TECHNICAL APPLICATION GUIDE

Silicone Molding With FDM Patterns

Silicone molding, also known as room temperature vulcanized (RTV) molding, is a fast and affordable solution for prototyping and short-run production. Offering lead times of three to seven days at just a fraction of the cost of an aluminum tool for injection molding, silicone molding is an attractive alternative for the production of plastic parts.

A silicone mold is made by pouring liquid silicone rubber over a pattern. After the rubber cures, it becomes firm, yet flexible. The result is a mold that can hold tight tolerances while reproducing extremely complex geometries, intricate details, and undercuts.

By replacing machined patterns with FDM® patterns, the mold-making process can be completed in two to three days. And unlike machining, complex and intricate shapes have little effect on the time or cost of the FDM pattern.

An important consideration, which is often overlooked, is that FDM patterns can endure the mold-making process. They can withstand the weight of the rubber and heat from an accelerated curing process. Additionally, the strength of the FDM material makes it possible to extract complex patterns from the silicone mold without breaking, which means that patterns can be reused to make multiple molds.

Silicone molded MRI cover and tooling. Clockwise from top left, silicone mold, complete MRI assembly with cast urethane cover, finished and painted urethane cover, raw cast urethane cover, FDM master pattern for creating the silicone mold.

APPLICATION COMPATIBILITY

TECHNOLOGY	IDEA	DESIGN	PRODUCTION
FDM	2	3	3
PolyJet	NA	5	5

(0 – N/A, 1 – Low, 5 – High)

COMPANION AND REFERENCE MATERIALS

Technical application guide	• Document
Application brief	• Document
Video	• Commercial • Success story • How It's Used
Case Studies	• ScanMed
Referenced processes	• Best Practice: Orienting for Strength, Speed or Surface Finish • Best Practice: CAD to STL • Best Practice: Sectioning an Oversized Part • Best Practice: Applying Custom Toolpaths for Thin • Walls and Bosses • Best Practice: Bonding • Best Practice: Optimizing Seam Location • Best Practice: Media Blasting • Best Practice: Solvent Smoothing • Best Practice: Painting

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SILICONE MOLDING WITH FDM PATTERNS

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1. Process Overview

There are many styles and approaches to the “art” of silicone molding. Two common methods include:

- **Single pour:** The master pattern is placed on spacers so that when the silicone is poured, the pattern is encapsulated. It is then extracted by cutting around the parting line.
- **Two-pour (lay-up):** An “A-side” and “B-Side” are poured with silicone and assembled to make the final silicone mold.

The following information covers the two-pour mold-making process that uses the pattern lay-up approach. Beyond substituting an FDM pattern for a traditional pattern, there are no other modifications.

