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Polyurethane Molds Processing Guideline - Ultracur3D® RG 1100 B

User Guideline

DESCRIPTION

3D printing PU molds, instead of traditionally CNC machining them, enables the rapid production of prototypes, helping to assess design and functionalities at an earlier stage. It also allows companies to offer a broader variety of prototypes, or even small series, to potential customers for early feedback.

Getting started with the use of 3D printed molds for polyurethane involves careful mold preparation, ideally combined with know-how in design for additive manufacturing (DfAM), printing, post-processing, and finally, polyurethane injection or casting. If done correctly, this method can greatly shorten lead times and reduce costs during the early stages of any PU foaming project, compared to traditionally CNC-milled molds.

QUICK FACTS

Material:

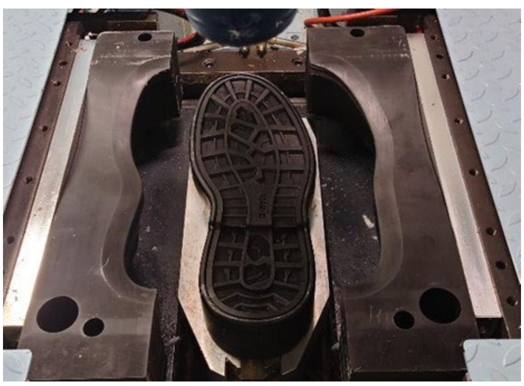
Ultracur3D® RG 1100 B / xPRO1100-Black

Recommended Printers:

XiP Pro by nexa3D

Partner:

Nexa3D, BASF Polyurethanes



PU Mold Sample Design by BASF Forward AM

To achieve the best possible performance, the following chapters should be followed.

Our tests at BASF Polyurethanes GmbH in Lemförde have led to key guidelines that ensure precision in every step, optimizing the additive manufacturing process for polyurethane molds. Testing was done during all steps of creating PU-foam parts: starting from machining of the printed parts, to demolding, cleaning and testing of different molds like casting, injection as well as round-table molds.

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High Heat Deflection Temperature

High Chemical Resistance

Extended technical data

MATERIAL DETAILS

Rigid Resin with Superior Stiffness and Demolding behavior

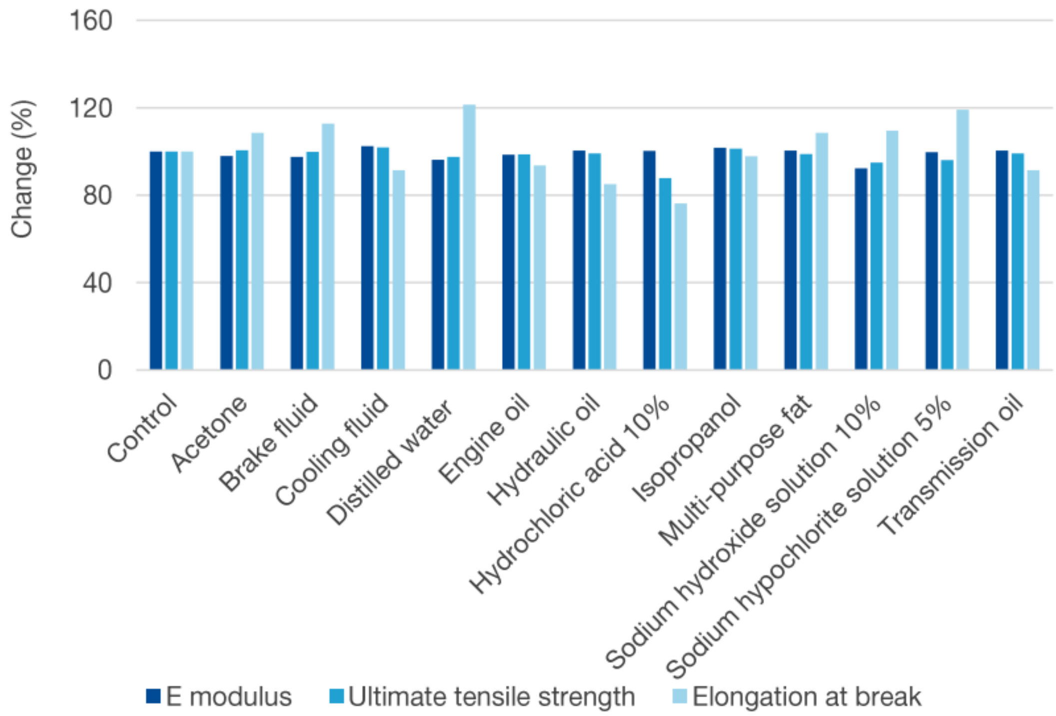
- Young's modulus: 2950 MPa
- Tensile strength: 70 MPa
- Heat deflection temperature (HDT): 100°C
- Water absorption (24h): 0.14%
- Impressive all-around temperature resistance
- Very high chemical resistance
- Compatible with standard mold release agents and cleaning solvents.

