The 3D Thermo-Mold

The ultimate guide to prepping, printing, and manufacturing with a 3D printed thermoforming mold

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Dedication

This booklet is the culmination of 9 months of research, ideation, failures, successes, patience, and most of all, the knowledge that each team member was able to bring to the project as a result of the 4 years of instruction and guidance given to them from professors in their respective EDMM departments at WMU.

A special thanks is to be given to Professor(s) Dana Hammond, Jay Shoemaker and Mike Konkel, as well as Michael Green and Allin Kahrl, for their assistance throughout this project.

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About this Project

This project was introduced and eventually undertaken by the Society of Plastics Engineers at Western Michigan University. An initial mold design was designed in a CAD program and eventually 3D printed for testing. Unfortunately, timing did not allow for the project to be continued as COVID-19 would halt all operations. This project was thus shelved and reintroduced in 2021 for a senior design project and the results of this project and what was learned along the way are presented in this document.

Materials Criteria

The two most important criteria for material selection and their importance are summed up in this equation:

Cost-Efficiency

+

Availability

=

Happiness (Ease of Manufacturing)

Specifically:

Cost-Efficiency	Availability
All materials had to be available at a reasonable price. Reasonable price was determined to be $	All materials had to be available in at least x amount of stores (online or brick and mortar) at the same price.

Materials Used

ABS - Polycarbonate Sheets

ABS-Poly-Carbonate sheets were the plastic sheets of choice to make the product. The mixture of ABS and polycarbonate produces a product with good strength and wear-resistance, which are necessary characteristics for the product that was being manufactured.

PLA Filament

PLA is the most common type of 3D filament on the market. It's commonality in the 3D world lent itself well to the availability and cost-efficiency criteria.

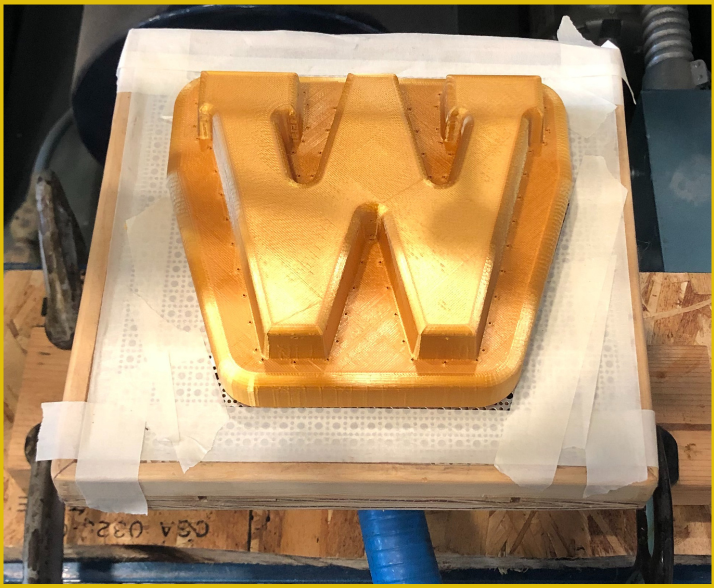
Equipment

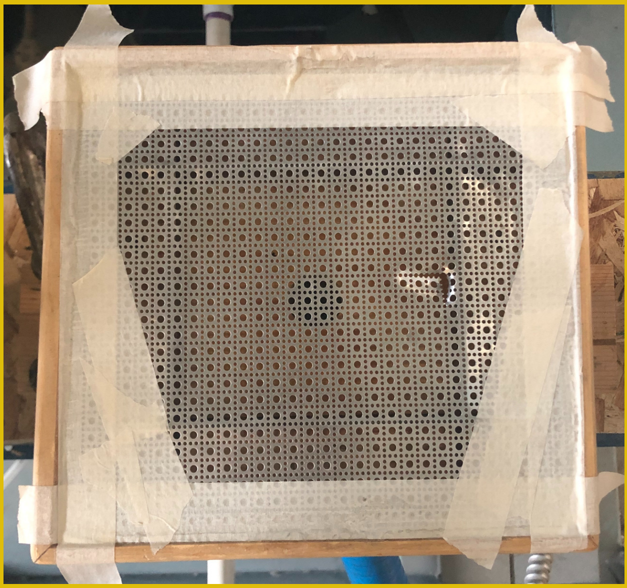
1. Thermoform Machine

The most important piece of equipment during this process is the thermoforming machine. The thermoforming machine melts the plastic at the desired or optimal temperature and allows the mold to be thrust into the plastic so that it takes shape. Prepping details for the thermoform machine are discussed in the section "Process for Mold Use".

Equipment

2. Vacuum Table





The second most important piece of equipment in this process is the vacuum table. This table supports the mold while the porous surface allows the vacuum pump to suck the air between the mold surface and heated plastic out and draw the plastic sheet into the shape of the mold. Prepping details for the vacuum table are discussed in the section "Process for Mold Use".