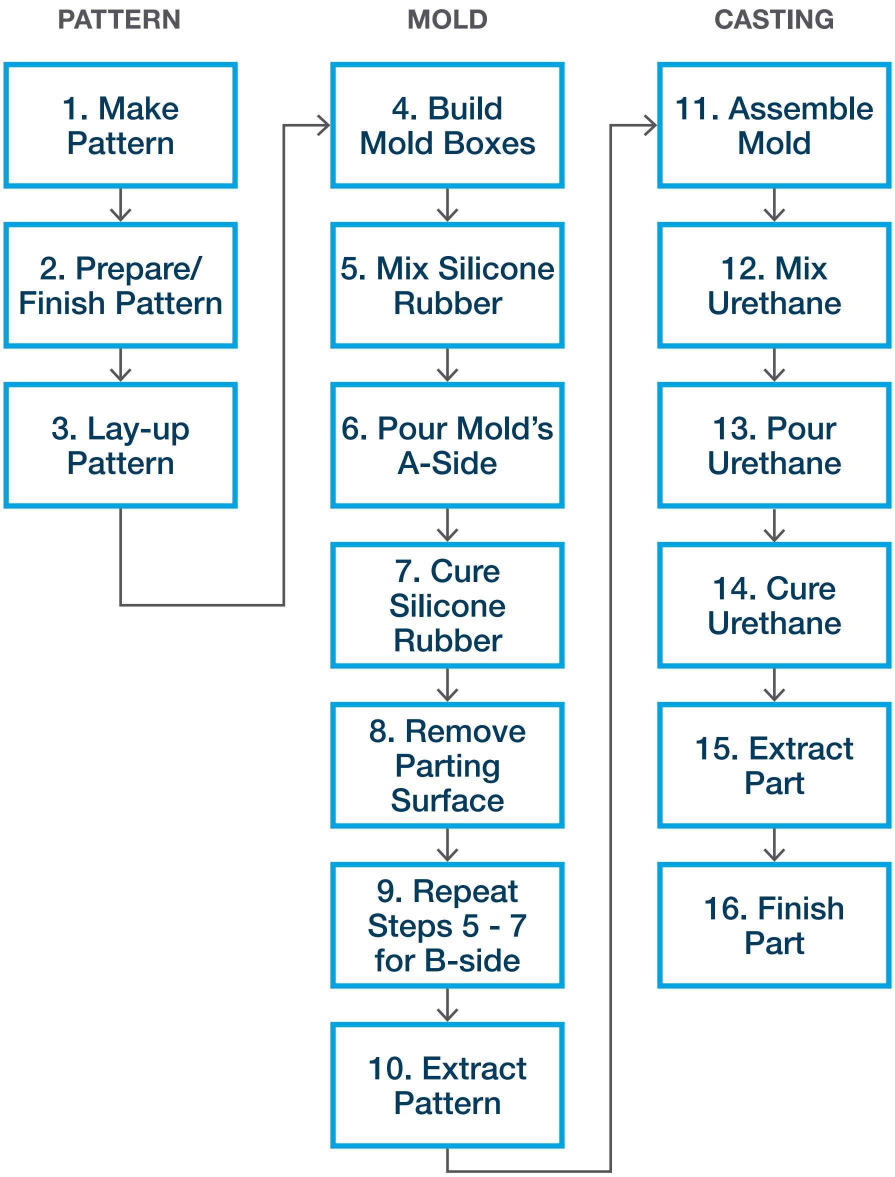

Figure 1: Cast urethane component (blue) is part of a magnetic resonance imaging (MRI) array.

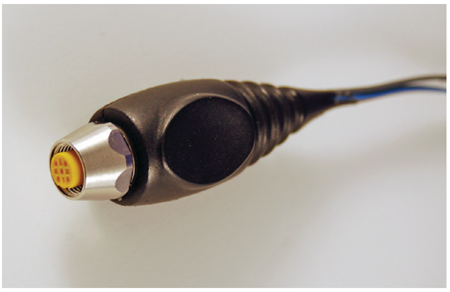

Figure 2: Overmolded connector that was cast in an RTV mold made from an FDM pattern.

2. Pattern Design

Start with the CAD model for the part that will be cast. In most cases, no modifications are necessary (Figure 3).

2.1. Suggestions

The following items offer some optional and as-needed suggestions. Note that these actions apply to patterns made from any process; they are not FDM-specific.

2.1.1. Omit draft angles (optional).

Silicone molds are flexible, so draft angles are not needed (Figure 4). However, if they exist in the part's design (e.g., as in an injection molded part) there is no reason to remove them.

2.1.2. Remove features (as needed).

Eliminate problematic features from the CAD model. When finishing the cast urethane part, mill, drill or tap to add the features. Small undercuts are allowed since the flexible silicone material will deflect when extracting cast parts (Figure 5).

- "Trapped" features
  Example: A hole with a centerline perpendicular to the direction of mold separation (Figure 6). This feature will trap the pattern in the mold unless a side pull is added.
- Narrow holes or channels
  These features will grip the silicone, which may cause it to tear when extracting the pattern. Additionally, these features are often difficult to reach when sanding parts. Any layer lines that remain will lock into the silicone, which increases the likelihood of tearing.

  An alternative is to produce an insert that will form the hole or channel. The insert is placed in the pattern prior to pouring the silicone. After the silicone cures, the insert becomes part of the mold.

2.1.3. Add gates and vents (optional).

If desired, add gates and vents to the CAD model which will make them part of the pattern (Figure 7). This eliminates a step in the mold-making process.

2.1.4. Add shrinkage compensation (optional).

Most often the shrinkage of the silicone is offset by the shrinkage of the cast urethane, so compensation is unnecessary (Figure 8). However, if casting a urethane with high shrinkage, such as low-durometer materials, calculate the net shrinkage between the silicone and the urethane. Scale the CAD model by this value to compensate.

Optionally, shrinkage compensation values may be applied when processing the file in the Insight™ software.

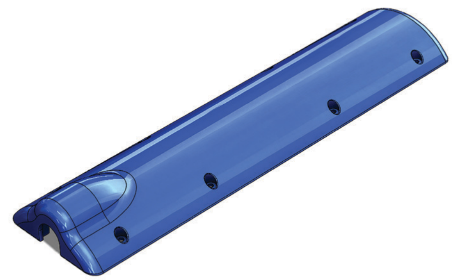

Figure 3: Start with a CAD model that includes all the design details.

