WHITE PAPER

Low-Volume Rapid Injection Molding With 3D Printed Molds

This white paper provides methods and guidelines for using stereolithography (SLA) 3D printed molds in the injection molding process to lower costs and lead time. Through the real-life case studies with Braskem, Holimaker, and Novus Applications, you'll learn how this hybrid manufacturing process enables on-demand mold fabrication to quickly produce small batches of thermoplastic parts.

formlabs

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Introduction

INJECTION MOLDING

Injection molding is one of the leading processes for manufacturing plastics. It is widely used for mass-producing identical parts with tight tolerances. It is a cost-effective and extremely repeatable technology that yields high-quality parts for large series. It can produce volumes from 1,000 to 100,000+ of parts at very low unit costs. Injection molding has a short cycle time, with each machine capable of building new parts every 15 to 60 seconds. It is a fast, intensive process where high heat and pressure are involved to melt thermoplastic and force it inside a mold.

Because of these extreme molding conditions, the tools are traditionally made out of metal by CNC machining or electric discharge machining (EDM). These are expensive industrial methods that require specialized equipment, high-end software, and skilled labor. As a result, the production of a metal mold typically takes four to eight weeks, and costs anywhere from $2,000 to $100,000+ depending on the shape and the complexity of the part. Due to these high costs, manufacturers are looking at ways to minimize the cost of custom tool production and reduce lead times to bring products to the market faster.

Desktop 3D printing is a powerful solution to fabricate injection molds rapidly and at low cost. It requires very limited equipment, saving CNC time and skilled operators for other high-value tasks in the meantime. Manufacturers can benefit from the speed and flexibility of in-house 3D printing to create the mold and couple it with the production force of injection molding to deliver a series of units from common thermoplastics in a matter of days. They can even achieve complicated mold shapes that would be difficult to manufacture traditionally, enabling development teams to be more innovative. Furthemore, product development benefits from the ability to iterate on the design before investing in hard tooling.

Even though 3D printing molds can offer these advantages when used appropriately, there are still some limitations. We should not expect the same performance from a 3D printing polymer mold as from a machined metallic one. Critical dimensions are harder to meet, cooling time is longer because the thermal transfer occurs slower in plastic, and printed molds can easily break under heat and pressure. However, some companies managed to produce series of hundreds of parts with printed molds and even thousands of shots for very simple designs. Low-run injection molds are great assets for engineers to deliver limited batches of end-use parts or prototypes in the final plastic, for pre-production tests.

FAST FABRICATION OF SHORT-RUN INJECTION MOLDS

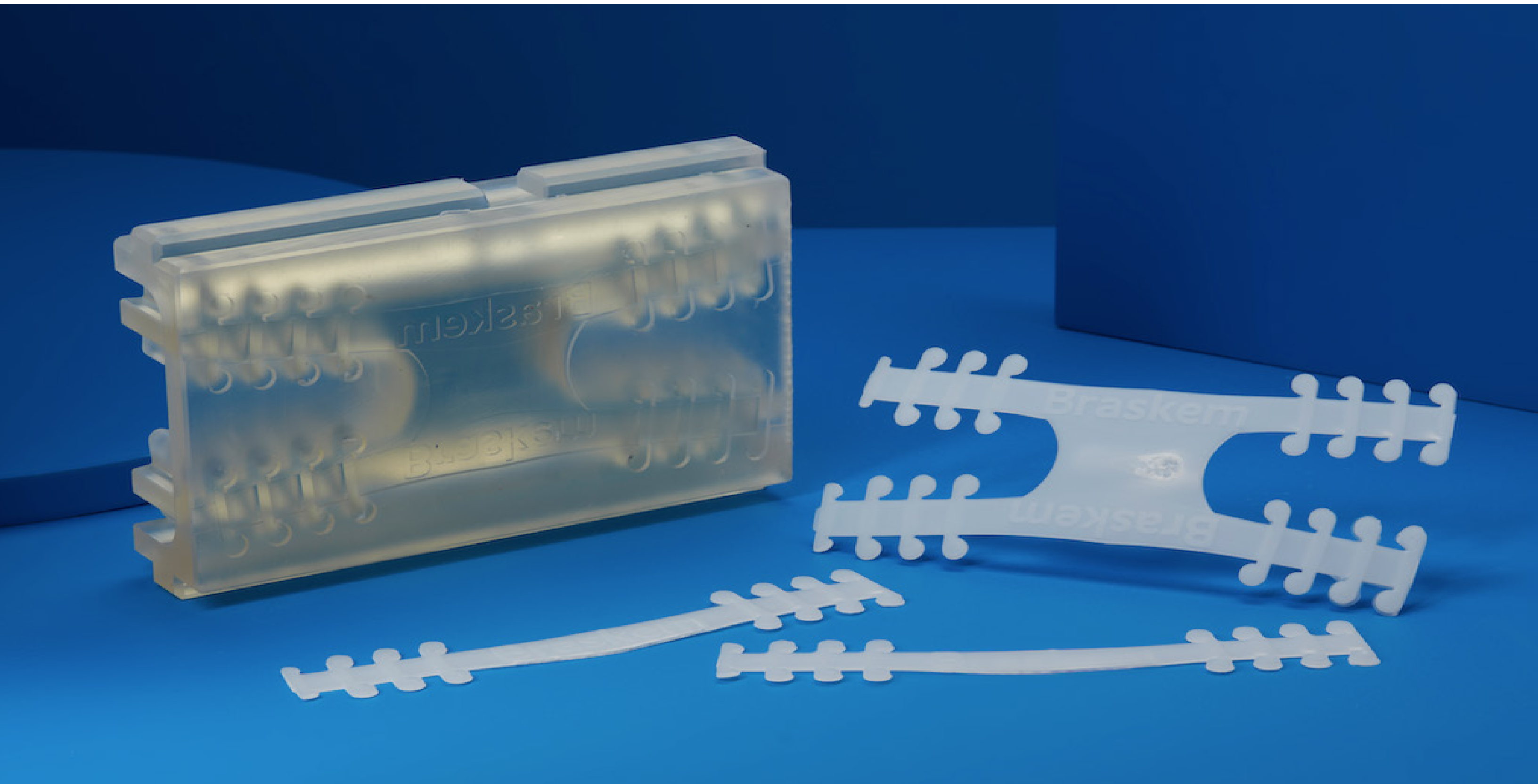
Stereolithography (SLA) printing technology is a great choice for molding. It is characterized by a smooth surface finish and high precision that the mold will transfer to the final part and that also facilitates demolding. 3D prints produced by SLA are chemically bonded such that they are fully dense and isotropic, producing functional molds at a quality not possible with fused deposition modeling (FDM). Desktop SLA printers, like those offered by Formlabs, simplify workflow as they are easy to implement, operate, and maintain.

