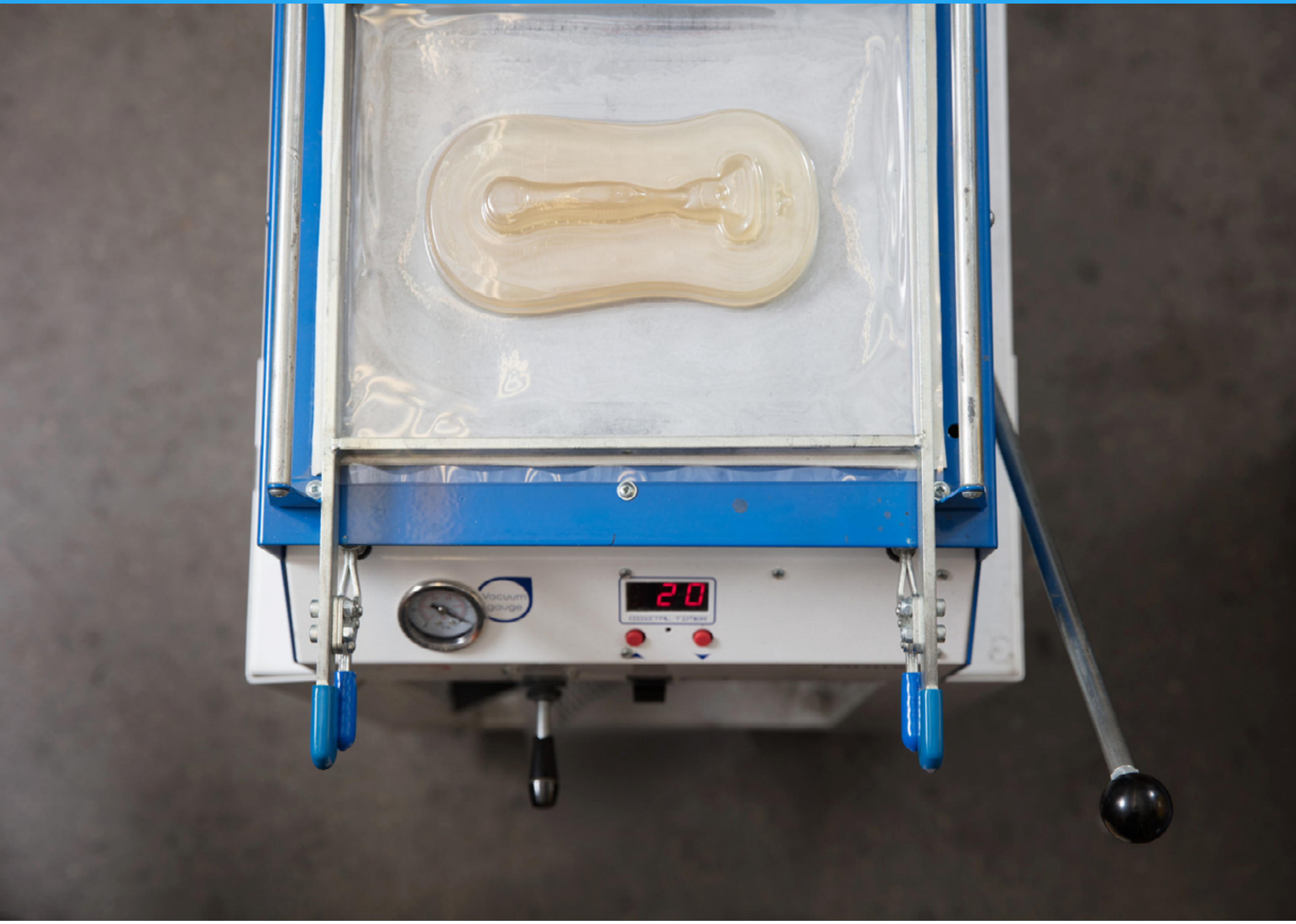

FORMLABS WHITE PAPER:

