3D Printing as a Method for Fabricating Lab-Scale Process Equipment

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Project Background

Opportunity:

3D printing is widely used for mechanical prototypes, but has not been investigated for fabrication of process equipment. Process equipment must be capable of withstanding heat, pressure, and solvents.

Objective:

Design and fabricate lab-scale distillation column using a multistep fabrication process with 3D printed molds. The focus was to create a distillation column capable of separating water and ethanol.

Distillation is a separation process that uses heat to separate mixtures based on relative volatility of their components. Column material is Chemical-Resistant Silicone Rubber (R-2374 A) which is insulative, sturdy (Shore 65A), compatible with ethanol and water, and stable at high temperatures (up to 204 °C).

A schematic is shown below:

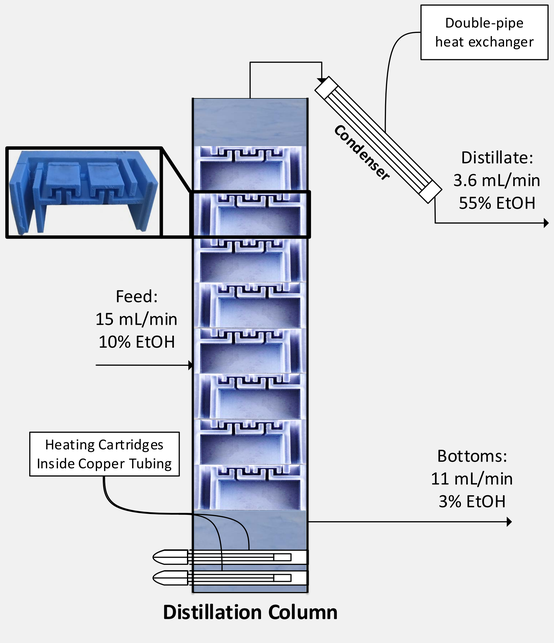
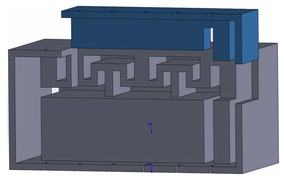


Figure 1. Water-ethanol mixture is fed to the column and boiled using heating cartridges. The vapor (distillate) exits the top with higher ethanol concentration.

Fabrication Flow

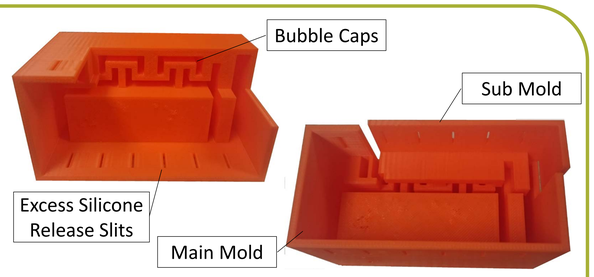
Pre-casting

- Aspen HYSYS® - identify flowrates, compositions, and energy requirement
- SolidWorks - model tray unit mold
- MakerBot Replicator 2X® - print ABS molds



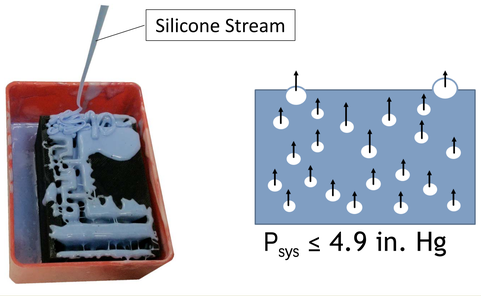
Mold

- ABS is compatible with silicone
- Bubble-cap design prevents weeping
- Part thickness was engineered to improve demolding and structural integrity
- Two-part mold creates backchannel for consistent composition on each tray



Casting

- Silicone and catalyst mixed slowly to prevent encapsulating air
- Poured from a distance as a thin stream to eliminate bubbles
- Degassed in a vacuum furnace. Six vacuum cycles, 5 min. each, at -25 in. Hg gauge

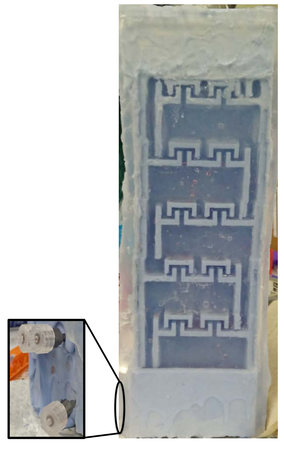


Column Assembly

- Mold release was removed from silicone using water and acetone before adhering with uncured silicone
- The assembled trays were immersed in translucent silicone and degassed to create a front wall
- Column consists of 5 trays, top, and bottom (height ≈ 1 ft.)
- Peristaltic pump installed and connected using needles with Luer-Lok fittings

Reboiler

- A $^{3}/_{8}$" OD copper tube was inserted into $^{5}/_{16}$" holes created with a drill press in the column base
- Heating cartridge (200 W, ¼" diameter) was inserted into copper tubing



Results

- Established a molding and assembly process to fabricate process equipment using a 3D printer
- Assembled a lab-scale bubble-cap distillation column
  - Operational pressure tested by running water and air counter-currently
  - Operational temperature tested by boiling water in column base for an hour
- Composed guide for fabrication process

Lessons Learned

- The negative space of molds must be a projection of a two dimensional geometry
- Mold release is necessary to facilitate demolding and must be removed before adhesion
- Silicone cast must have a sturdy edge to provide a grip for demolding
- Silicone does not easily adhere to other polymers (plastics), but can be used such as an O-ring

Future Work

- Test reboiler
- Install a condenser and reflux pump
- Test distillation operation

Acknowledgements:

- Dr. Alex Yokochi - sponsorship and guidance
- Yousef Alanazi - lab assistance
- Dr. Skip Rochefort, Brian Paul, and Todd Miller - advice on polymer adhesion
- Dr. Skip Rochefort and Dr. Travis Walker - allowing us to use the 3D printer
- Britany Swann, Steph Walker, and Dalton Myas - assistance with the 3D printer operation
- Andy Brickman - help with lab equipment
- Kristen Holmes – for assistance with the drill press
- Dr. Phil Harding - guidance and advice

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