RG 1100 B Chemical Resistance

Test Method and Specimens

ASTM D638 type IV tensile bars were soaked in each fluid at room temperature, one set for 30 minutes and one set for 7 days (check Extended TDS). Upon completion of the soaking time, the parts were removed from the test fluid and were dried to measure the weight and the mechanical properties.

Change in mechanical properties after 30 minutes immersion



More data about RG 1100 B can be found here: **extended TDS**.

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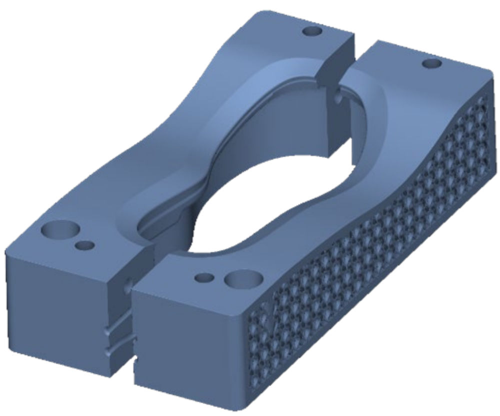
RECOMMENDED 3D PRINTERS

Ultracur3D® RG 1100 B is compatible with multiple 3D printers. However, a high-quality light engine is preferable to achieve the recommended layer times and resolution. An overview of validated 3D printers can be found here: **Printer Compatibility**. This specific case study was validated with a Nexa3D XiP PRO. Printing settings for the RG 1100 B can be found on NexaX under the name xPRO1100-Black.

MOLD DESIGN OPTIMIZATION

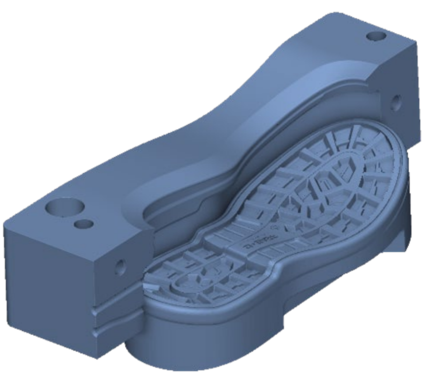
In general, the design guidelines of polyurethane molds should be applied, but with the consideration that thin features should be avoided, since the mold made of a photopolymer printed material such as the Ultracur3D® RG 1100 B, has lower strengths than aluminum or steel molds.

Employing an infill pattern can virtually eliminate warping during the printing process. For those new to Design for Additive Manufacturing (DfAM), BASF Forward AM offers comprehensive consulting services. These services are designed to help you fully grasp the extensive design opportunities enabled by this technology, as well as understand its limitations.



A few insights to keep in mind:

- Hollow the mold and fill it with infill to save up to 40% material and reduce warpage. Explore BASF Forward AM's DfAM Service to improve your mold design. Contact us to start optimizing today
- Keep a >5mm wall inside the mold to resist process pressure
- Allow a tolerance of 0.5mm between sides and stamp to ensure smooth movement



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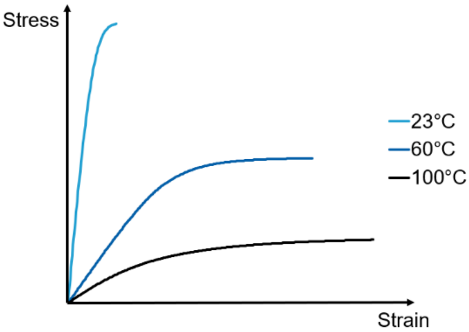
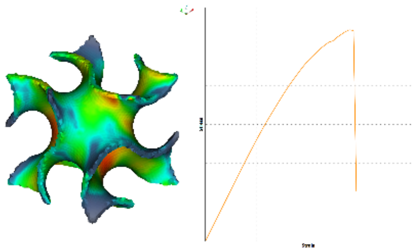
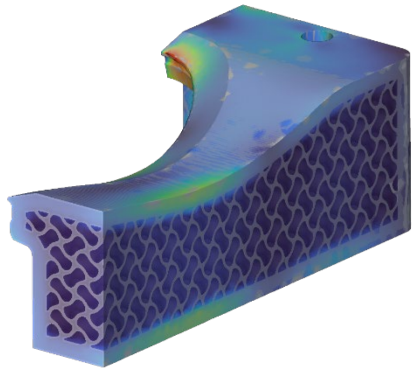
Simulation for design validation

Extensive material testing combined with BASFs Ultrasim® 3D material modelling allows for accurate predictions of 3D Printed molds in RG 1100 B, even with lattice structures.