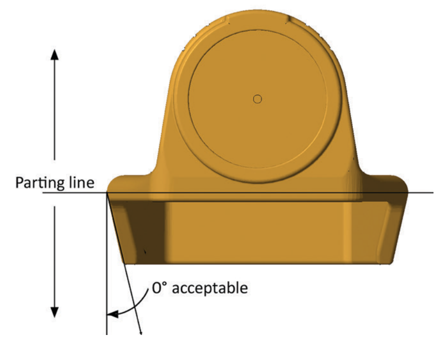

Figure 4: Flexible silicone molds do not require draft angles.

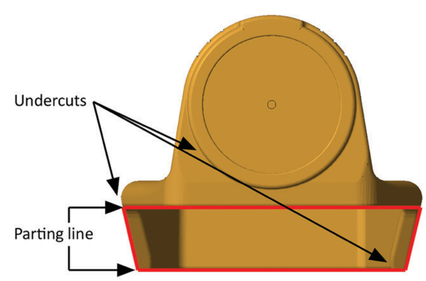

Figure 5: Small undercuts are allowable because the silicone tool will flex when extracting parts.

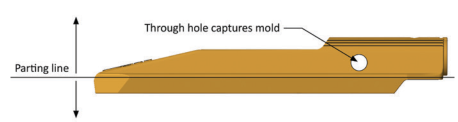

Figure 6: To simplify silicone molds, eliminate features that will prevent part extraction.

Figure 7: Gates and vents are added to the CAD model of the pattern.

2.1.5. Section patterns (as needed).

If a pattern exceeds the build envelope of the FDM printer, split it into two or more pieces. Carefully consider where these cuts will be made since the pieces will be bonded to create a single pattern.

Pattern segmentation may also be used to improve the strength or surface finish of individual features. If an ideal build orientation will negatively affect some areas, split them from the pattern so that they may be built with a different orientation (see Section 3.1).

See the *Best Practice: Sectioning Oversized Parts*.

2.2. Generate STL file.

When the CAD design work is complete, save the model as an STL file. Be sure to adjust settings, such as chord height, for the STL file so that small facets are created (Figure 9). This will produce smooth surfaces that require less post-processing when preparing the pattern. See the *Best Practice: CAD to STL*.

3. File Preparation

Import the STL file into the Insight or equivalent software for your Stratasys® system, and prepare it for the FDM build.

3.1. Orient STL file.

When orienting the pattern, consider surface quality, feature detail, feature strength, build time and post-processing (Figure 10). For FDM master patterns, the STL file is typically oriented for surface finish. See the *Best Practice: Orienting for Strength, Speed or Surface Finish*.

3.2. Slice STL file.

Consider using a small ***Slice height*** when fine features are present. Thinner slices will produce finer feature detail since the toolpath widths can be narrower (Figure 11).

3.3. Select part interior style.

The recommended style for most patterns is Sparse (Figure 12). This provides adequate strength while minimizing build time and material consumption. For large patterns, consider a ***Sparse – double dense*** fill that can better withstand the compressive forces of the silicone rubber. Additionally, increasing the wall thickness using custom toolpaths helps to prevent deflection.

Set the fill style to ***Solid – normal*** for thin-walled patterns – those with walls less than 3.8 mm (0.15 in) wide. Optionally, create custom groups (requires Insight software) to make these features solid while the overall pattern has a sparse fill. For additional information on custom groups, see the *Best Practice: Applying Custom Toolpaths for Thin Walls and Bosses*.

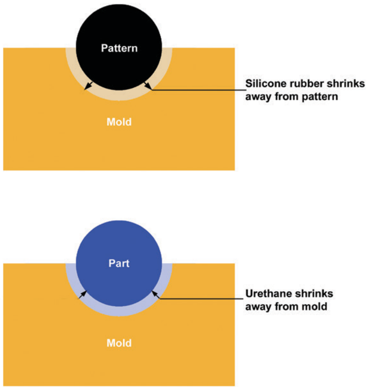

Figure 8: Silicone rubber and urethane shrink in opposite directions so compensation may be unnecessary.