Equipment

3. The Mold

The third most important piece of equipment is the mold itself.

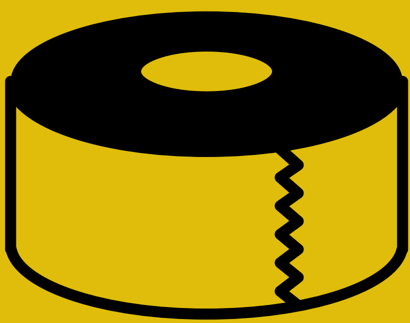
This is what the product you create will look like. When using a 3D printed mold, special considerations need to be taken in order to ensure the maximum number of products can be made without faults. Details of mold prep and usage are discussed in "Process for Mold Use".

Equipment

4. Calipers

Calipers are used to measure the change in the mold size over time. This is especially crucial as a plastic molds will change size as they are being heated up and cooled constantly.

5. Masking Tape



Tape is optional but tape (specifically masking tape) is great for covering up additional space on the vacuum table that isn't needed by the mold. This concentrates all of the vacuum suction power specifically on the mold itself and aides in part formation clarity.

Safety

It is important during any manufacturing operation to be safety-conscious. This means being aware of any hazards and protecting yourself (and others) to mitigate potential injuries. Some safety hazards that you could potentially run into during this process are:

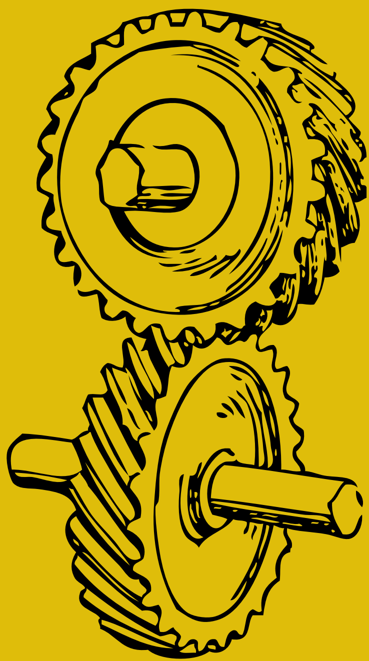
1. Heat

Source(s): Thermoforming mold, thermoforming bracket, 3D printer printing tip

How to Avoid: When thermoforming, allow time for both the mold and bracket to cool before attempting to remove the plastic part. When 3D printing, never place your hands near the printing tip. This prevents burn injuries.

Safety

2. Moving Parts



Source(s): Thermoforming machine, thermoforming bracket

How to Avoid: When adjusting your thermoform machine, be sure to watch your fingers when adjusting the machine r bracket. This will prevent any pinching or your fingers from getting caught in the machine. If necessary, use tools when adjusting the machine or have someone assist you.

Safety

3. Heavy Object Movement

Source(s): Thermoforming bracket, vacuum table

How to Avoid: When adjusting your thermoforming bracket or vacuum table, you may have to remove the bracket from the machine. Get assistance if necessary to avoid back injuries or other bodily harm.

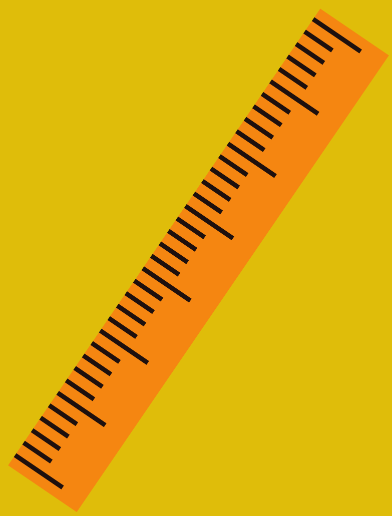
Process for Mold Construction

1. Design Adequate Supports

When designing your mold, ensure that there are adequate supports in your design. Supports help mitigate defects due to warpage by not only reinforcing sections of the mold but by absorbing the heat and preventing it from spreading throughout the part. The tri-hexagonal style shown above worked the best for this project but feel free to experiment and see what works best for you and your project needs.

Process for Mold Construction

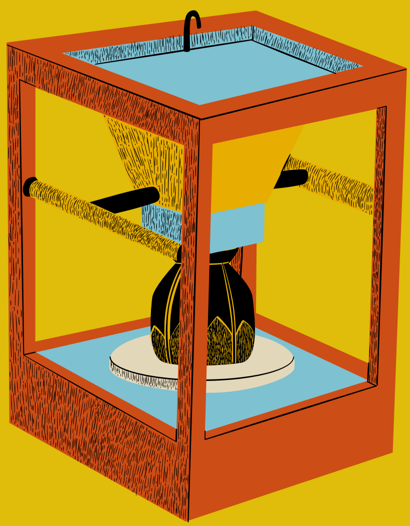
2. Identify the Size of Your Mold



Before you print your design, take some time to ensure that the size of your mold will fit within the print area of your mold. For molds that are larger than 1 cubic foot, you may have to print your mold in one piece and then glue with epoxy later.