To support short-run injection molding, Formlabs developed High Temp Resin, which has a heat deflection temperature (HDT) of 238°C @ 0.45 MPa, the highest among Formlabs resin and one of the highest among resins on the market. High Temp Resin can withstand high molding temperatures and minimize cooling time. This report will go through a case study with Braskem, a company that ran 1,500 injection cycles with one mold insert printed with High Temp Resin to produce mask straps. The company printed the insert and placed it inside a generic metallic mold integrated in the injection system. This is a powerful solution to produce medium series quickly. The printed insert can be replaced as the design evolves and in case of failure. It allows for creating molds on-demand with elaborate geometries that would be difficult to manufacture traditionally while still running multiple shots.

High Temp Resin, however, is quite brittle. In the case of more intricate shapes, it warps or cracks easily. For some models, reaching more than a dozen cycles can be challenging. To solve this challenge, French startup Holimaker turned to Grey Pro Resin. It has a lower thermal conductivity than High Temp Resin, which leads to a longer cooling time, but it is softer and can wear hundreds of cycles.

Formlabs recently released Rigid 10K Resin, an industrial-grade, highly glass-filled material, which provides a solution that can cope with a wider variety of geometries and injection molding processes. Rigid 10K has an HDT of 218°C @ 0.45 MPa and a tensile modulus of 10,000 MPa, making it strong, extremely stiff, and thermally stable. Novus Applications has injected hundreds of intricately threaded caps with a single Rigid 10K Resin mold. As more companies get their hands on Rigid 10K Resin we expect it to be an excellent asset to print sophisticated molds for injection molding.

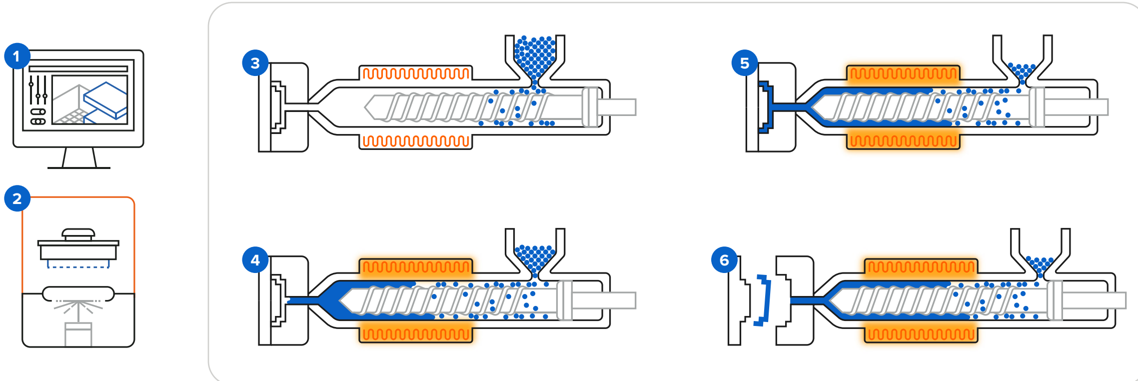
This white paper will first give a general overview of the workflow, design guidelines, and best practices for 3D printing molds for injection molding. Then, it will go into the details by covering three case studies on how each firm found success with their 3D printed mold.



Method

PROCESS WORKFLOW

INJECTION MOLDING PROCESS WITH 3D PRINTED MOLDS



1 Design the mold 2 3D print the mold 3 Mold clamping 4 Inject 5 Cooling 6 Demold

Common problems encountered with 3D printed molds are:

- Dimensional accuracy of the mold: it is important to take into account that the dimensional accuracy of a 3D printed mold is not as good as in a metallic machined mold. However, post-processing the prints will bring size variations closer to the ones of a machined mold.
- Breakage or cracking of the mold under pressure and heat.
- Cycle time: the cooling time is longer than with a metallic mold as the thermal transfer occurs slower in plastic parts.
- Demolding process:
  - Adhesion of the part to the mold can cause deterioration of the mold during extraction.
  - Flashing may occur and slow down the demolding step. This is an excess of material coming out of the mold during the injection when the mold is overfilled, or if the parting plane is not perfectly flat.

These issues can be mitigated by reducing the injection pressure, adapting the CAD file, and the demolding process. These three parameters will largely influence the success of the operation.

The complexity of the injection molding process is mostly driven by the complexity of the part and the mold structure. A broad range of thermoplastics can be injected with 3D printed molds such as PP, PE, TPE, TPU, POM, or PA. A low viscosity material will help reduce the pressure and extend the lifetime of the mold. Polypropylene and TPEs plastics are easy to process at a high amount of cycles. In contrast, more technical plastics like PA will allow a lower number of runs. The handling of a release agent helps to separate the part from the mold, in particular for flexible materials such as TPUs or TPEs.

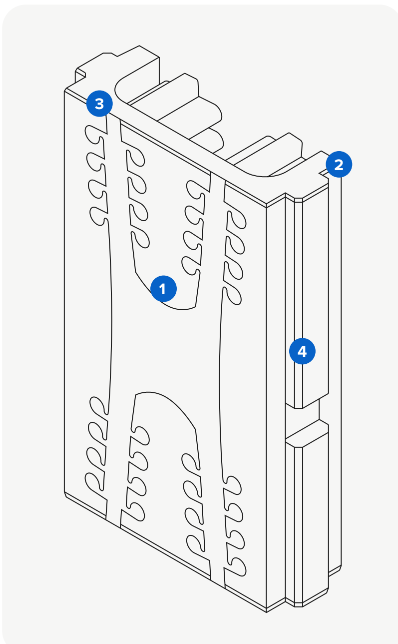
The type of injection press does not have a significant influence on the process. If you are new to injection molding and are looking into testing it with limited investment, using a benchtop injection molding machine such as the Holipress or the Galomb Model-B100 could be a good option. Desktop automated molders such as the product line from Babyplast are good alternatives for mass production of small parts.

DESIGN GUIDELINES

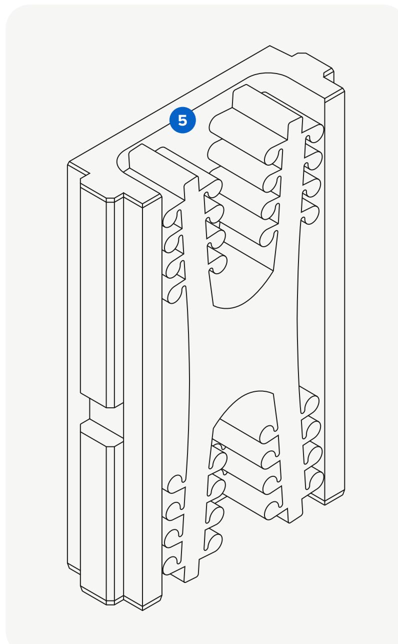
We recommend respecting the rules of design for additive manufacturing as well as the general rules for injection mold design, such as including two or five degrees of draft angles, maintaining a uniform wall thickness across the part or rounding up the edges. Here are a few helpful advice from users and experts, specific to polymer printed molds:

To optimize dimensional accuracy:

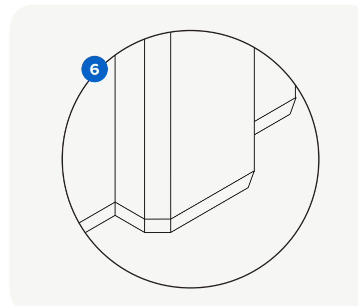
- Plan stock allowance on the mold to post-process and adjust sizes.
- Print one set of mold to understand dimensional deviations and account for this in the CAD model of the mold.

