



Comparison of Sealing Methods for FDM Materials

There are many methods, and even more materials, for sealing FDM parts. To assist in selecting the best approach, Stratasys, Inc. conducted a study to evaluate five methods for sealing parts made from eight FDM materials.

The selection criteria include investment (cost and time), difficulty, part design, performance and material compatibility.

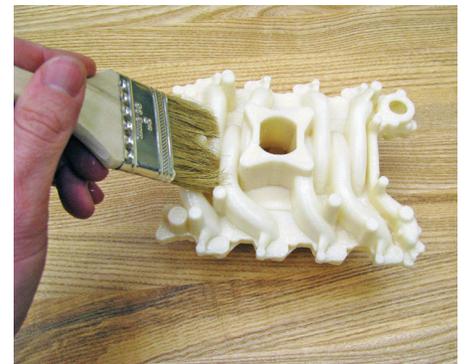


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COMPARISON OF SEALING METHODS FOR FDM MATERIALS

1. OVERVIEW

1.1. Selecting a sealing method.

A sealing method is selected for its compatibility with an FDM material and the application requirements. Additionally, operational considerations will influence selection.

1.2. Sealing method review includes:

1.2.1. Five sealing methods.

- Paint and filler
- Solvent
- Finishing Touch Smoothing Station
- Adhesive (epoxy)
 - Hysol E-20HP
- Adhesive (epoxy)
 - BJB TC-1614

1.2.2. Eight FDM materials.

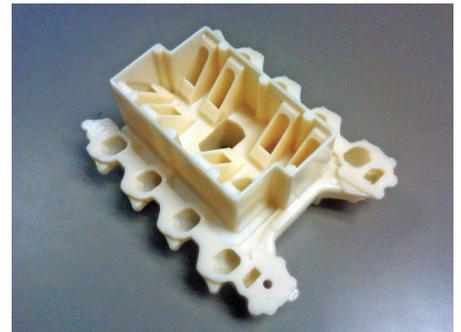
- | | |
|-------------------------|-------------------------------|
| • ABSi | • PC-ABS |
| • ABS-M30 | • PC-ISO |
| • ABS-M30i | • PPSF
(polyphenylsulfone) |
| • PC
(polycarbonate) | • ULTEM 9085 |

1.2.3. Eleven evaluation criteria:

- Cost: Expense of materials and consumables.
- Processing time: Time needed for application (part volume of 6 in³ (98 cm³)).
- Cure time: Time needed for part to fully cure.
- Additional equipment: Does process require equipment for application?
- Skill level: Difficulty or skill level required to have acceptable results.
- Geometry dependent: Is process dependent, in any way, on part geometry?
- Part size (maximum): Limitations in part size.
- Viscosity: Thickness of the sealant material when being applied.
- Accuracy retention: Degree to which accuracy of part remains unchanged.
- Maximum pressure: Highest pressure that the sealed surface can withstand.
- Chemical resistance: Is sealed surface resistant to common chemical agents?
- Temperature sensitivity: Is sealed part limited to exposure to low temperatures?



Manifold – sealing required for flow evaluation.



The features of the manifold are ideal for characterizing ease of application.

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1.3. Safety notes:

Follow manufacturer's safety recommendations when applying any sealing method. Also, wear personal protective equipment to avoid injury.

Pressure can be a hazard. The part may fail before the sealant, which at high pressure can cause a catastrophic failure similar to an explosion. Extreme caution should be used when pressurizing a part produced by an additive manufacturing method.

2. SELECTION MATRICES

2.1. Compatibility – method and material.

	<i>Painting & Filling</i>	<i>Solvent</i>	<i>Finishing Touch Smoothing Station</i>	<i>Hysol E-20HP Epoxy</i>	<i>BJB TC-1614 Epoxy</i>
ABSi	✓	✓	✓	✓	✓
ABS-M30	✓	✓	✓	✓	✓
ABS-M30i	✓	✓	✓	✓	✓
PC	✓	✗	✗	✓	✓
PC-ABS	✓	✓	✗	✓	✓
PC-ISO	✓	✗	✗	✓	✓
PPSF	✓	✗	✗	✓	✓
ULTEM 9085	✓	✗	✗	✓	✓

Table 1: Compatibility of FDM materials with sealing methods.