Process for Mold Construction

3. Allow for Adequate Printing Time



Due to the complexities of molds, when you are certain that your design is perfected (it's okay if it isn't!) it is imperative to not only make sure you have enough filament BEFOREHAND but that also that you can allow adequate printing time. Most 3D printers aren't very fast and even a small mold will take time.

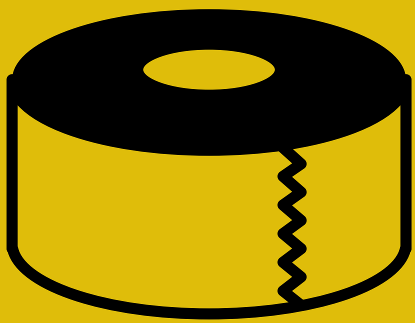
Process for Mold Use

1. Spray Mold Release on Your Mold

Much like a traditional aluminum mold, when you use a plastic mold you must use mold release. Apply a generous amount to the top of your mold and all crevices. This will allow for a easier removal of your part later which is especially crucial when heating plastic on plastic.

Process for Mold Use

2. Cover the Excess Spaces Surrounding Your Mold on the Vacuum Table



Once you place you mold on your vacuum table, use masking tape to cover up the excess spaces around the mold. This concentrates the vacuum strictly to the area of the mold and increases the definition of the final part.

Process for Mold Use

3. Determine Your Process Settings

Oven Temp.	~80% of 450 F
Time In-Oven	14 seconds
Mold & Part Cooling	60 seconds
Mold Cooling*	120 seconds

When you actually begin making parts, it's important to determine what process characteristics will you give you the best results. All machines are not made the same so you'll want to spend some time figuring out what works best for your operation. Above are the process characteristics used for this project. Feel free to use them as a starter to see what's best for you.

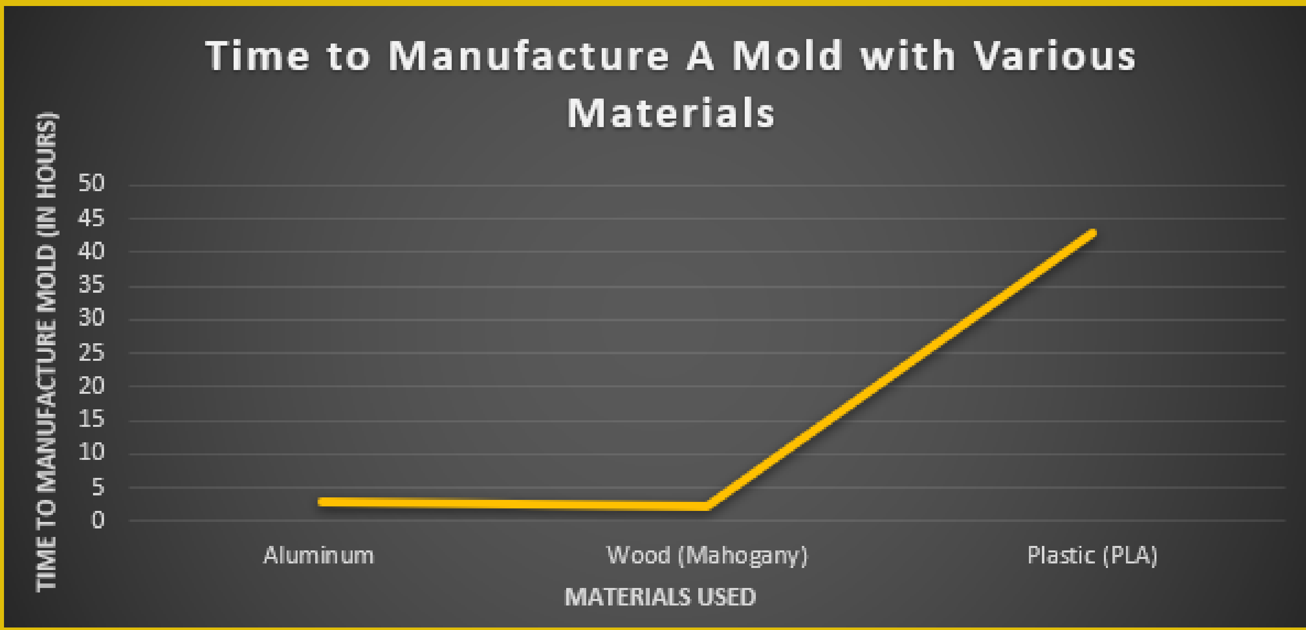
*= the mold is cooled after the part is separated from the mold

Part Results

After some time figuring out the best process settings, we were able to produce 100 "perfect" parts. It was decided that since the most a small thermoforming company will produce is 1-200 parts (300 at absolute max) 100 parts was an acceptable baseline. Then, even if a second mold was needed, it would still be more cost and time efficient than if the small business were to invest in a one-off aluminum mold. q

Why This Method?