Moldmaking with 3D Prints

Techniques for Prototyping and Production

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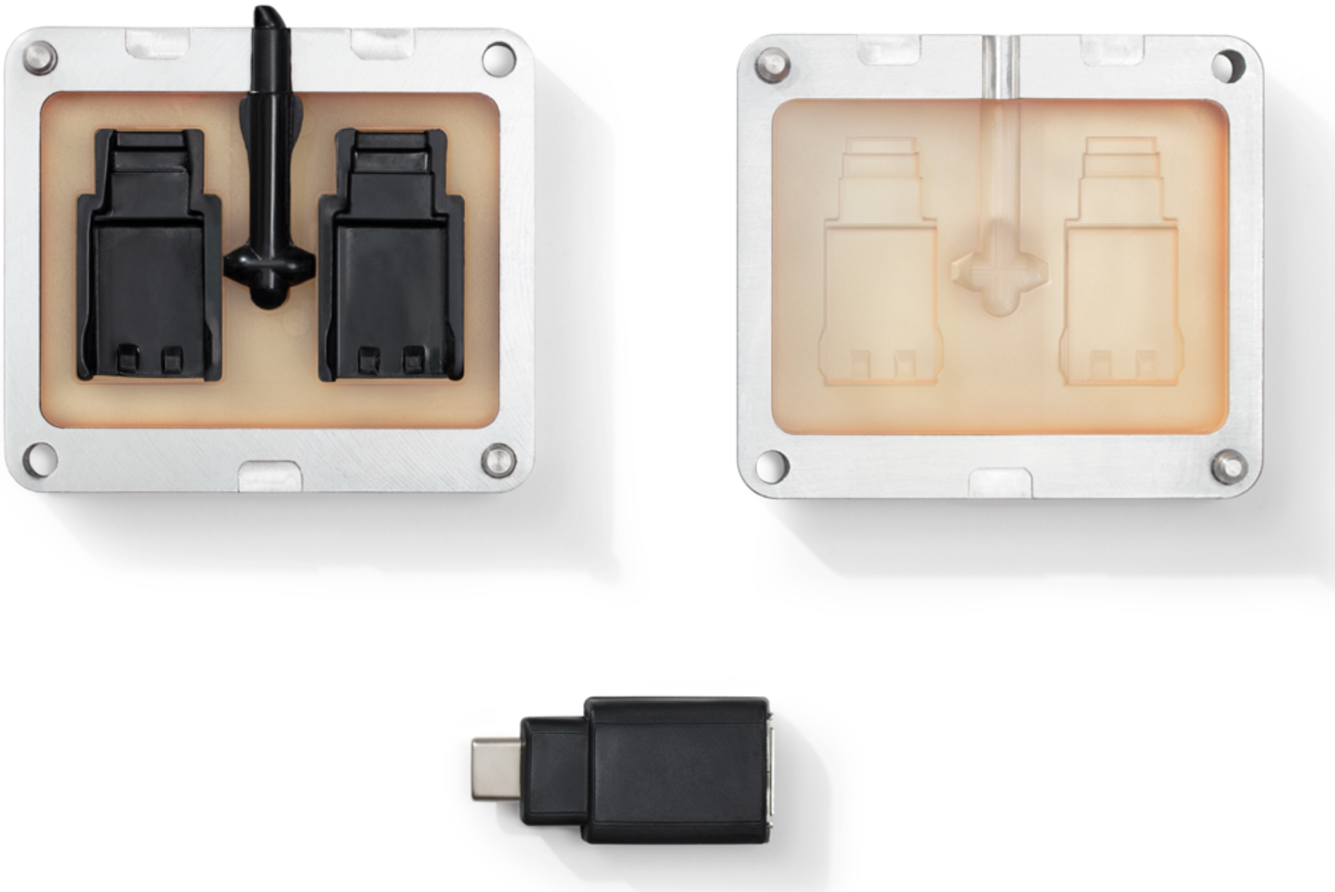


Moldmaking with desktop 3D printing allows engineers and designers to get much more functionality from their 3D printer, beyond prototyping alone. Moldmaking opens up a world of production materials, and provides the ability to produce short run batches and test mold designs prior to committing to expensive tooling.