2.2. Relative comparison.

	<i>Paint & Filler</i>	<i>Solvent</i>	<i>Finishing Touch Smoothing Station</i>	<i>Hysol E-20 Epoxy</i>	<i>BJB TC-1614 Epoxy</i>
Cost	\$	\$	\$	\$\$	\$\$
Processing Time	2 hr	5 min	5 min	10 min	10 min
Cure Time	24 hr	18 hr	18 hr	24 hr	2 hr
Additional Equipment	No	No	Yes	No	Yes
Skill Level	Low	Moderate	Low	Moderate	Moderate
Geometry Dependent	No	No	Yes	Yes	No
Maximum Part Size (in./cm)	NA	NA	14 x 20 x 18 (35 x 51 x 46)	NA	NA
Viscosity	Low	Low	NA	Med.	Low
Accuracy Retention	Great	Good	Great	Poor	Good
Maximum Air Pressure	N/A	Atmospheric	Atmospheric	65 psi+	65 psi+
Chemically Resistant	No	No	No	Yes	Yes
Maximum Temperature (°F/°C)	Varies	176 (80)	176 (80)	212 (100)	347+ (175+)

Table 2: Selection criteria results for sealing methods.

3. Sealing Methods

3.1. Paint & Filler.

3.1.1. Description.

This simple and inexpensive surface treatment method seals parts without making them airtight or watertight. A combination of body filler and paint closes the surface by plugging pinholes and surface porosity.

3.1.2. Process.

Apply body filler, spot putty or glazing putty to all surfaces (Figure 3) and allow to dry. Sand part surfaces to desired finish. Then apply one or more coats of primer or paint to seal the part (Figure 4).

3.1.3. Characteristics.

Since this is a manual operation, both the accuracy of the part and the degree to which it is sealed are influenced by the skill and care of the bench technician. There are no advantages in temperature or chemical resistance and the result is not airtight. So, paint and filler are used for applications where surface infiltration is undesirable, such as thermoforming or RTV mold masters.

3.2. Solvent.

3.2.1. Description.

Solvents work by chemically melting the plastic on the surface of a part. The process is simple, fast and inexpensive.

This method is an alternative to the Finishing Touch Smoothing Station when parts exceed the system's chamber capacity or a system is unavailable.

Solvent options include MEK, Weld-On #3 and similar products.

3.2.2. Process.

There are two techniques:

- Dipping: Submerge the part in solvent for a short duration, usually less than 30 seconds (Figure 5).
- Brushing: Liberally apply solvent to the surfaces of the part with a brush.

After exposure to the solvent, drain the part and blow off any excess. Allow the part to rest for 18 or more hours—time varies with the solvent used and application method—before putting it into service.

3.2.3. Characteristics.

The solvent's melting action is quick and aggressive. Therefore, dimensional accuracy is difficult to control. Parts sealed with this method should be limited to low-temperature (below 176 ° F / 80° C), low-pressure (atmospheric) applications. Solvent sealing is suitable for all ABS-based FDM materials.



Figure 3: Apply body filler or spot putty to surfaces (MRI component shown).



Figure 4: Apply paint to seal surface.



Figure 5: Dip components (shown) in solvent, or apply it with a brush.

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3.3. Finishing Touch Smoothing Station.

3.3.1. Description.

The Finishing Touch Smoothing Station (Figure 6) seals a part's surfaces as it smooths. The process, which uses a vaporized smoothing agent, is quick and nearly labor-free. As a vapor, the smoothing agent accesses all externally accessible features.

3.3.2. Process.

Chill part in cooling chamber for 10 to 15 minutes. Transfer part to the smoothing chamber (Figure 7) and expose to the vapor of 20 to 30 seconds. Allow the part to dry and surfaces to harden to the touch. Repeat as necessary.

Allow the part to cure for 12 to 18 hours before putting it into service.

3.3.3. Characteristics.

This process has the best combination of ease-of-use and accuracy retention. With a few minutes of instruction, any operator can seal a part while preserving dimensional accuracy. For these reasons, it is often selected when electroplating parts or using them as patterns for investment casting. Another application is functional testing of liquid-holding geometries like bottles or cooling lines in molds.

This sealing method should be limited to low-pressure and low-temperature applications. Above atmospheric pressure, the sealed surface may develop pinhole leaks. At temperatures above 176 to 212° F (80 to 100° C), the sealed layer of thermoplastic will blister. Also, the vapor may not reach deep within internal passages, so a combination of methods may be needed (e.g., combine with solvents for passages).

The Finishing Touch Smoothing Station can be used only with ABS materials.