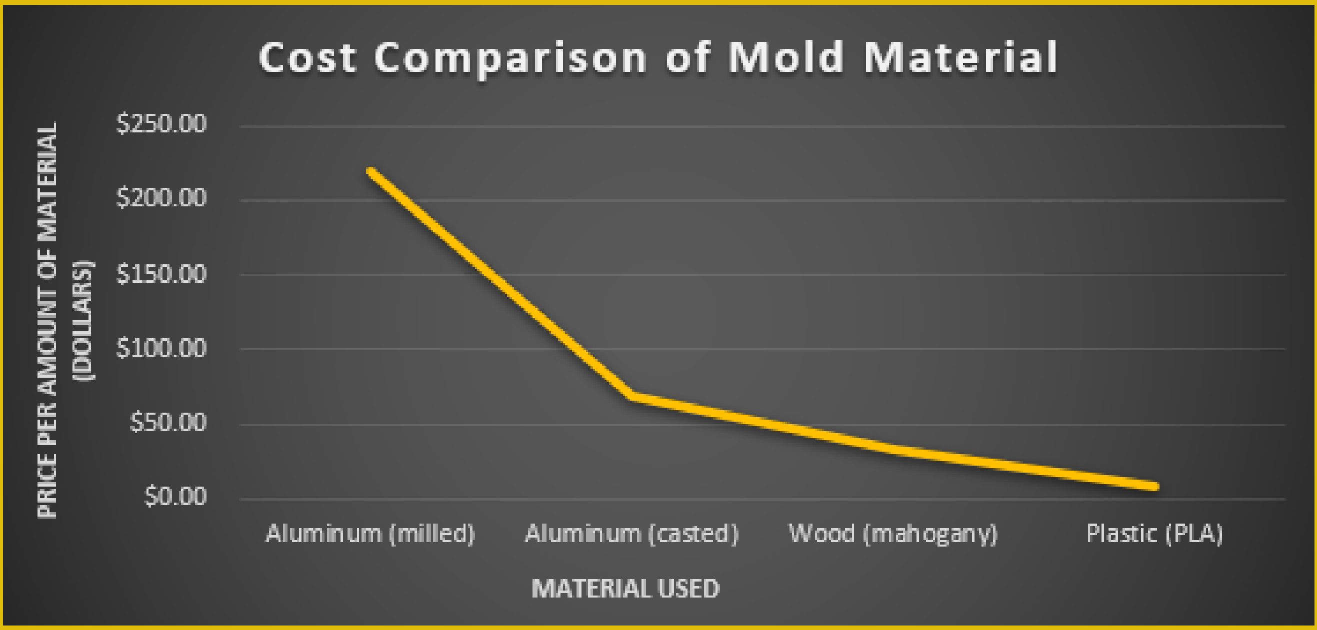
1. Reduction in Time



One benefit of this method is the reduction of time to manufacture the mold. To machine (as in to mill) the mold itself will only take approximately 2 hours and 49 minutes but when you include the lead time, the entire process from order to delivery of the mold is usually within 4-6 weeks. In the case of wood, it takes slightly less time to manufacture the mold at 2 hours and 20 minutes but once (again) the lead time is factored in, it can take anywhere from 2-4 weeks. To 3D print a mold, it willl take approximately 2 days (48 hours total) before your mold is complete.

Why This Method?

2. Reduction in Cost



In comparing the cost of material, 3D printing comes out as the better option here as well. In today's market, the amount of aluminum that would need to be acquired for machining the mold shape would be $219.89. Alternatively, the amount of aluminum to simply cast the mold would be $69.64. Compared to the $7.80 worth of PLA it took to create the mold, that is a 96.45% and 88.80% decrease in cost respectively. To make the mold out of mahogany (as wood is cheaper than aluminum) would require about $32.99 worth of wood. Compared to the $7.80 worth of PLA, 3D printing the mold is 51.97% cheaper.

Verdict

When it comes to thermoforming, small businesses don't have to suffer financially. 3D printed molds can produce great quality parts at a fraction of the time and cost of a traditional aluminum mold or even a wood mold. Since time and cost are the two greatest barriers to small thermoforming businesses, using 3D printed mold will allow for businesses to have greater outreach and possibly open up market spaces that weren't available to them before. It is in every small business owner's best interest to take a look into how this can be implemented into their business and how it can reduce the stress that can come with thermoforming.