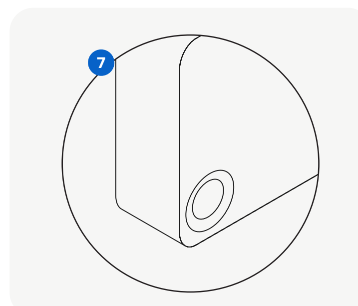


Front of the mold



Back of the mold





To extend the lifetime of the mold:

1. Open up the gate to reduce the pressure inside the cavity.
2. When possible, design one side of the stack flat while the other side carries the design. This will lessen chances of blocks misalignment and risk of flashing.
3. Include large air vents from the edge of the cavity to the edge of the mold to allow the air to escape. This yields a better flow into the mold, minimizes pressure and alleviates flashing in the gate area to decrease cycle time.
4. Avoid thin cross-sections: surface thickness less than 1-2 mm may deform with heat.

To optimize the print:

5. Adjust the back of the mold to minimize material: reduce the cross section in areas that are not supporting the cavity. It will save costs in resin and diminish risks of print failure or warpage.
6. Add chamfer to help to remove the piece from the build platform.
7. Add centering pins at the corners to align both prints.

OTHER BEST PRACTICES

To optimize dimensional accuracy:

- Print molds flat, directly on the build platform without support to reduce warpage whenever possible. Skipping supports also saves printing time, labor, and resin.
  - Select a base surface that will minimize overhangs.
  - If your design does require support, avoid contact on molding faces to improve surface quality.
- Post-process the printed mold: desktop milling or hand-sanding will help to fit both halves of the mold together and avoid flashing.

To extend the lifetime of the mold:

- Keep the injection pressure and speed low.
- Support all free-hanging cores, in particular small diameter cores.
- Place the printed mold inside a metallic frame or print the insert and machine the outside of the mold to provide support against the downward pressure and heat of the injection nozzle. Standard aluminium frames are readily available from injection molder manufacturers. Another option could be to use a metallic modular mold base system, such as the Master Unit Die Quick-Change or similar solutions, allowing to quickly switch and replace printed mold inserts.

To facilitate the demolding process and reduce cycle time:

- Employ interchangeable stacks to run new cycles while the other sets cool in order to decrease the cooling time, which compensates for the low thermal-conductivity of a plastic mold.
- Cooling can be accelerated by applying compressed air to cool the mold.
- Apply a release agent for some technical thermoplastics. Mold release is widely available and silicone mold release, are compatible with Formlabs Grey Pro Resin, High Temp Resin, and Rigid 10K Resin. Novus Applications uses solutions from Slide and Braskem uses the MR303 silicone food grade release agent from Sprayon.
- Print at a small layer height as the smooth surface helps to separate the plastic part from the mold—50 microns or even 25 microns on High Temp Resin if the model presents very fine details. It will also improve dimensional accuracy.

CHOOSING THE RIGHT RESIN

From these case studies, we suggest to choose the printing resin based on the criteria from the table below. Three stars means the resin is highly effective, one star is less effective.

CRITERIA	HIGH TEMP RESIN	GREY PRO RESIN	RIGID 10K RESIN
High molding temperature	•••	•	••
Shorter cooling time	•••	•	••
High pressure	•	••	•••
Increase cycle number for complex geometries	•	••	•••

CASE STUDIES

In this section, we will go through the case studies from Braskem, Holimaker, and Novus Applications.

Braskem Fabricated 3000 Mask Straps in a Week With a High Temp Resin Mold Insert

This case is an example of a very simple insert geometry, flat with no fine features, where reducing cooling time was critical to produce thousands of polypropylene (PP) parts in a short time.

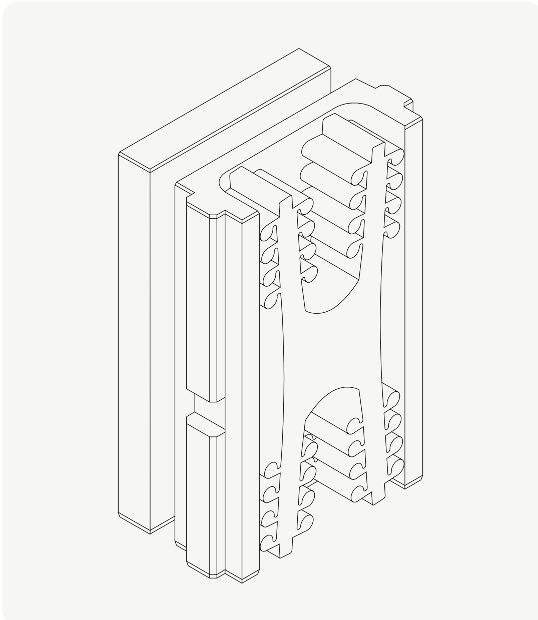
BACKGROUND AND CHALLENGE

Being one of the world's leading petrochemical companies, Braskem is well experienced in injection molding. Michelle Sing, Jake Fallon, Collins Azinger, and Fabio Lamon work on exploring opportunities with additive manufacturing for Braskem's customers. One particular interest is to help their community gain access to temporary tools and gain flexibility in production with in-demand mold fabrication. The urgent need for masks during the COVID-19 crisis led them to test the viability of using a 3D printed mold with injection molding. They needed to design and produce thousands of masks straps within a week to distribute to Braskem employees, which would have been impossible with traditional injection molding.

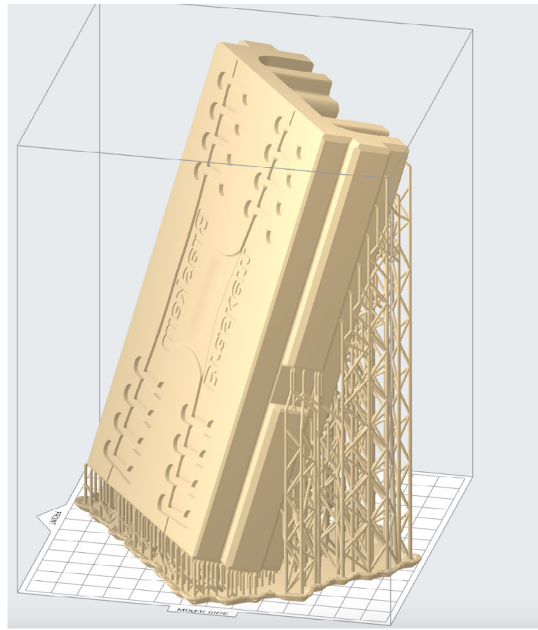
DESIGN PROCESS

Fallon went through three design iterations with this insert in order to increase the number of cycles before breakage, lessen flashing to shorten demolding time, and save resin. Here is an overview of the modifications:

	MOLD V1	MOLD V2	MOLD V3
Design features	Draft angles	Draft angles Largen gate	Draft angles Largen gate Added large vents (against flashing) Reduced the cross-section in some areas
Results	500 cycles	1500 cycles	1500 cycles Alleviated flashing 28% in resin savings



The one-side mold insert directly locked to a metallic plaque.