3.4. Hysol E-20 HP epoxy.

3.4.1. Description.

This medium-viscosity, two-part epoxy adhesive is promoted as an industrial-grade material. It has a short working time (approximately 20 minutes), which makes it a bit more challenging to use than other epoxies.

3.4.2. Process.

Like all two-part epoxies, thoroughly mix the two components. Then apply the epoxy with a brush (Figure 8) or putty knife. Optionally, a mixing dispenser may be used.

After application, allow the epoxy to cure for 24 hours before sanding to the desired finish level. Be careful not to sand through the layer of sealant.



Figure 6: Finishing Touch Smoothing Station seals the surfaces of ABS parts.

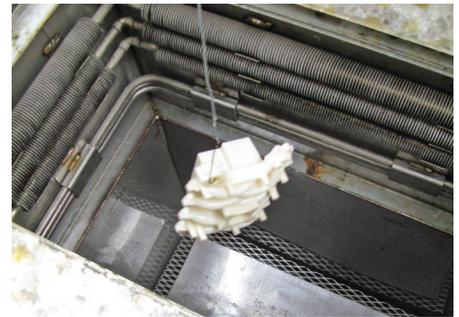


Figure 7: Place part in smoothing chamber for 20 to 30 seconds.



Figure 8: Apply epoxy adhesive and brush over surfaces.

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3.4.3. Characteristics.

The advantages of this method are that it does not require an investment in equipment and the end result is ideal for harsh operating environments. Hysol E-20HP can withstand temperatures that match or exceed those of the FDM materials, and it is resistant to many chemical agents. The tough, durable and strong coating will maintain an airtight seal up to a pressure of 65 psi (448 kPa).

This sealing method is a manual operation that can be a bit challenging when attempting to seal large or intricate parts. Since the epoxy is brushed on the surface of the part, inaccessible features, such as internal channels, cannot be sealed. Also, the thickness of the epoxy combined with the manual application will diminish dimensional accuracy.

3.5. BJB TC-1614 epoxy.

3.5.1. Description.

This material is a low-viscosity, two-part epoxy that penetrates porous materials. It is easy to apply since it has a working time of two hours (Figure 9).

3.5.2. Process.

Thoroughly mix the two components and condition the material and FDM part (Figure 10) at 120° F (49° C). Next, place the part and epoxy in a bag or container, ensuring that the part is fully immersed. Draw a vacuum to pull the epoxy into the part (Figure 11). Note that high vacuum pressures are not needed because of the material's low viscosity.

Drain the part and heat cure for 1.5 to 2.0 hours.

3.5.3. Characteristics.

TC-1614 offers good chemical and thermal resistance while remaining airtight up to at least 65 psi (448 kPa). The thinner viscosity and vacuum-assisted penetration helps to preserve dimensional accuracy and seal features that may otherwise be inaccessible. However, this is one of the more expensive options due to the need for an oven and vacuum chamber as well as the cost of materials when waste is included.

4. Recap - Critical Success Factors

4.1. Keys to selection:

- Sealing pressure.
- Material compatibility.
- Application criteria.
- Safety, time, tools and supplies.



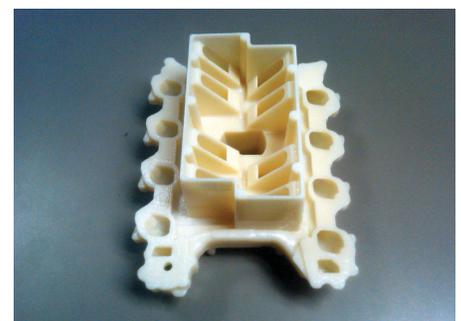
Figure 9: Manifold (right) immersed in two-part epoxy.



Figure 10: Condition part and epoxy in an oven.



Figure 11: Draw a light vacuum to pull epoxy into the part.



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CONTACT

For questions about the information contained in this document, contact Stratasys at www.stratasys.com/contact-us/contact-stratasys.

stratasys[®]

E info@stratasys.com / STRATASYS.COM

HEADQUARTERS

7665 Commerce Way, Eden Prairie, MN 55344
+1 888 480 3548 (US Toll Free)
+1 952 937 3000 (Intl)
+1 952 937 0070 (Fax)

2 Holtzman St., Science Park, PO Box 2496
Rehovot 76124, Israel
+972 74 745-4000
+972 74 745-5000 (Fax)

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