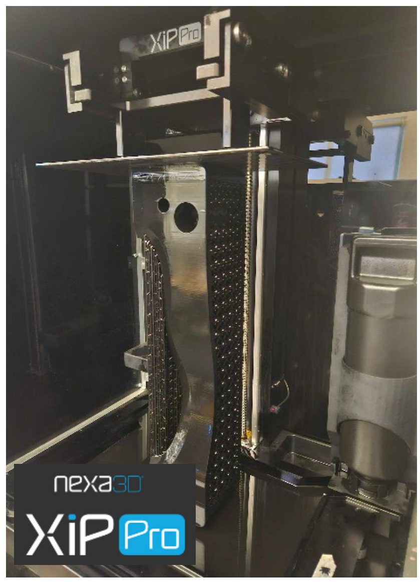




PRINTING

To ensure the highest quality of edge sharpness at the parting line, it's advised to position the molds either horizontally or vertically relative to the printing plate. It's important to avoid overhangs and undercuts; if present, they necessitate support structures within the mold cavity, which can degrade quality.

For optimal detail sharpness, a layer thickness of 50 to 70 microns is recommended, though thicknesses up to 100 microns can still be effective. In the context of large geometries, such as those found in molds for polyurethane, it's essential to account for extended travel distances and increased waiting times. Ensuring a completely flat surface is crucial, particularly at the parting line and on the mold's back side. Mechanical finishing might be necessary to achieve this flatness. Failure to maintain these standards can result in stress fractures when the molds are clamped.



POST PROCESSING

To achieve final mechanical properties and the necessary thermal resistance of the molds, post processing is required after printing. The individual steps are illustrated below:

In the **User Guideline**, initial material settings and handling recommendation can be found. Heat treatment is optional but strongly recommended as it can increase heat resistance, resulting in higher durability and preventing the expected shrinkage under thermal stress during the process.

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PROCESSABILITY AND MACHINABILITY

Shrinkage and warpage is common to all plastics processes, especially those where part thickness is high. This is also true for 3D printing processes.

As molds or mold inserts are used in a technical environment of precisely machined metal components, machining and reworking 3D printed molds is a good way to achieve tighter tolerances for proper fit and alignment.

The tables below show recommendations for rpms and cutting speeds found to work well with RG 1100 B. The right cutting speeds depend on the equipment and progression like coated vs uncoated tools, blade angle or feed rate. Cutting speeds highlighted bold are to be considered starting points.

Different rpms were tested, best results are calculated into a recommended cutting speed as follows:

v_c [m/min] Cutting speed
n Revolutions per minute
d [mm] Cutting tool diameter

$$v_c = \frac{n \times \pi \times d}{1000}$$

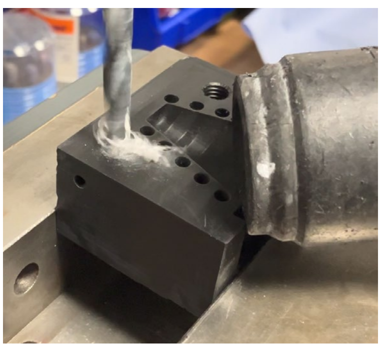
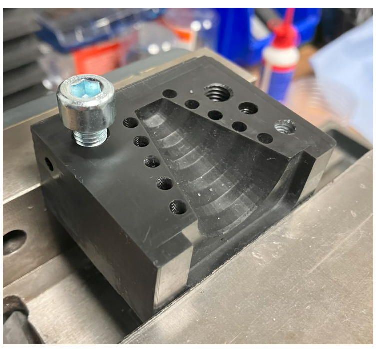
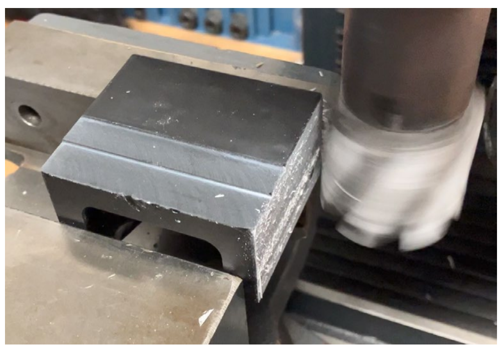
Drilling			
Tool	**RPM**	**v_c**	**Comment**
D4,2 HSS Drill	1800 – 2200	**23** – 30	Easy progression, good overall result. Careful on the pressure to reduce chipped edges and heat build up.
D6,2 HSS Drill	800 – 1000	**25** – 31	

Tapping diameter is recommended to not exceed M8, as it exerts high forces and can damage or even break the part. The best approach, especially for bigger diameters, is to directly 3D print and later recut the thread.

Cutting oil hugely improves the result. Although direct tapping works, the resulting thread is slightly chipped, though functional.