The final CAD file of mold insert loaded into Formlabs PreForm print preparation software. The part was printed tilted with supports. Smaller molds can also be printed directly on the build platform to minimize post processing time.

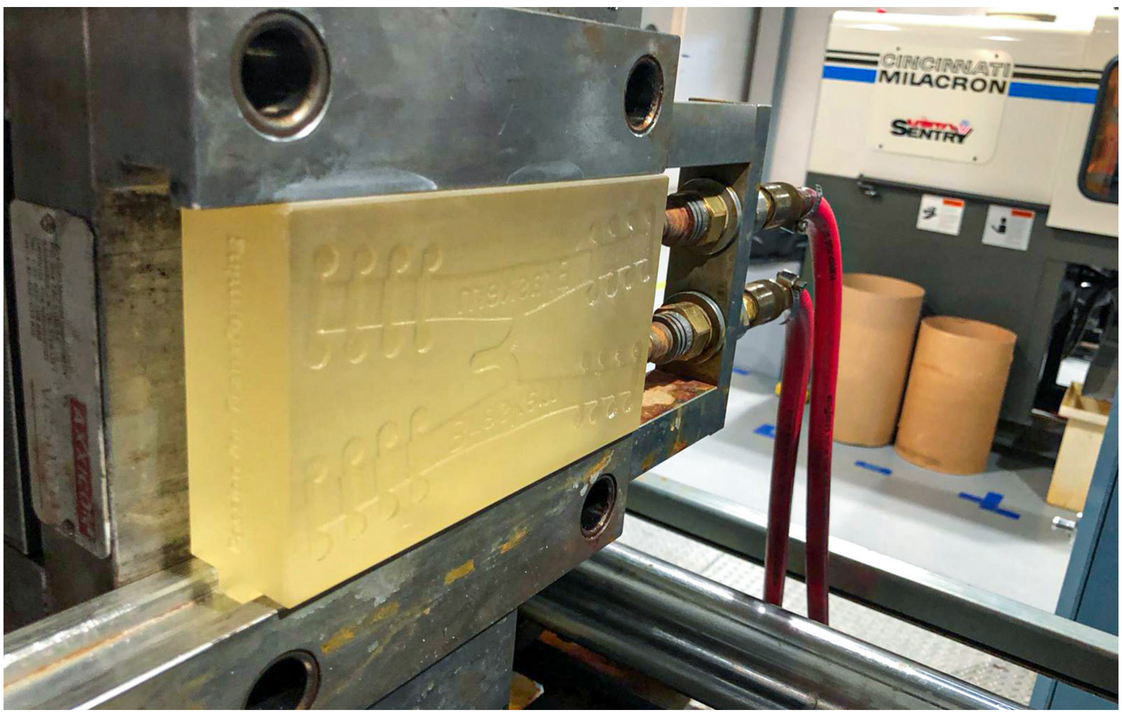
PRINTING PROCESS

The team printed on the Form 3 with High Temp V2 Resin. Thanks to the Form 3's Remote Printing feature, Fallon could work on the CAD file from home and start the print remotely, so that the part would be printed by the time he arrived back to the office in the morning. He opted for a 50 micron layer height in order to balance time to print while obtaining a good surface finish and help demolding. This resin was chosen because of its high HDT that could handle an average molding temperature of 230°C with a short cooling time. Formlabs Rigid 10K Resin could also bear this temperature for such a short exposure, however, the cooling time would be slightly longer. It took about 24 hours to build the part, they were subsequently washed in IPA for six minutes, post-cured for 120 minutes at 80°C, thermally post-cured for three hours at 160°C and then hand sanded to fit inside the system.

MOLDING PROCESS

The team operated an all-electric press Cincinnati Milacron 110 Ton Roboshot. Braskem was using a one-sided printed insert, slid into the system and directly locked to a metallic plaque, which helped to hold at high pressure. They injected generic polypropylene (PP), which has good flexibility and toughness. They chose a higher melt flow PP for low viscosity in order to minimize the injection pressure, extend the lifetime of the mold, and avoid flashing. To minimize the injection pressure they kept the temperature in the barrel higher to reduce the viscosity of the melted plastic. Some of the molding conditions were: 5-ton clamping pressure, 30 second cycle time, injection speed of 0.5 in/s, and hold pressure of 5000 psi for ~8 seconds.

Cincinnati Milacron Roboshot.

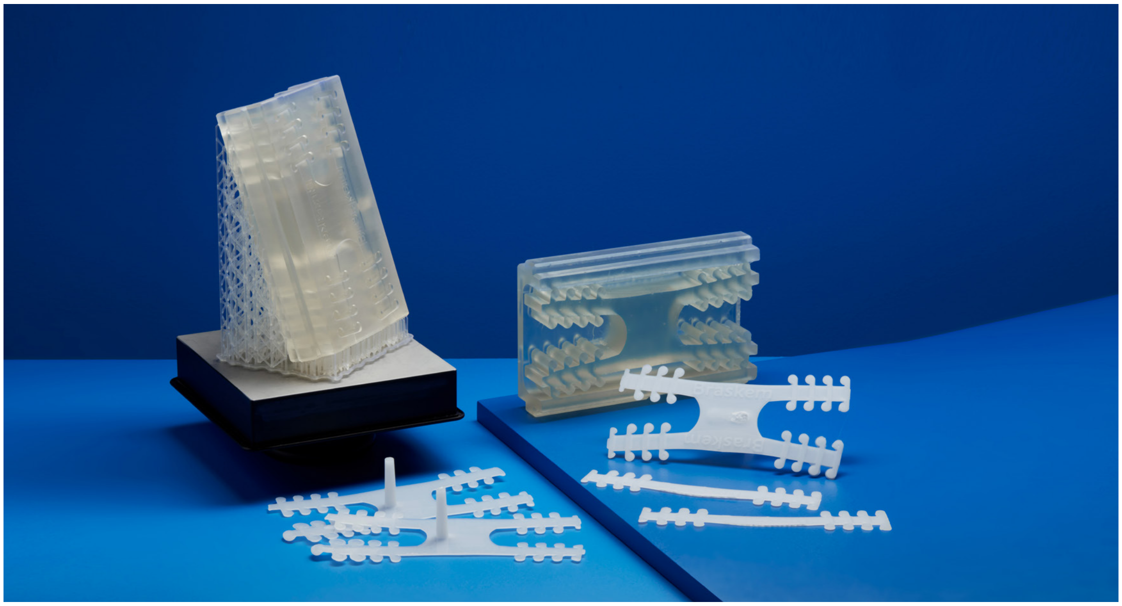


The printed mold insert (V1) slided in the injection molding machine

The demolding process was quite labor-intensive. The team trimmed the gate and purged the vents manually. They applied a silicone-based mold release agent to facilitate the separation, spraying after every 50 to 60 shots. There were no ejection pins or cooling system. However, they managed to reach an average total cycle time of 30 seconds, including cooling and manual separation.