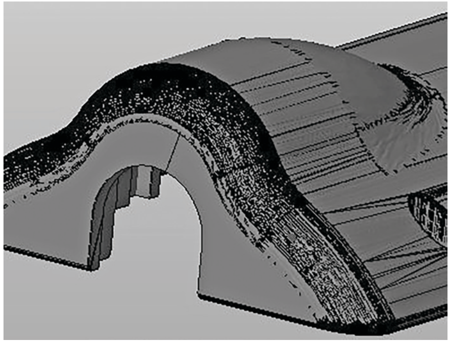

Figure 9: Export high-resolution STL files to minimize pattern finishing.

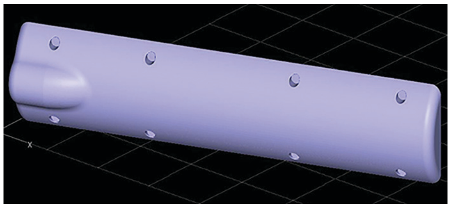

Figure 10: In Insight software, orient the file for the best balance of quality and time.

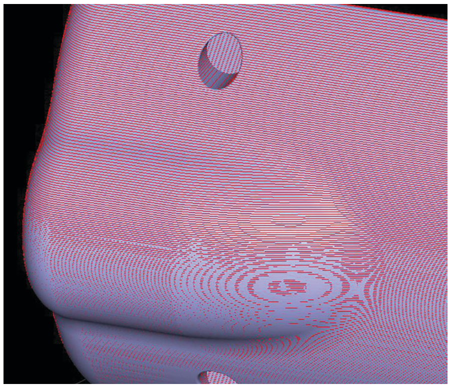

Figure 11: Consider using a small slice height for fine features.

3.4. Use surface finish improvement settings (requires Insight software).

These options improve the downward facing part surfaces where the supports interface with the pattern. These settings are "checked" by default for parts with soluble support material. To prevent features from being trapped when using breakaway support, the default settings will deactivate several of these options.

Check the boxes for (Support > Setup > Advanced parameters) (Figure 13):

- Two layers of support face
- Two layers of base top
- Add perimeter to support face

Further surface improvement can be achieved by selective location of seams on a noncritical surface. For details, see the Best Practice: Optimizing Seam Location. Also consider using custom groups to improve the aesthetic quality of a pattern's surfaces. For additional information on custom groups, see the *Best Practice: Applying Custom Toolpaths for Thin Walls and Bosses*.

4. Materials

All FDM materials are suitable for silicone molding patterns (Figure 14). FDM materials are inherently inert, which allows the silicone to cure around them without negative side effects.

4.1. Material recommendations.

Although all FDM materials are suitable, ABS materials are preferred for pattern making because their mechanical and thermal properties are well-suited for the application (Figure 15). Additionally, the use of ABS materials makes the pattern preparation process easier, faster and less labor intensive because of the variety of finishing techniques available. Plus, ABS materials have soluble supports that eliminate manual removal. Finally, ABS is the most economical FDM material option.

5. Pattern Preparation

After constructing the FDM pattern, remove support material and finish the surfaces to the desired level of smoothness. The casting will exhibit the same characteristics as the FDM pattern, so confirm that the surfaces and features of the pattern match all project requirements.

5.1. Remove supports.

5.1.1. Breakaway supports

If the pattern is made of an FDM material that uses breakaway supports, manually remove them (Figure 16).

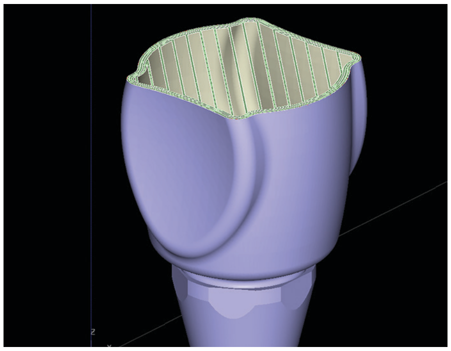

Figure 12: An example of sparse part interior style.

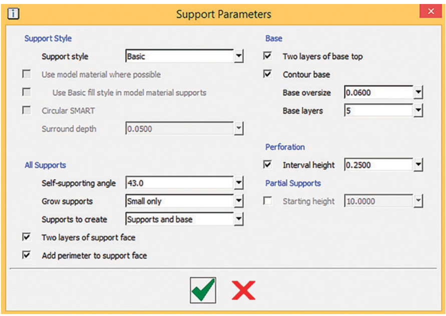

Figure 13: Check boxes for surface finish improvement.

Figure 14: All FDM materials are suitable for RTV patterns.

Figure 15: ABS is preferred for patterns because it is easy to finish and low cost.