Milling			
Tool	**RPM**	**v_c**	**Comment**
D10 Carbide coated 4 bladed HSS mill cutter	2000 – 2500	**60** – 80	Easy progression, good overall result. Up cut milling creates less chipped edge
D40 HSS 6 bladed mill cutter	500 – 800	**65** – 100	Resulting surface is smooth and shows little to no chipped edges

For best results, only do conventional (up-cut) milling with less than half the tools diameter engaged.

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Tumbling

Tumbling is an effective way to smoothen surfaces and reduce unwanted defects, e.g. stair step effects from 3D printing. However, sharp edges will be rounded in this process.

MOLDING PROCESS

3D-printed insert in base mold. From left to right: assembled 3-piece mold, open mold after injection, midsole after last removal, outsole profile after removal

Molding trials were performed on a round-table system using a standard DESMA mold design using a 300g/L PU-Foam. Fully solid printed molds as well as gyroid filled molds were tested with good results. The molds were installed and heated for 3 hours up to working temperature. Two different PU footwear systems were also tested, a sport and a safety shoe system, respectively.

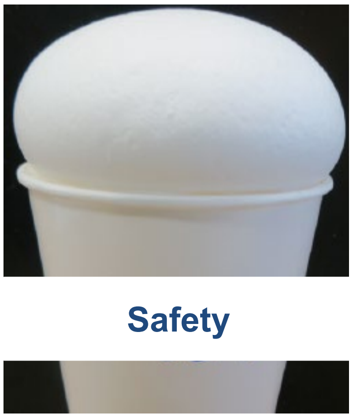
The demolding time of the systems were 4 and 6 minutes, and PU foam soles with densities of 300-450 g/L were produced. By using Gorapur LS 1040-120B as release agent the produced soles could be released without any problems. During production of the soles, the molds were subjected to machine-induced closing forces up to 7.4 ton.

For more details and news on PU soles please visit www.footwear.basf.com

DEMOLDING

For the demolding trials three different BASF Elastopan® PU systems were tested: Elastopan® Sport, Elastopan® Safety and Elastopan® Casual. Elastopan® PU systems offer high-performance and innovative solutions for producers of casual shoes, safety shoes, boots and sport shoes. These are tailor-made polyurethane foam systems for the production of unit-, mid-, out- and insoles. It is compatible with casting and direct injection machines.

Casual



Safety

Sport

Release agents used:

- **Marbo Super Release S (Silicone):** A standard silicone-based release agent characterized by a higher density of 550g/L.- Recommended
- **Gorapur LS 1040-120B (Wax):** This wax-based release agent is notable for its lower density, ranging between 250-300g/L, making it suitable for specific applications.- Recommended
- **Keck 1502/334:** A specialized release agent designed to facilitate the demolding process. It enhances the separation of the outsole from the midsole during manufacturing. – Not Recommended (*as it is specifically designed for metal molds and may not offer the same release effectiveness or compatibility with photopolymer materials)*

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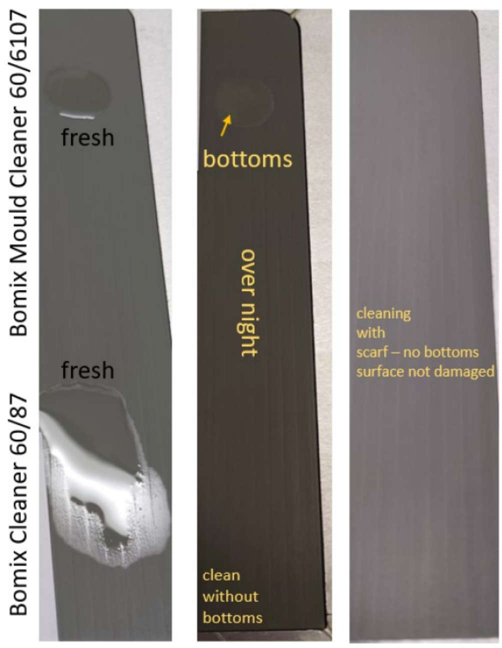
Sample	System	Release Agent
Top Left	Elastopan Sport	Marbo Super Release S
Center Left	Elastopan Safety	Marbo Super Release S
Bottom Left	Elastopan Casual	Marbo Super Release S
Top Right	Elastopan Sport	Gorapur LS 1040-120B
Center Right	Elastopan Safety	Gorapur LS 1040-120B
Bottom Right	Elastopan Casual	Gorapur LS 1040-120B

After 5 to 6 samples, the demolding temperature of the inlay increased to approximately 45/46°C, which is well below the highest temperature resistance of our RG 1100 B.

CLEANING



Tests were conducted on the 3D printed inlay using release cleaner and mold cleaner**. Bomix Cleaner 60/87**, specifically formulated for release agents, and **Bomix Mold Cleaner 60/6107**, designed for removing stuck foam parts in the mold, were applied. The cleaner was left on the surface of the inlay overnight, and no issues were observed on the surface.