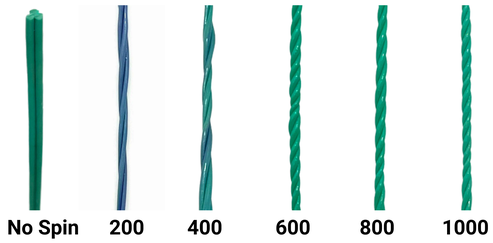
Printing

The printing process involved manually extruding the filament at the top of the hollow stepper motor and manually lowering the bed as the print head was spun. The 3 strands of filament spun together to form a single-twisted strand. At a spin rate of 200 steps/second, the Carbon Fiber PLA did not create an effective twist and instead resembled the 0 steps/second samples (the “no spin” samples). Thus, samples for the Carbon Fiber PLA with a spin rate of 200 steps/second were not included in the sample collection.

Printing Parameters		
Material	**Nozzle Temperature (°F)**	**Bed Temperature (°F)**
Silk PLA	190	85
Carbon Fiber PLA	205	85

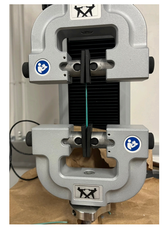


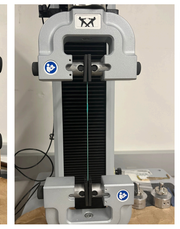
PLA Samples

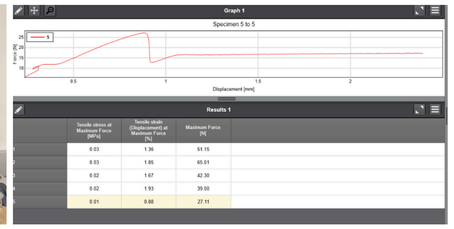


Testing

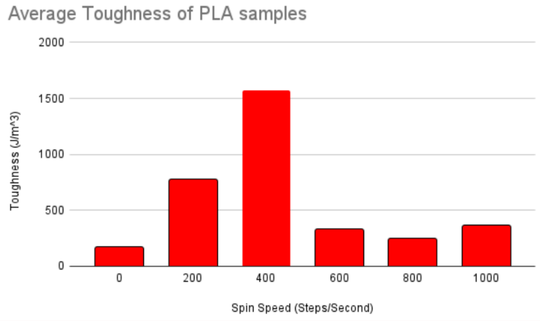
The tensile strength of the printed strands was tested using an Instron Tensile Testing machine under consistent parameters: a 0.1 mm/s clamp displacement rate, a starting clamp distance of 47.5 mm, and precise centering of each strand. Before testing, the strand diameter and length were measured. After testing, maximum tensile stress, strain, and force were recorded. The Instron software generated Stress vs. Strain graphs and displacement data at 0.1 mm intervals.







Data/ Results



Conclusion

The results did not support our hypothesis, however, for future experiments, other plastics such as Polyethylene Terephthalate Glycol-modified (PETG), Thermoplastic polyurethane (TPU), Biodegradable filaments, Metallic filaments should be tested to study the effects of twists on these strands. Also, creating a better extruding system that follows the rotation of the printhead would create more consistency within the twisted strand structure. A better extruding system would also resolve the issue of the filament twisting within the print head, which would often cause clogs within the heatsink and lead to failure in printing. Future work will include making and testing more samples of the Carbon Fiber material to compare the results to the PLA material.

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