5.1.2. Soluble supports

Dissolve the support material from the pattern following the instructions supplied with the soluble support detergent (Figure 17).

When no support material remains on the pattern, soak it in tap water or rinse thoroughly to remove all traces of the support solution (Figure 18). Residual detergent may react with or inhibit fillers, primers or silicone rubbers.

Next, thoroughly dry the pattern to remove all moisture. To accelerate drying, expose the pattern to hot, well-circulated air. If using ABS material, do not exceed 75 °C (165 °F).

5.2. Bond sections (optional).

If the pattern is built in sections, bond the pieces prior to surface smoothing to create a single pattern. See the *Best Practice: Bonding* for details.

5.3. Smooth surfaces.

The silicone rubber mold will transfer the finish of the pattern to the molded parts. It is important to have all surfaces of the pattern as smooth as what's needed for the intended use of the castings.

Although appearance may not be a critical consideration, the pattern must still be smooth enough to allow the silicone rubber mold to release it. Layer lines will cause the silicone rubber to grip and hold the pattern, which makes extraction difficult and may cause the mold to tear.

Surface smoothing may include any combination of chemical smoothing, sanding, painting and filling, and media blasting.

5.3.1. Solvent smoothing (optional)

Solvents will chemically smooth the surface of ABS materials to produce a consistent, mold-ready pattern. For details, see the *Best Practice: Solvent Smoothing*.

5.3.2. Sanding, filling and painting

Sanding, filling and painting can be the key to achieving the surface finish that you want for the pattern (Figures 19 and 20). Typically, this step is iterative and ends when you feel you've achieved the desired level of surface smoothness. For details, see the *Best Practice: Painting*.

5.3.3. Media blasting

Media blasting is an inexpensive and quick alternative to sanding. It can be used to prepare a part for painting or as a way to add texture to a part. See the Best Practice: Media Blasting.

5.4. Clean pattern.

Remove dust and debris from the pattern before proceeding to making the mold.

Figure 16: Remove breakaway support material.

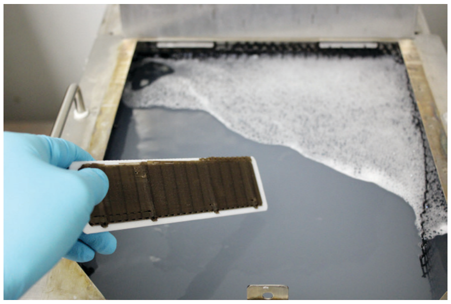

Figure 17: Remove soluble supports in the support removal tank.

Figure 18: Thoroughly wash pattern to remove support removal detergent.

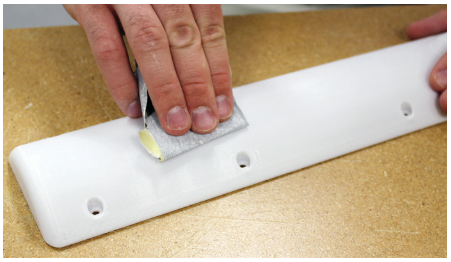

Figure 19: Sand pattern after support removal.

6. Mold Making And Casting

Using the FDM pattern, establish a parting surface by combining it with modeling clay. Then assemble the mold box, apply mold release, mix the silicone rubber and pour it into the box.

After curing, repeat the process for the other side of the mold.

After curing the second side, extract the FDM pattern (Figure 21). Robust and dimensionally stable, the pattern may be stored and reused to create additional silicone molds (Figure 22).

Either addition or condensation cure silicones may be used. If heat is applied to reduce the cure time of addition cure silicone, ensure that you have selected an FDM material that has sufficient mechanical properties at the elevated temperature.

After mixing the urethane or other thermoset material, pour or inject it into the silicone mold. When the urethane has cured, extract the part and finish it as desired (Figure 23).

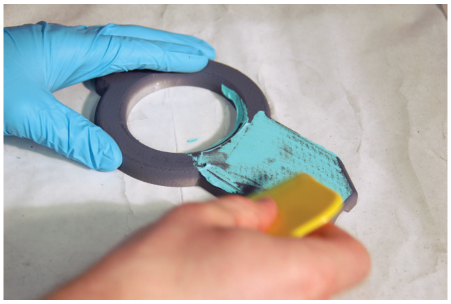

Figure 20: Spread filler evenly to fill depressions.

