Bonding FDM TPU 92A
Product/Post Processing

Overview

Joining and repairing parts are routine operations for all manufacturing processes. Additive Manufacturing is no exception. When selecting a thermoplastic polyurethane (TPU) bonding method, the primary considerations are the strength and flexibility of joint created by the bonding process.

Common applications for bonding are:

- Joining sectioned parts
- Joining assemblies
- Repairing parts

This Best Practice describes how to bond FDM TPU 92A to FDM TPU 92A. In most cases, TPU does not share the same bonding processes as rigid thermoplastics or thermoset plastics. Bonding generic TPU material to itself and other polymers is difficult. Very few adhesive manufacturers offer a solution for TPU bonding.

TPU bonded joints need to be flexible, high strength and high elasticity. TPU is a low surface energy material with poor surface wetting. When applied to TPU, the adhesive forms a drop instead of spreading over the material surface. This minimizes the adhesive's contact with the surface. Low surface materials have lower attraction to other types of molecules.

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Bonding Method Selection (FDM TPU 92A Only)

The following table describes the bonding methods and their characteristics:

Table 1: FDM TPU 92A Bond Method Characteristics

Bonding Method	Option	Cost	Working Time* (Minutes)	Cure Time* (Hours)	Viscosity*	Bond Tensile Strength*	Bond Flexibility*
Adhesive	3M™ 4475 (Adhesive)	Low	20	24	Medium	High **	High **
	Loctite® Plastics Bonding System (Cyanoacrylate)	Low	0.5	12 - 24	Low	Low	Low
	Loctite® 406 or 495 (Cyanoacrylate)	Low	0.5	24	Low	High **	Low **
	Hysol® E-20HP (Epoxy)	Medium	20	24	Medium	High **	Low **
Solvent	Micro-Mark® SAME STUFF	Low	5	8	Low	Very low	Very low
Welding	Hot Air	Low	Long with heat	NA	Equals material	High	High

* See manufacture's data sheet for details.
** Surface must be prepared by sand blasting.

Bonding Method Descriptions

A) Adhesive: 3M 4475 Industrial Plastic Adhesive (Adhesive)

- Description
  - One-part adhesive
  - Does fill gaps: bond surfaces do not need a tight interface
  - Medium working time (~20 min)
- Characteristics
  - Creates a high tensile strength and high flexibility bond.

NOTE: 3M 4475 is the recommended adhesive for FDM TPU 92A bonding.

Figure 1: 3M 4475 Industrial Plastic Adhesive

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B) Adhesive: Loctite Plastic Bonding System (Cyanoacrylate)

- Description
  - Two-step process
  - Does not fill gaps: bond surfaces must have a tight interface.
  - Fast working time (~30 sec)
- Characteristics
  - Creates a low tensile strength and low flexibility bond.

NOTE: This is not a recommended bonding method, because of low bond strength

Figure 2: Cyanoacrylate adhesives

C) Adhesive: Loctite 406 or 495 (Cyanoacrylate)

- Description
  - One-part adhesive
  - Does not fill gaps: bond surfaces must have a tight interface.
  - Fast working time (~30 sec)
- Characteristics
  - Creates a high tensile strength but low flexibility bond.

Figure 3: Loctite 406/495 (Cyanoacrylate)

D) Adhesive: Hysol E-20HP (Epoxy)

- Description
  - Two-part adhesive
  - Does fill gaps: bond surfaces do not need a tight interface
  - Medium working time (~20 min)
  - Requires Application gun & mixing nozzle.
- Characteristics
  - Creates a high tensile strength but low flexibility bond.

Figure 5: Hysol E-20HP (Epoxy)

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E) Solvent: Micro-Mark SAME STUFF

- Description

– Solvent evaporates too fast to bond surfaces.

- Characteristics

– Creates a very weak tensile strength bond, even when the surfaces have been sandblasted.

NOTE: This is not recommended method, because of a very low bond strength. FDM TPU 92A begins to break down if it is left in MEK solvent for several minutes.

Figure 6: Micro-Mark SAME STUFF

F) Welding: Hot Air (gun)

- Description and Method

– Melts FDM TPU 92A with hot air.

– Use FDM TPU 92A filament as welding stick.

- Characteristics

– The welding bond has similar properties and characteristics as the FDM TPU 92A part, however, it is very hard to get a consistent weld bead.

– Any voids in the welding process will result in a decrease of the bond strength.

NOTE: This is not a recommended bonding method, as its success depends highly on the skill of the operator. In any case, before using this method, it is recommended that the operator spend a substantial amount of time mastering it to ensure the strength of the joint. Pushing and pulling the welding stick will be difficult, due to its flexibility. In addition, the pool of heated TPU will stick to the welding stick.

TIP: This process can be used for filling large gaps or seams.


Figure 7: Hot air gun—Leister®, Hot-Jet S


Figure 8: Welding with hot air

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Optimizing Bond Strength

The strength of the bond varies depending on the bonding method, wall thickness, and geometry type. For maximum bond strength, allow the recommended cure time to elapse before applying force to the bonded area. The edge of the bonded area has the highest stress when force is applied to it. Bond strength can be maximized by extending the adhesive beyond the bond area and by selecting the appropriate joint type.

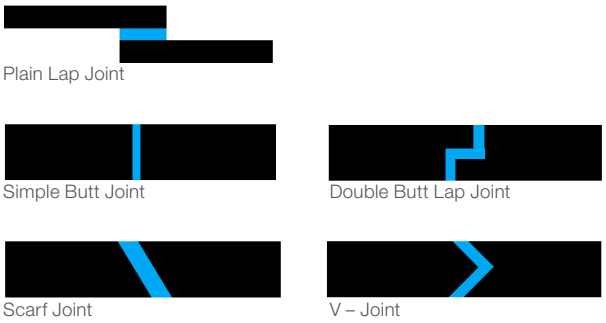

Figure 9: Joint method samples

TIP: Unless you design a gap between surfaces at the bond area, that area of the part will be larger after applying the adhesive.