RESULTS

The team ran 1500 injection cycles with one printed mold before breakage. Producing four straps per minute, they used two molds for the total production and more than 6000 mask straps that were distributed to Braskem team members in the USA, Mexico, and Brazil. The high number of cycles is largely the result of the structural simplicity of this insert—flat with a large gate, no intricate features, and held inside a metallic frame. For this project, Braskem went from idea to production within a week.



The mold insert printed with High Temp Resin next to the two-straps injected in polypropylene

COSTS ANALYSIS

Braskem considered three possibilities to produce these masks. By choosing injection molding with in-house 3D printed mold they obtained 90-94% time saving and 80-97% cost saving compared to the alternatives.

	IN-HOUSE DIRECT 3D PRINTING	INJECTION MOLDING WITH OUTSOURCED METALLIC MOLD	INJECTION MOLDING WITH IN-HOUSE 3D PRINTED MOLD
Equipment	FDM printer	Injection molding machine, PP	Form 3 printer, High Temp Resin, Injection molding machine, PP
Mold production time	Zero	30 days	One day
Mold production costs	Zero	$10,000-15,000	$200
Production time, including lead time for mold fabrication	13 minutes / strap	5-7 minutes / strap	30 seconds / strap
Production costs	$0.26 / strap	$1.27 / strap	$0.05 / strap

Holimaker Produces 100s of Technical Parts With Grey Pro Molds

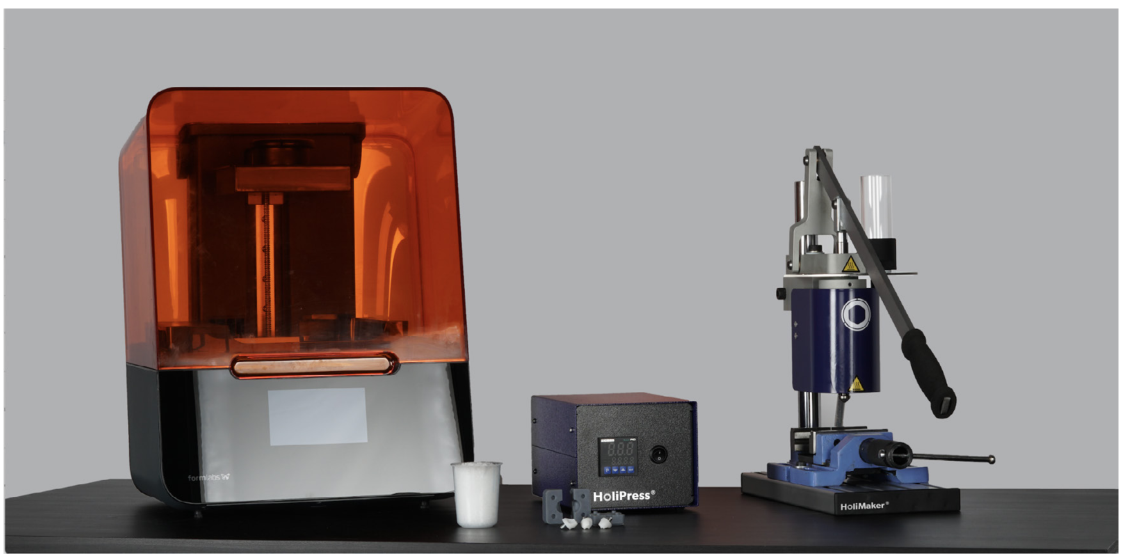
This case shows how Grey Pro Resin can be an alternative to High Temp Resin in case of mold failure due to demanding shapes. If cooling time is not a priority, Grey Pro Resin is a good option to augment mold longevity.

BACKGROUND AND CHALLENGE

The french startup Holimaker wants to make plastic manufacturing accessible by fabricating micro-industry tools for plastic processing. Their core product, the Holipress, is a manual injection molding machine that enables engineers and product designers to process plastic on their desktop for prototypes or low-volume production.

The company offers feasibility studies to their customers to allow them to assess the technology before purchase. In these studies, the Holimaker team usually produces a small batch of parts with the Holipress to test mold designs, injected materials, and to demonstrate the general production workflow before scaling to large-volume manufacturing.

Holimaker uses 3D printed molds in 80% to 90% of their current project. We met with Managing Director Aurélien Stoky and Marketing Director Vivien Salamone to understand how they combine both technologies.



The Holipress next to the Form 3 printer

"The blocker in injection molding is to manufacture the mold. In order to democratize injection molding and make it accessible to everyone, we had to find a complementary technology to produce our mold. Desktop printing was a perfect fit for this. We combine the flexibility of 3D printing with the productivity and quality of injection-molded plastic," Stoky and Salamone said.

Holimaker has looked into alternative ways for mold making. For orders over a thousand parts, they would employ a machined aluminum mold, but for smaller quantities, they run the press on 3D printed molds. In some cases they combine both in a similar way as Braskem: for large volumes with demanding geometries, they machine the outside of the mold and 3D print the insert, which is replaced over time.

DESIGN PROCESS

Usually, the team iterates on three to four models per project in order to optimize the design. They follow the general molding recommendations, such as including draft angles. They mostly work on small parts, and add 0.1 mm vents and 0.5 mm runners. In addition, they respect a few printing rules such as including chamfers to help to remove the piece from the build platform, some centering pins to align both prints and notches to assist opening with a screwdriver. They usually use 10 mm thick molds and avoid thin cross-sections. Parts that are only 1-2 mm thick cannot endure the high temperatures.

3D PRINTING PROCESS

Holimaker's team prints the molds, directly on the build platform at a 50 microns layer height. This orientation saves printing time and resin by not using support structures; the team also observed better dimensional accuracy on the mold surfaces after curing. If dimensional errors occur, it is usually on the outside of the block that they post-process with hand sanding to fit the frames.

Holimaker favors Grey Pro Resin for most of their studies. This material has lower temperature resistance than High Temp Resin but it is less brittle and allows for a higher number of cycles for difficult geometries. Grey Pro Resin can also be drilled and handled repeatedly, and could be employed in standard industrial press.

MOLDING PROCESS

The team uses the Holipress injection molding machine in all their studies. It is a small manual press, easy to use, and available at a tenth of the cost of an industrial press. The molds are placed into a prefabricated aluminum frame which holds the pressure better and ensures that the injection nozzle is not in direct contact with the printed mold.

With Formlabs printed molds, Holimaker injects a broad range of thermoplastics with different levels of hardness from Shore 40A to 90A, at a three to five minutes cycle time. The number of cycles per mold varies from about 10 parts for a PA injected at 270°C to 100s of parts for a PP, TPE, or POM injected at lower temperatures. Holimaker is developing an integrated cooling system to help reduce the cooling time before demolding.

POM football cleats injected in the Holipress from molds printed with Grey Pro Resin.

RESULTS

The team chose SLA 3D printing from Formlabs for its part quality and ease-of-use."The quality of our injected parts is very good because of the high quality molds. And when I start a print in the evening, I am almost sure to have a good mold ready the following day" they said.