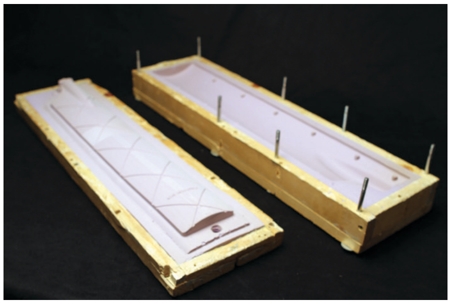

Figure 21: A silicone mold after the pattern has been extracted.

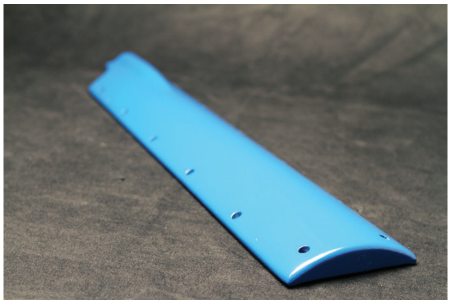

Figure 22: An FDM pattern (painted) can be used to create multiple molds.

Figure 23: A urethane casting before painting.

7. Key Process Considerations

Obstacle		Resolution				
		Lights-out operation	*Design optimization*	*Build optimization*	*Secondary processes*	*Pattern orientation*
Surface finish	Layers and toolpaths are visible in cast part and make pattern/part extraction difficult, possibly tearing the mold.		✔	✔	✔	✔
Build time	Throughput not competitive with machining.	✔	✔	✔		✔
Small features	Deep, narrow features are difficult to finish and may lead to mold tearing. Thin features may deflect or break when pouring mold or extracting pattern.		✔	✔	✔	✔

Table 1: Common obstacles and resolutions.

7.1. Resolution details:

- "Lights-out" operations:
  - Increase throughput and efficiency by managing job scheduling to leverage "lights-out," automated operations.
- Design optimization:
  - Design patterns to optimize the FDM process: include self-supporting angles, offset surfaces, variable density, material removal and wall thicknesses.
  - When designing patterns consider the build orientation and its effects on surface finish, feature resolution and pattern strength.

- Eliminate features that will:
  - Trap the pattern
  - Make pattern release difficult
  - Deflect when pouring the mold
  - Break when extracting the pattern

- Build optimization:
  - Use advanced Insight software tools for fill styles and custom groups (i.e., strength, material expense and build time).
  - Use recommended fill styles but opt for Sparse fill wherever suitable.
  - Select appropriate slice heights for feature size, surface finish and build time.
- Secondary processes:
  - Use vapor smoothing, solvent smoothing, sanding, filling (body fillers) or coating (epoxy) to smooth pattern surfaces to enhance mold release and casting quality.
  - Add machined inserts for small pattern features that may deflect or break.
  - Add machined inserts for small mold features that may tear.
- Part orientation:
  - Position the part to improve feature accuracy, surface finish and strength.

8. Tools And Supplies

8.1. Required items:

- Sandpaper: 120 – 1500 grit wet/dry
- Chemical finisher (solvent smoothing)
  - Micro-Mark® SAME stuff, MEK, acetone, IPS Weld-On® 4 or similar
- Degreaser: PPG® DX330 (or similar)
- Filler/putty:
  - Hysol® EA9394 Paste Epoxy
  - 3M™ Acryl-Green Spot Putty
  - 3M Acryl-Red Glazing Putty
- Primer:
  - PlastiKote® T235 (sandable) or standard (gray)
- Casting material:
  - Silicone rubber (typically Pt or Sn catalyzed)
  - Urethane
  - Wax
  - Epoxies
- Modeling clay
- Mold release (water-based)
- Miscellaneous tools:
  - Knives, mixing paddles, jars, etc.

8.2. Optional items:

- Finishing Touch® Smoothing Station (Figure 24)
- Vacuum chamber
- Pressure pot
- Buffing compounds
- Oven for thermal post-cure

8.3. Sources:

- All the materials needed are commonly available from:
- Automotive supply/painting supply retailers
- Hobby shops/hardware stores
- Mold supply houses

8.4. Software:

- Print Wizard
- CatalystEX™
- Insight (document developed with Insight 9.0)

Figure 24: Finishing Touch Smoothing Station.

9. Recap – Critical Success Factors

9.1. Follow best practices:

- Use good pattern and mold design practices.
- Use good silicone molding practices.
- Smooth pattern surfaces with:
  - Build orientation, slice selection and enhanced mode
  - Filling, sanding and polishing

9.2. Eliminate adoption obstacles:

- Reduce build time and material expense.
- Leverage automation.
- Optimize pattern design.
- Remove challenging features from pattern.

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