# Team Mixology—3D Ceramic Printing

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## Introduction

Standard body armor is typically a blend of ceramic materials. Additive manufacturing (3D printing) opens the door to easily introducing additives into ceramic mixtures. Utilizing a 3D printer to investigate ceramic armor blends provides a viable, cost-effective method for optimizing properties of potential material combinations. The project goal was to optimize printer performance by designing an auger capable of providing a well-mixed, variable ratio mixture of armor ceramic chemistries such as $B^4C$ and SiC.

## Problem Statement

Update the design of an additive manufacturing feed mixing device print-head for the production of ceramic body armor plates for Army Research Labs. The device must be compatible with the Lulzbot Taz 3D printer, achieve a homogenous mixture, reduce material transfer time, and minimize parts necessary.

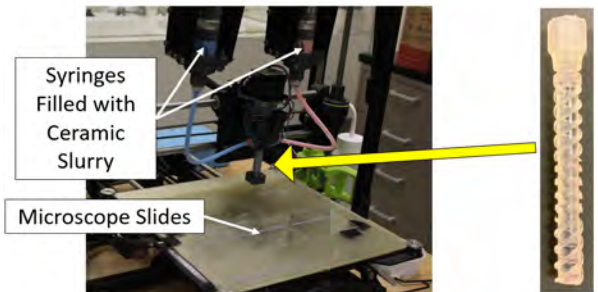


**Figure 1:** Original Printer Setup and Auger Design

## Auger Design

Features were varied to find the optimal auger for mixing. The varied features included: Channel depth, thread pitch and nubs, and added scrapers and other chaotic mixing designs.

- Original Testing:
  - Deep vs. shallow threading
  - 2, 3, or 4 threads
  - No nubs, 9 nubs, 24 nubs

**Figure 2:** Original Tested Augers

- Current Testing:
  - Scraper
  - Barred-Cone

**Figure 3:** Current Testing Augers

## Modeling and Simulation Effort

- Objective value being maximum vorticity along the shaft.
- SolidWorks CFD solution, evaluated under required flow rate and auger rotation with horizontal sampling of maximum and minimum vorticity
- Value interpretation based on sustained high vorticity; lag time controlled through internal volume.

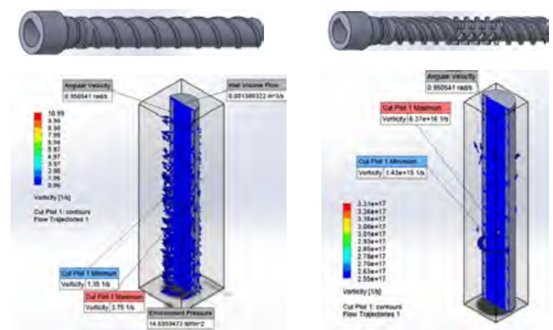

**Figure 4:** Auger Vorticity Profile

## Results

Nubs maximize vorticity with the longer the nub length the greater chaotic mixing induced. However, this likely negatively impacts overall material transport time. Additionally, the wiring changes show that up to 12 linear actuators could be used in one system.

## Bio-Printer Re-design

**Updated Carnegie-Melon Bio-printer for high viscous fluids**

- More centralized material storage prior to extrusion
- Original design optimized for smaller syringe, slightly less viscous fluid than our ceramic slurry/toothpaste test material
- Bulkier 3D printed design
- Still uses threaded push rod to push syringe
- Shortens tubing, complicates coding

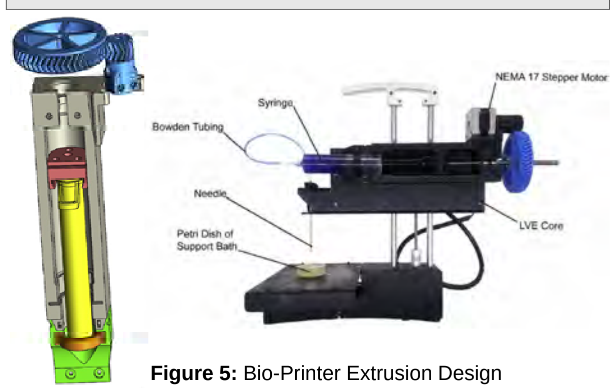


**Figure 5:** Bio-Printer Extrusion Design

## Linear Actuator Re-design

- Reworked geared extrusion
- Modified bio-printer
- Use of linear actuator
- Simpler code
- No driver necessary
- Less parts (less maintenance)

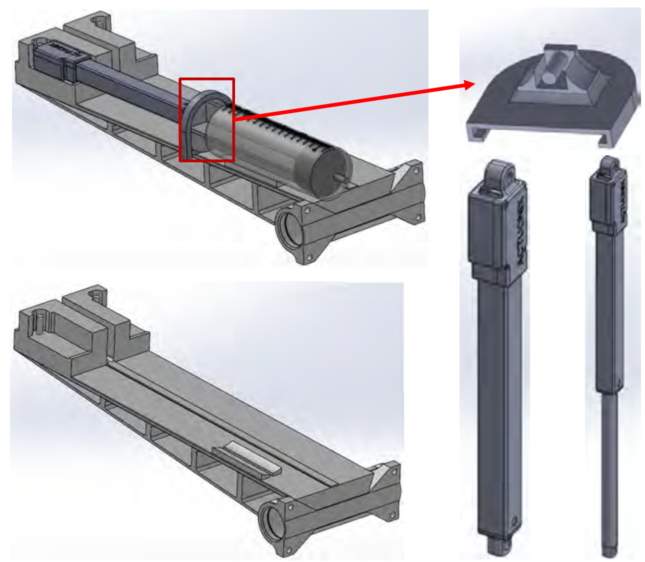

**Figure 6:** Linear Actuator Design

## Project Impact

- Cheaper and faster ceramics manufacturing
- Complex geometry ceramics manufacturing
- Highly viscous material printer for tar, slurries, bio-materials, etc.
- Increase effectiveness and resiliency of ceramic body armor
- New materials and additives can be added to ceramics
- Move away from heavy, bulky, inflexible, inefficient current armor

## Future Work

Going forward, Team Mixology will fully implement and test the new linear actuator design and its effects on the extrusion process while simultaneously improving the efficiency of the mixing apparatus.

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