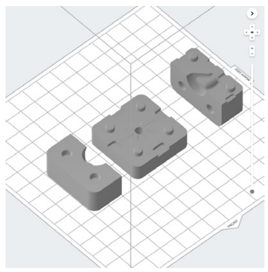
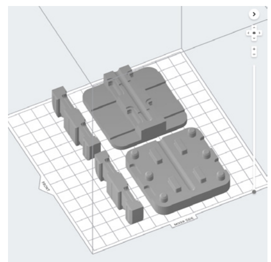
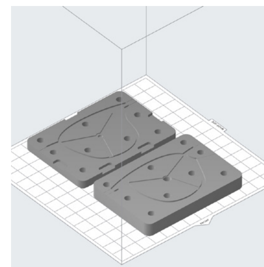
Stoky and Salamone had used another desktop printing technology before, but observed too much deformation on the prints.

“Formlabs parts offer great dimensional accuracy and surface finish, If there is a dimensional error, it is very minor, and it is uniform on the three axes, therefore we can predict it and post-process it. With other desktop printers, we could not control the deformation," said Stoky.

The team also appreciates the simple workflow that is easy to learn and operate, including the Form Wash and Form Cure which totally automate the washing and curing process. They can go from design to molded parts within a working day and then also iterate the design to optimize the model.

> *"We often design the mold in the morning, print it during the day and we can test the injection in the afternoon to modify the CAD model and start a second print overnight, "*
>
> **Aurélien Stoky**

Holimaker shared a few cases from their customers to give a better understanding of the part, molding conditions, and results of their feasibility studies.

COMPANY	SMART POWER	FERME 3D	EYEWEAR MANUFACTURER
Product	Football cleat	Face shield clip	Eyewear frame
Need	Pre-production prototypes in different thermoplastics, to test on the field and select the final material for mass production.	Test a solution to produce a series of 10,000s of parts in a short time.	Test compatibility of eyewear materials with printed molds to produce a series of 200 frames
Mold CAD			
Injected part			
Materials injected	POM (180°C), PA 6.6 (270°C), PP (210°C)	PP (food-grade, 220°C)	ASA (240°C), PA (240°C)
Number of parts for one mold	60	100	70
Cycle time	Two minutes	Two minutes	Two minutes
Project lead time	One week	One week	Two weeks

COSTS ANALYSIS

	OUTSOURCE MACHINED METAL MOLD	IN-HOUSE 3D PRINTED MOLD
Equipment	Holipress, thermoplastics	Holipress, thermoplastics, Form 3 printer, Grey Pro Resin
Mold production time	Three to five weeks	One week
Mold production costs	4-5X	1X

Novus Applications Inject Molded Hundreds of Threaded Caps With a Rigid 10K Three-Parts Mold

This case investigates the behavior of Formlabs latest engineering material, Rigid 10K Resin. Thanks to its high stiffness and temperature resistance, Rigid 10K will expand the longevity of more intricate molds undergoing high pressure and temperature.

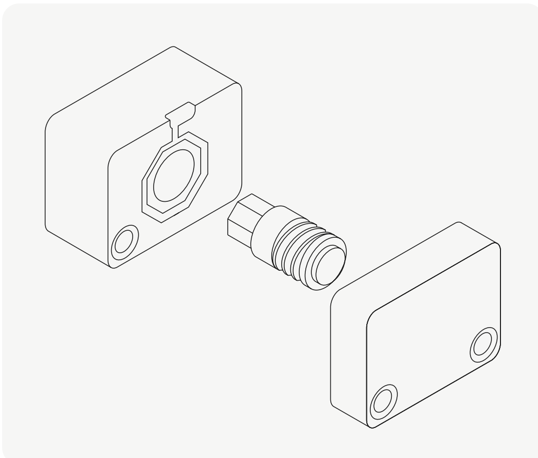
The printed three-parts mold with the caps injected in polyethylene.

BACKGROUND AND CHALLENGE

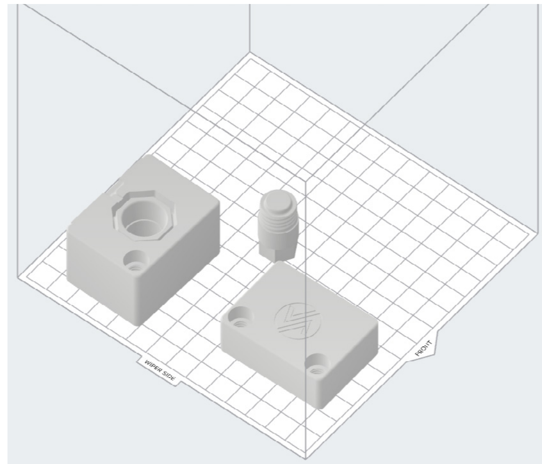
Novus Applications is a product development company focusing on consumer goods. Experienced in injection molding and 3D printing, they run design for manufacturing and moldability studies for their customers. Speed is crucial for the team as they need to quickly deliver low-volume series of prototypes. They conducted an internal study to test the viability of using a 3D printed mold in the injection molding process to fabricate a small batch of caps. They were specifically looking at the dimensional stability and longevity of the printed molds; how it would behave under the heat and pressure of the process and how many injection cycles they could expect from one mold.

THE DESIGN PROCESS

Mark Bartlett, the founder and president of Novus Applications, wanted his team to create a generic cap with an internal thread which was applicable for both tubes and bottles. It requires a complex, three-parts stack with a dynamic threaded core, which can be transferred to complicated injection molding applications. Bartlett followed the usual recommendations for designing a mold for injection molding. Specifically, he included draft angles to facilitate the demolding process, supported all free-hanging cores where possible, and avoided very thin cross-sections. In an effort to reduce the pressure in the cavity, he drew large gates and incorporated venting to get the gas out of the mold. Finally, some extra material was planned to groom the blocks in a post-processing step.



This is a three-part mold with a moving B side cavity (left), a threaded side-action core (middle) and stationary A side (right).