The joint strength can also be increased by designing the part to have a more complex joint method. For example, a dove or lap joint works better than a butt joint when shear forces are present. Combining joint types is another solution for achieving improved bond strength.

Safety Note

Before using the adhesive, make sure that you:

- Read the manufacture's Safety Data Sheets (SDS) for the adhesive and follow manufacture's safety recommendation when applying the adhesive.
- Observe manufacturer's recommendations for safety, material handling, and storage.

Recommended Bonding Process

Adhesive: 3M 4475 Industrial Plastic Adhesive

The following instructions describes the process for bonding pieces with 3M 4475 Industrial Plastic Adhesive.

1. Prepare a work area for the bonding process.

   It is recommended to use a work surface that can be removed and discarded (for example, parchment paper), or a surface that adhesives do not stick to and can be wiped off (for example, a silicone baking sheet).

Figure 10: Sample work area and equipment

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2. Sandblast the bonding area.

   The key to creating a strong joint when bonding FDM TPU 92A is changing the surface energy of the bonding area. Sandblasting with an aggressive media changes the FDM TPU 92A surface energy. Sandblast the entire bonding area of both surfaces, as well as the surfaces beyond the bonding areas. Try to sandblast at least 0.1 inches beyond the bond area. The edge of the bonded area has the highest stress when force is applied to the joint.

   If your bond area is restricted and you cannot apply adhesive outside the bond area; you may not get the highest strength joint.

   TIP: To check the FDM TPU 92A for a surface energy change; place a drop of water on the sandblasted area. Then place a drop of water on an area of the TPU part that has not been sandblasted. On the sandblasted FDM TPU 92A, the drop of water spreads and stretches, indicating that the surface energy changed from low to high, as shown in Figure 11.

Figure 11: Surface energy before (left) and after sandblasting (right)

   NOTE: Sandblasting is the preferred method. During testing, manual sanding did not have consistent results. If a sandblaster is unavailable, the FDM TPU 92A part can be prepared for bonding with a clean sheet of 80 grit sandpaper. When performing manual sanding, you need to sand beyond the bonding area on both surfaces. During this process, make sure that the edges of the bonding areas are also sanded and change the direction of the sanding motion several times. In addition, take time to do this thoroughly and to ensure that the entire area is sanded, including any complex surfaces.

3. Clean the bonding area.

   Put isopropyl alcohol on a clean cloth and wipe the bonding area. Wait 5 minutes to allow the alcohol to evaporate. This removes most contaminates from the bonding areas.

4. Apply adhesive to all bonding areas.

   The best practice is to extend the adhesive beyond the bonding areas. The edge of the bond area has the highest stress when force is applied to it. Extending the adhesive beyond the bond area results in the highest bond strength. The adhesive should have a consistent thickness on the bonding area without starving the surface. Adhesive that is applied too thin or too thick reduces the bond strength.

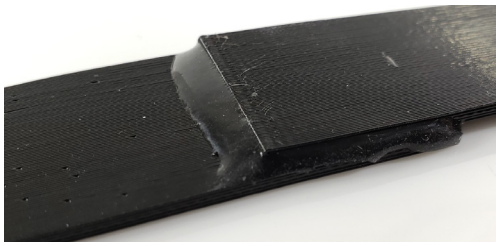

Figure 12: Consistent adhesive thickness on the bonding area

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5. Hold or clamp the pieces. If the bond area is hard to clamp or small, the operator may want to place a piece of parchment paper between the clamps and part. In some cases, the bond area maybe hard to hold in position while trying to clamp, the operator may want to use some tape to hold the parts in position while clamping.

   NOTE: Consult the manufacturer's instructions for cure time.

6. Observe the bonding area. Look for gaps or extra adhesive.

   If there is extra adhesive in the bonding area, wipe it off with an application stick or a flexible tool.

7. After the adhesive is fully cured remove the clamps.

Figure 13: Clamping the pieces while the adhesive sets

Figure 14: Bonded area after the adhesive is fully cured

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Reference - Tools, Equipment and Materials

Adhesives:

- 3M 4475 Industrial Plastic Adhesive (Adhesive)
- Loctite Plastics Bonding System (Cyanoacrylate)
- Loctite 406 (Cyanoacrylate)
- Loctite 495 (Cyanoacrylate)
- Hysol E-20HP (Epoxy)

Solvents:

- Micro-Mark SAME STUFF (Methylene Chloride)

Tools, Equipment and Materials:

- Sand Blaster and Media—

  Our tests were performed using a Media Blast & Abrasive Inc., Model N-200 Standup Cabinet with the air pressure set to 70 PSI. The media used was US Technology Corp. Polymedia Type III, Lot PB-1264, Size 20/30.
- Sandpaper, 80 grit
- Clamps, Home Depot, 3in Steel Spring Clamp with Pivot tip #99539
- Isopropyl Alcohol
- Application sticks (Popsicle sticks) or flexible stick
- Work area protection; parchment paper or silicone mat
- Paper towels or rags
- Hot air (gun) - Leister®, Type Hot-Jet S, (Set at black knob 3, red knob 6)
- Hot air tip - Leister 107.148 oval
- Applicator - 3M™ Scotch-Weld™ EPX™ manual applicator (DMA 50 or equivalent)
- Nozzle - Loctite Static Mixer, 50ml, 98623

Figure 15: Hot air gun and tip

Figure 16: Applicator and nozzle

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