This white paper will cover three such moldmaking strategies: injection molding, thermoforming and casting elastomers. Typically, molds are made with Formlabs Clear Resin, preferred for its translucency, although any Standard Resin is appropriate, and High Temp Resin is ideal for more thermally demanding molding processes. It should be noted that these processes are best suited to stereolithography (SLA) 3D printing, given that printed parts are both isotropic and watertight.

Prototyping and Short Run Production with 3D Printed Tools

Process	Equipment	Lead Time	Material Cost (e.g: 300 ml / cm^3 mold)
In-House Mold Creation and Part Production	Form 2 & molding machine	5–24 hours (mold print time)	Approx $50 in High Temp Resin
Outsourced SLA Mold	molding machine	3–5 days	Approx $700 from service bureau printing on industrial SLA
Outsourced Metal Mold	molding machine	1–2 weeks	Approx $6,400 from service bureau machined in alum
Outsourced Mold Creation and Production	none – fully outsouced	1–3 weeks	Ranging from $4,000 to $15,000, depending on volume and materials

Silicone casting and some benchtop injection molding is possible with Formlabs Standard Resins. High Temp Resin, which has the highest HDT @ 0.45 MPa of any 3D printing materials currently on the market, makes it possible to print parts that can be used for higher temperature moldmaking such as thermoforming and injection molding of materials with higher melt temperatures.

Injection Molding

High-resolution SLA 3D printing with the Form 2 can be used to rapidly prototype inexpensive injection molds that can produce real parts in a wide variety of thermoplstics. Benchtop injection molds can be used to validate mold designs before manufacturing metal tooling, or to produce short-runs of parts.

The whitepaper Injection Molding from 3D Printed Molds discusses benchtop injection molding using molds printed in Formlabs Clear Resin. With the release of Formlabs High Temp Resin, developed for higher temperature resistance and stiffness, the white paper has been updated to describe the benefits of printing molds in High Temp Resin instead, which is less likely to fail due to thermal shock or temperature-related deformation.

Learn more about **Injection Molding from 3D Printed Molds**

An enclosure mold for a USB device, 3D printed with the Form 2 and High Temp Resin.

This straight-pull mold contains a core, cavity, and two gates leading to the two halves of the enclosure. Molds printed in High Temp Resin can be used to mold a wide variety thermoplastics without thermal shock or temperature-related deformation.

Formlabs High Temp Resin is capable of injection molding a wide range of plastics.

3D printed mold tools reproduce the precise finish quality of SLA printing on the Form 2. Molds can be printed at 100 micron layer resolution for faster prototyping, or 50 microns is recommended for high detail and smoothness.

The USB enclosure part with electronics, molded in HDPE from a High Temp tool.

Over the course of three iterations, this USB enclosure mold was adjusted to remove sink marks, air traps and correct for part shrinkage. The total cost of materials for prototyping this mold tool in High Temp Resin: $25.

Thermoforms

3D printing thermoform dies on the Form 2 is a fast and effective method to create high quality vacuum-formed parts for small batch production. Printed thermoform dies can be used to make packaging prototypes, clear orthodontic retainers, and food-safe molds for chocolate confections.