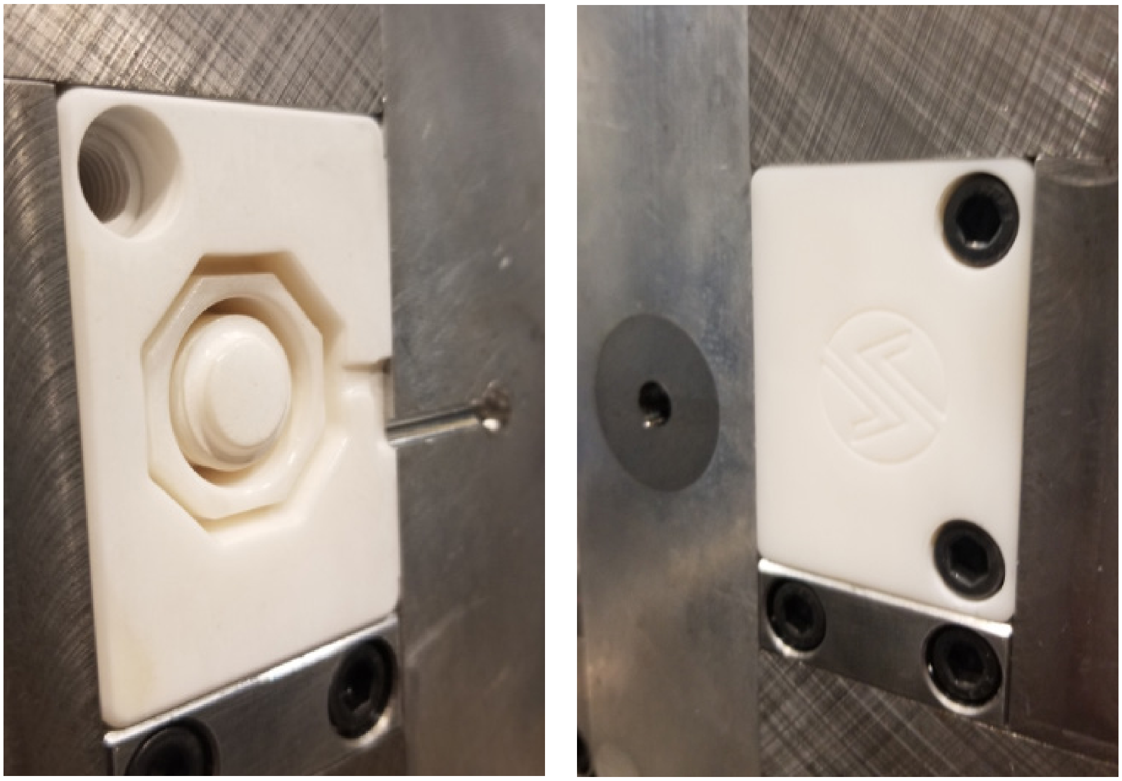
The CAD file of the mold loaded into Formlabs PreForm software for print preparation.

THE PRINTING PROCESS

Bartlett was looking for a printing part stiff enough to withstand the pressure of the process while able to render the fine details of the design. Having used FDM printing technology before, he needed the higher resolution that SLA technology can offer. He opted for Formlabs Rigid 10K Resin as it is an extremely stiff material with high tensile strength and tensile modulus, and great dimensional stability. Formlabs High Temp Resin was also considered but did not perform as well on small features, he needed the mechanical properties that Rigid 10K Resin offers rather than the thermal properties of High Temp Resin.

The molds were printed overnight on the Form 3 printer with Rigid 10K Resin at 50 micron layer height. They printed extra side-action cores in case of failure during the demolding. They were subsequently washed in IPA twice for 10 minutes and post-cured. We recommend to post-cure Rigid 10K Resin parts in Form Cure for 60 minutes at 70°C and then heat the part at 125°C for 90 minutes for a higher HDT. The parts were then post-processed to match the desired sizes. Mark designed the molds with additional stock allowances in mind so that the mold's key surfaces and features could be fine-tuned in post-processing operations, allowing him to achieve a perfect fit inside the press. Common post-processing operations include drilling out or reaming holes and sanding or milling faces to achieve the tight tolerances necessary to reduce print defects.

THE MOLDING PROCESS



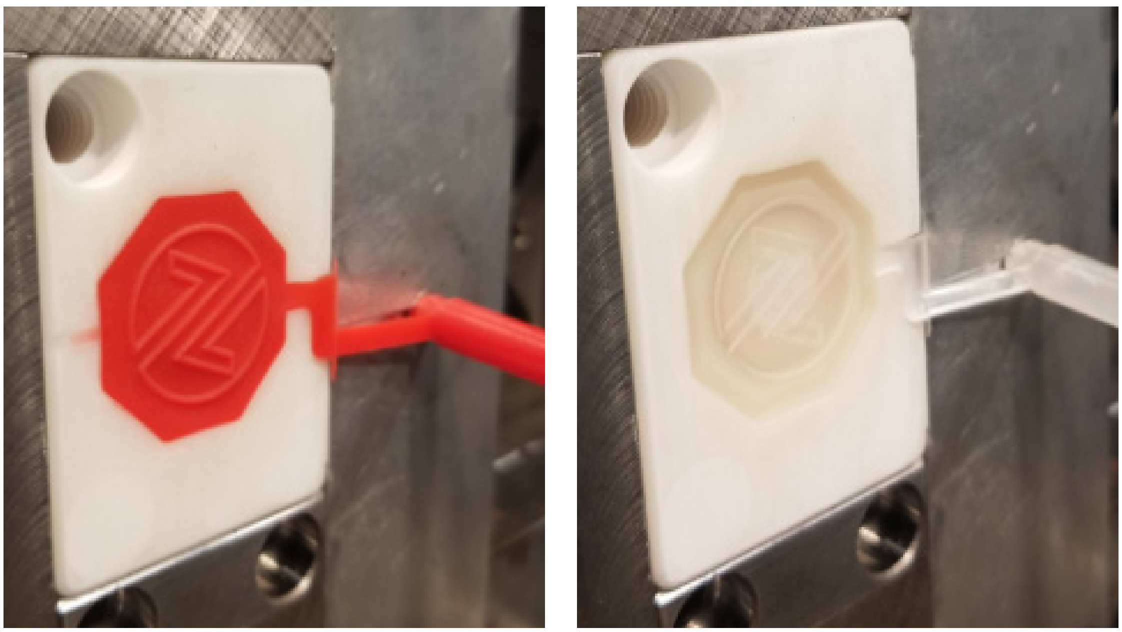
The printed molds were placed into a metallic frame before injection. The side-action core went inside the B side (left) which got locked to the stationary A side (right).

The team operated an all-electric Sumitomo 50 ton press. The printed molds were placed into a prefabricated metallic mold frame inside the machine. They injected three different materials; a low melt PP (P5M6K-048 Red), high melt PP (PP1013H1 White), and high melt polyethylene (PE) (Marlex 9018 HDPE). PP is quite easy to process and does not require very high pressure. The table below shows the injection conditions used for one printed mold.

INJECTED MATERIAL	P5M6K-048 RED	PP1013H1 WHITE	MARLEX 9018 HDPE
Melt index	35	7.5	20
Nozzle temperature	390°F, 199°C	410°F, 210°C	400°F, 204°C
Injected pressure	6,800 PSI	9,500 PSI	7,200 PSI
Cycle time	48 sec	50 sec	68 sec
Number of injection cycles	30	30	30
Pressure to failure		11,500 PSI	

Cycle times were slower than in a traditional injection molding process, including the injection, cooling, and manual demolding. The injection speed was reduced in order to keep the pressure low. To shorten the cooling time of the plastic mold, Bartlett printed multiple cores and was not running consecutively on the same core in order to leave the ones cooling on the side. There were no water cooling channels available but the aluminium frame could absorb some part of the heat. The demolding process is a sensitive step as the mold can be damaged during the operation. The team was ejecting and unscrewing the part from the side-action core manually, and had to pay attention to not break the core during the separation. They first applied a release agent to facilitate it, but it turned out not to be necessary as the draft angles were sufficient. They did not notice any chemical reaction between the printed resin and the injected materials.

RESULTS



The mold cavity after the injection of P5M6K-048 Red (left) and PP1013H1 White (right) materials.

