Optimizing Mini-Tubular-Ceramic Production

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This project would not have been possible without the help of Prof Eileen Rossman and Dr. Hans Mayer

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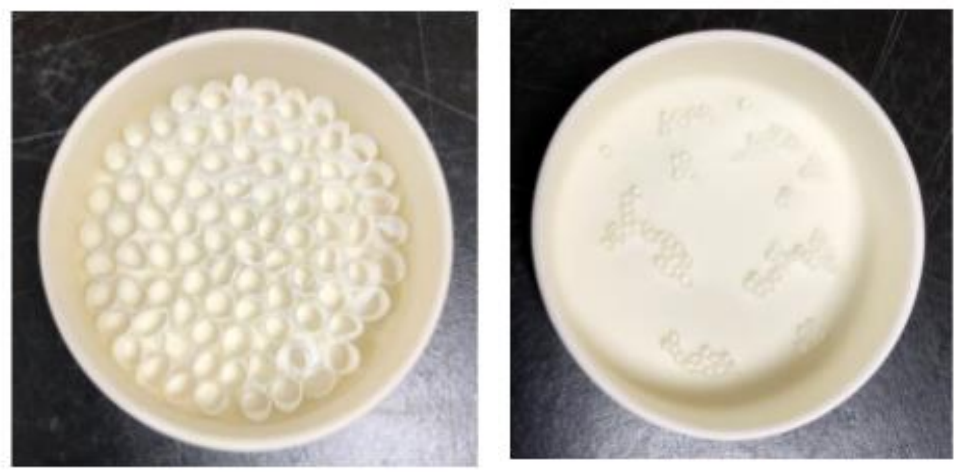
Scientists at Lawrence Livermore National Labs (LLNL) are researching new filter technology that utilizes Mini-Tubular-Ceramics (MTC's). MTC's are placed inside a large cylinder, disrupting airflow through the cylinder and helping clean the air. MTC's are made from an electrospun nanofiber ceramic mesh which is first peeled from a backing before being formed into small rings. These rings are then heat treated, causing them to shrink 60x volumetrically. The goal of this project was to increase the rate of production of the MTC's, enabling more thorough tests to be performed.



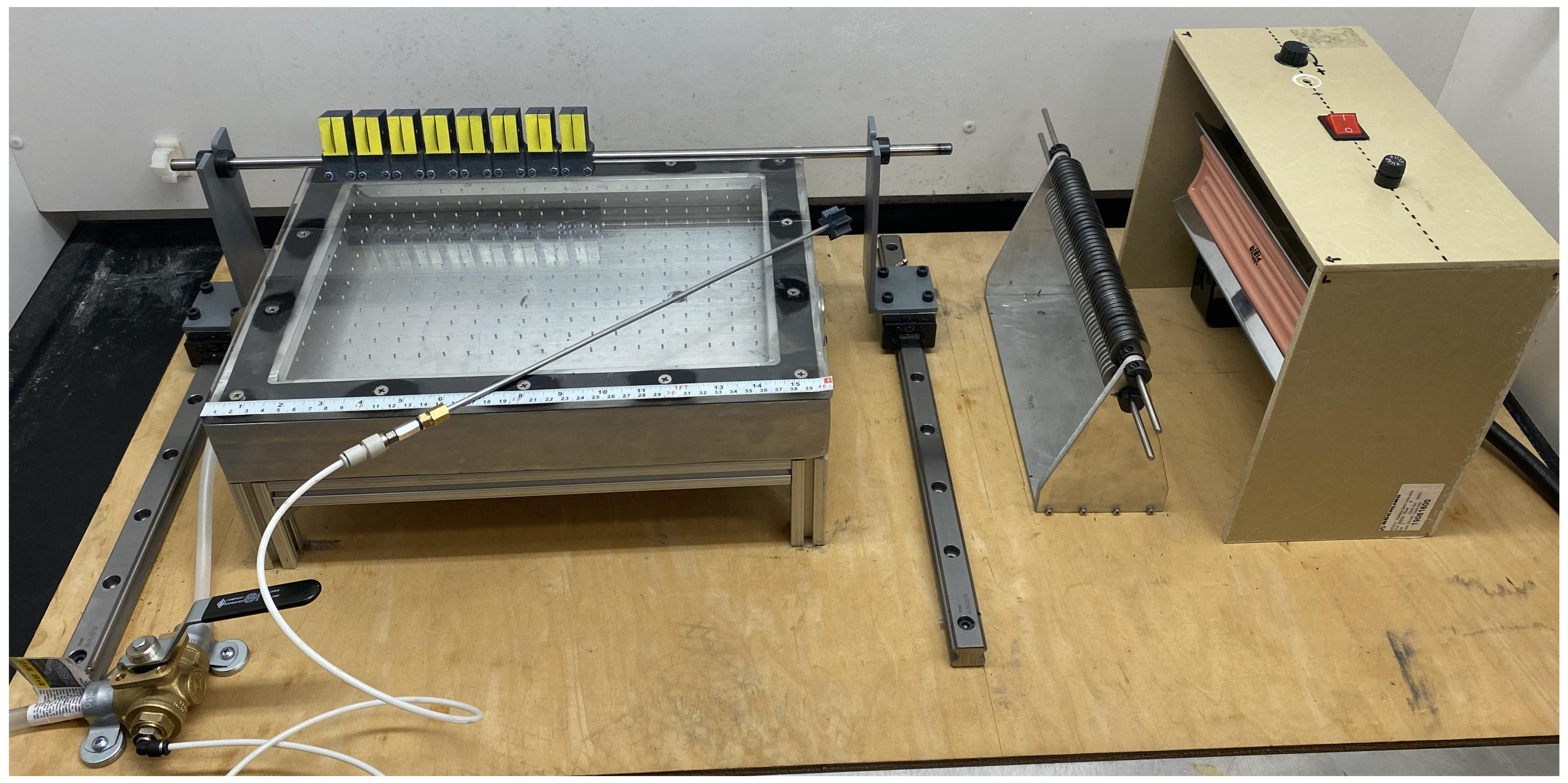
Left: Finished MTC. Right: Post heat-treated MTC