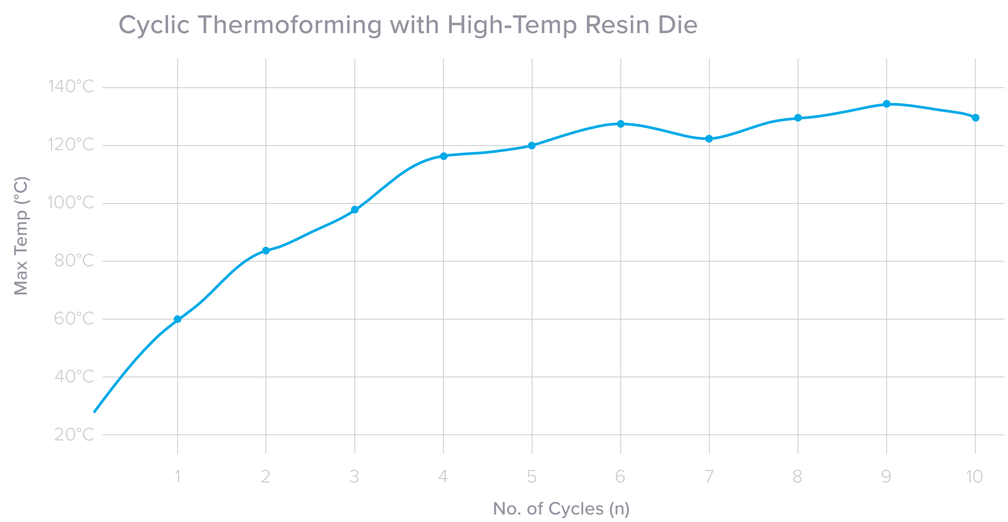
Thermoform dies experience less pressure than injection molds, but still reach high surface temperatures. High Temp Resin resists deformation and surface degradation from the combined heat and pressure of thermoforming with most plastics. Standard Resins may also be suitable for thermoforming with some lower temperature plastics such as vinyl.

CASE STUDY

Example prototype packaging formed with a Formech thermoformer.

Thermoforming a thin sheet of polycarbonate over a High Temp Resin die results in a part that is transparent, while matching the geometry and detail of the printed die. Thermoformed packaging can be easily prototyped and incorporated into the design process alongside 3D printed product prototypes, all on the Form 2. The printed die was used without any extra processing beyond the necessary UV post-cure. A texture is recommended in thermoform design to prevent air from becoming trapped under the sheet—the layer lines on the printed thermoform die can be helpful in this regard.

TEMPERATURE CONTROL

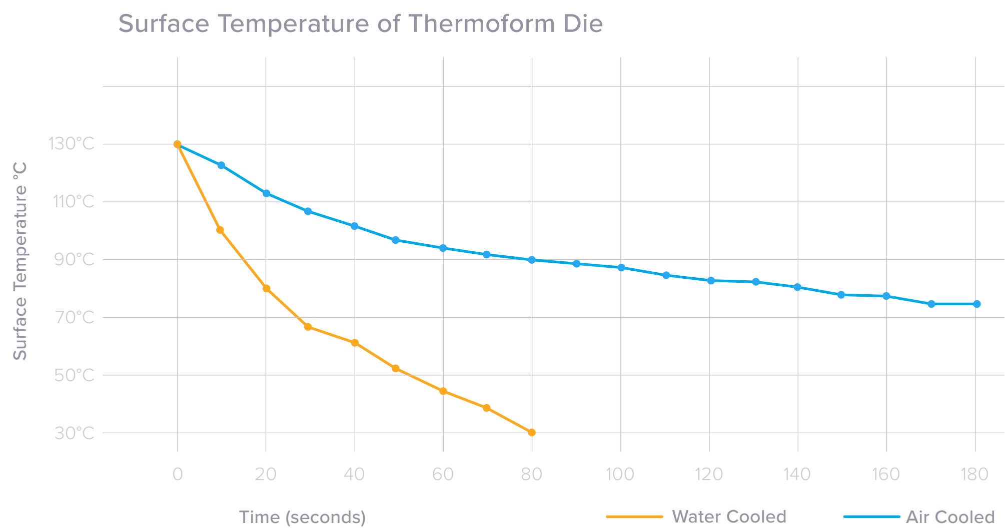


Surface temperature of the die reaches a plateau at 130 °C.

The surface temperature of the printed die will increase over multiple cycles. High Temp Resin is highly resistant to deflection, whereas if using Standard Resins, you must allow the printed die to cool between cycles, otherwise deformation and degradation may occur.

If temperature build-up becomes a limiting factor in moldmaking efficiency, cooling channels are an effective way to to draw heat out of the print. When used in conjunction with an automated thermoforming machine, a water-cooled die can produce a larger run of parts with shorter cycle times.