With maintaining the injection pressure under 11,500 PSI, the team operated about a hundred of injection cycles for one mold. The lead time of this project was about two days, from idea to production. The team drew the mold in a few hours, printed it overnight, injected the parts, and took another half a day for demolding. They used only one CAD model, however, more complicated parts would require a few more days for design iterations.

The next table displays measurements on the final part injected in three different materials. For each, the team measured 20 diameters of the inside of the threaded cap to assess the repeatability of this process. We can observe an average deviation from the mean diameter of ±0.04mm over these 60 caps, reflecting a good dimensional stability.

MATERIAL	P5M6K-048 RED		PP1013H1 WHITE		MARLEX 9018 HDPE	
Mean	0.515 in	13.072mm	0.520 in	13.207 mm	0.517 in	13.134 mm
Cycle number	Deviation (in)	Deviation (mm)	Deviation (in)	Deviation (mm)	Deviation (in)	Deviation (mm)
1	0.000	0.009	0.002	0.052	0.000	-0.003
2	0.002	0.060	0.001	0.027	0.002	0.048
3	0.001	0.034	0.000	0.001	-0.002	-0.053
4	0.005	0.136	0.001	0.027	0.004	0.099
5	0.000	0.009	-0.001	-0.024	0.003	0.074
6	-0.001	-0.017	-0.001	-0.024	0.000	-0.003
7	-0.001	-0.017	-0.004	-0.100	-0.001	-0.028
8	-0.002	-0.042	0.002	0.052	-0.001	-0.028
9	-0.002	-0.042	-0.002	-0.050	0.000	-0.003
10	0.000	0.009	-0.003	-0.075	0.001	0.023
11	0.000	0.009	0.004	0.103	-0.001	-0.028
12	-0.003	-0.067	0.001	0.027	-0.001	-0.028
13	0.000	0.009	-0.001	-0.024	0.002	0.048
14	-0.002	-0.042	-0.001	-0.024	0.002	0.048
15	0.003	0.085	0.003	0.077	-0.002	-0.053
16	0.000	0.009	0.002	0.052	-0.001	-0.028
17	-0.002	-0.042	-0.002	-0.050	-0.002	-0.053
18	-0.003	-0.067	-0.003	-0.075	0.001	0.023
19	0.000	0.009	0.002	0.052	0.000	-0.003
20	-0.002	-0.042	-0.001	-0.024	-0.002	-0.053
Average from absolute deviation	0.001	0.038	0.002	0.047	0.001	0.036

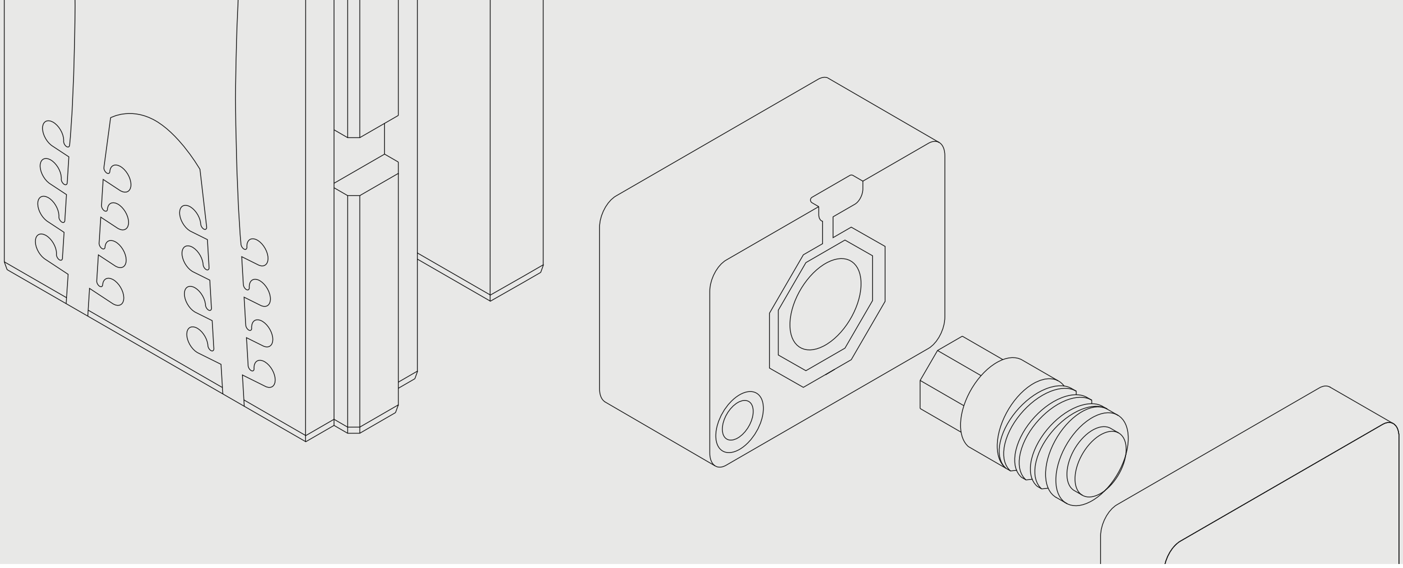
COSTS ANALYSIS

> *"If my customer only needs 20 parts why would I need an aluminum mold? With 3D printing technology, the team shows a much faster learning curve, the production is more unattended—specifically thanks to the Form 3's ease-of-use."*
>
> **Mark Bartlett**

With this workflow, Novus Application saved a lot of time and simplified a previously complex process. Normally, they would have machined the mold in-house out of a block of steel or aluminum, which would be far more labor-intensive. It would take a few more days and require high-end software with highly trained operators. Due to the more expensive equipment and materials, both machine time and the production cost of the mold would have been substantially higher. For this project, Bartlett estimates that 3D printing the mold cost less than half of machining it in house.

"It always depends on the part that you are working on—I can print complex parts accurately way faster than I am going to machine them," said Bartlett.

	IN-HOUSE MACHINED METAL MOLD	IN-HOUSE 3D PRINTED MOLD
Equipment	CNC machine and software Injection molding machine PP, HDPE	Form 3 printer Rigid 10K Resin Injection molding machine PP, HDPE
Mold production time	Two days	One day
Mold production cost	2X	<1X



Conclusion

The conversation around 3D printing and injection molding is often oppositional, but it's not always a question of one versus the other. By directly 3D printing parts or using 3D printed molds for injection molding for prototyping and low-volume production, your company can leverage the benefits of both technologies. This will make your manufacturing process more time- and cost-efficient and allow you to bring products to the market faster. With this hybrid process, it is possible to shorten the time from concept to production while delivering a series of parts in traditional thermoplastics.

With the recent release of the Form 3L, Formlabs' large format SLA 3D printer, you can scale this process to large molds and tackle even more applications. Users are also exploring techniques such as electroplating or assembling a multi-material printed stack to expand the capabilities of short-run molds.

Thanks to injection molding, engineers and product designers can produce short-runs of end parts or prototypes to test the final material that will be adopted in mass production. With desktop SLA 3D printing, they can now make it happen affordably, within a few days.

Do you have questions about using an SLA printer for injection molding or other engineering and manufacturing applications? Reach out to our solutions specialists or request a free sample of one of the three materials showcased in this white paper.

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