This project is a continuation of a previous Cal Poly senior project. We began by analyzing their design, figuring out what worked and what didn't. We decided to keep the existing vacuum table (used to peel the backing off the mesh) and rework the cutting, rolling and sealing mechanisms.

The mesh is cut into long strips using our primary cutter. The design is like a paper cutter, however fixed blades proved to deform the material. This was solved by using rotating blades. The idea of rotary cutting blades comes from a pizza cutter – there is no warping of the material due to a continuously changing point of contact with the material.

The vacuum mandrel is designed to pick the peeled mesh up off the table and roll it into a cylinder of a specified diameter. Coated with Teflon and featuring a 3D printed removable end cap, the mandrel is designed so operators can easily place finished MTC's in a crucible for heat treatment.

Like the primary cutter, the secondary cutter features rotary blades to cut tangentially. The secondary cutter however serves the dual purpose of sealing the disks. A ceramic heater provides radiative heat to several sealing disks on the secondary cutter assembly, which creates a sealed 'band' around the circumference of the MTC.



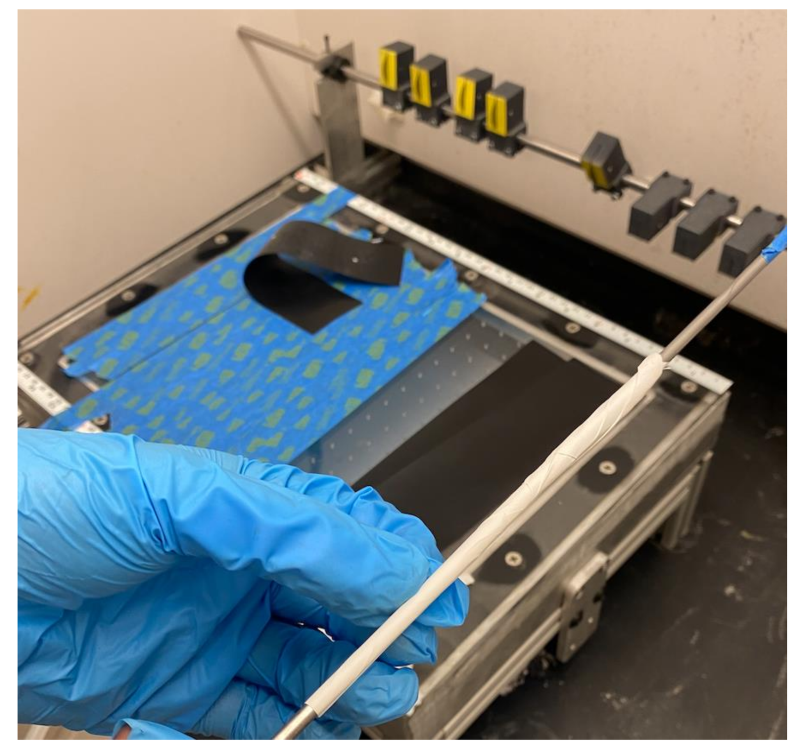
Final MTC production assembly featuring vacuum table, vacuum mandrel, primary cutter, secondary cutter, heater, electrical infrastructure and pump.

Aluminum was used for most components, which we cut using the Mustang 60 water jet. Our blade holders are 3D printed, meaning that they can be quickly and cheaply made if wear occurs. The heater box features fiberglass for safety and insulation.

Left: Printed blade holders. Center: Mandrel manufacturing.
Right: Waterjet-cut sealing disks

The mandrel was made using an aluminum jig, which allowed for 1/16" diameter holes to be drilled in sequence using a microchuck and pillar drill. Both the pump and heater were wired to standards conforming with LLNL and Cal Poly. The entire assembly is mounted to a plywood base for ease of transport and maintaining relative position between subassemblies.

Testing was performed in the Cal Poly Material Engineering fume hood, due to the hazards associated with the nanofiber mesh. We first tested our process on functional prototypes before measuring the abilities of our final product.



Testing in the MATE lab

We are very proud of the work we have accomplished during this senior project, and very grateful for everyone who helped us along the way. This final prototype will help our sponsors refine the specifications of the material. Our machine was designed with scalability in mind – you can imagine several of these machines, automated with actuators, such as motors, creating millions of MTC's. We hope that the concept of our manufacturing process will live on when MTC's become mass produced.

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