Conformal water channels visible in a High Temp thermoform die.



Temperature after heating of a cooled and non-cooled tool.

Conformal cooling channels are easy to incorporate when designing for SLA 3D printing, and print successfully without any internal supports that could disrupt flow. After printing, the channels are flushed of uncured resin using isopropyl alcohol. The mold is connected to a pump and a source of cold water. Integral water cooling as a strategy can also be applied to Standard and Tough Resin parts, to reduce heat deflection when used in higher temperature environments.

Casting with Elastomers

High-precision molds for most flexible elastomers, such as silicone and urethane rubbers, can be printed on the Form 2 using Standard Resin. The transparency of Clear Resin allows the material to be observed during the pouring or injection process. Flexible materials can be easily removed from rigid SLA-printed molds, and have applications ranging from modelmaking to functional overmolding. Silicone molding can also be used to quickly replicate printed masters, greatly reducing production time where multiples of rigid parts and objects are needed.

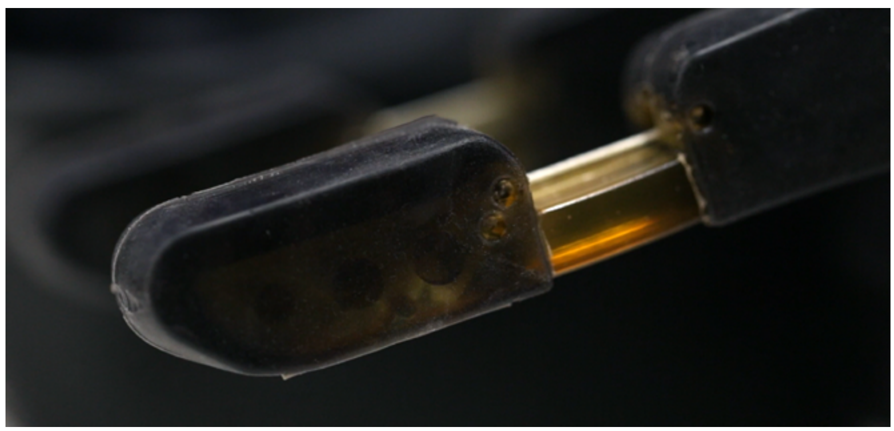
CASE STUDY

Molds printed on the Form 2 are being used to create composite parts with advanced integrated functionality. Prefabricated subcomponents such as electronics, metal, and SLA printed elements may be embedded and sealed within soft overmolds.

RightHand Robotics used the Form 2 to create production units of their robotic gripper through urethane overmolding. Molds were printed in Clear Resin, with Black Resin inserts forming the internal structure.

The Form 2 allowed RightHand Robotics to transition from prototypes to short run production without having to outsource expensive tooling. The fast transition from initial printed prototypes to production materials, which have longer lifespans in cyclic flexing, was accomplished by 3D printing molds on the same Form 2 hardware they used for initial prototyping.

The first overmolded layer of RightHand Robotics' multi-stage process incorporates urethane joints that can withstand many cycles of flexure, while providing the high elasticity needed to reliably return the gripper to the open state.



The outer layer gives the gripper enhanced tactile sensitivity and control, as well as sealing sensor electronics, through the use of softer low-durometer rubber.

SLA 3D printed parts can also be encapsulated within molds to provide a rigid structure to flexible materials. The overmolded layer can be mechanically bonded to the insert by adding holes, depressions, and pillars to printed parts, which strengthens the assembly and reduces the need for chemical adhesives.

Attachment features mechanically bond overmolds without chemical adhesives.

Conclusion

Moldmaking on the Form 2 is a powerful strategy for producing parts in small batch quantities, and in commonly used plastic and elastomeric materials. 3D printed tools enable engineers and designers to easily prototype parts that look and function just like the final product, in geometries and material configurations that are challenging via 3D printing alone, such as encapsulated electronics and thin packaging. For high temperature moldmaking, High Temp Resin offers superior thermal properties at a lower cost, and with shorter lead times than outsourcing the moldmaking process.

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