APPLICATION BRIEF

Bonding FDM Parts

Overview

For parts too large to fit on a single build, for faster job builds with less support material, or for parts with finer features, sectioning and bonding Fused Deposition Modeling (FDM) parts is a great solution. There are many methods, and even more materials, for bonding FDM parts. The primary considerations when selecting a bonding method are the strength of the bonded joint and the compatibility with each FDM material. For strength data, Stratasys conducted lab testing at the University of Texas El Paso to measure tensile strength. Other criteria – including time, cost, operation difficulty, part configuration and general performance – were also considered. Accuracy of bonded parts, however, is dependent on many factors. For example, adhesive characteristics, such as viscosity, will influence accuracy. The skill of the technician, style of joint and type of fixture will have even greater impact.

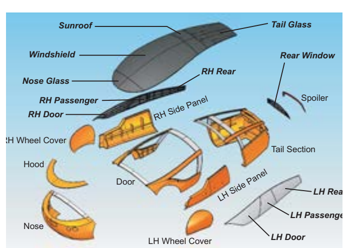
Application Outline

To assist in selecting the bonding approach most suitable for your needs, the following is a brief evaluation of the common methods for joining parts made in varying FDM materials.

Adhesive (Epoxy): Two-part epoxies are commonly used to bond FDM parts. The epoxy components are mixed and then applied with dispensers, brushes or infiltration. The viscosity will range from thin and caulk-like to thick and putty-like, so application techniques will vary. After application, bonded sections are fixtured or clamped while the epoxy cures. Epoxies will differ in cure durations, material properties and bond strengths. But in general, they are easy to use, and they offer very good mechanical strength, and typically exhibit good temperature resistance and chemical resistance. These adhesives offer the advantage of working times of 20 to 70 minutes, so minor adjustments can be made after mating the sections. However, the trade off is long curing times. When cured at room temperature, parts cannot be handled for many hours, and curing cycles will last from one to five days. If heat-cured, the cycle can be significantly accelerated.

FDM parts will achieve required strength with a bonded joint.

One benefit of bonding FDM parts is the ability to section fine features and build them with a finer slice setting, allowing for a more accurate part.



Nine body panels were built with Fortus 3D Production Systems.

BENEFITS OF FDM

- Extend FDM advantages to oversized parts
- Split part and build separately to:
- The part will achieve the required strength with a bonded joint:
  - Combine fine resolution, smooth surfaces and strength
  - Decrease build time
  - Decrease material us

FDM IS A BEST FIT

- Parts are too large for an FDM system
- Equipment and resources are available
- Bulky parts have small, fine features

Adhesive (Cyanoacrylate): Cyanoacrylate is commonly known as super glue. It is a fast-curing adhesive that can be used for quick, easy repairs and light-duty bonding applications. Super glue is simply applied to mating surfaces, and the sections are joined. The adhesive sets in a few minutes. The tensile strength of super-glued FDM parts is higher than that of epoxy adhesives. However, its resistance to high temperatures, chemicals and solvents is poor. Therefore, bonding with super glue may diminish the performance of an FDM parts. So, it is recommended for concept models and form/fit prototypes rather than functional prototypes or manufactured parts.

Jim Kor with the Urbee prototype and FDM full-scale, functional body panels bonded.

Solvent: Solvent bonding works by chemically melting the plastic on the surfaces to be joined. The solvent can be brushed onto sections that are then mated and clamped together, or it can be injected into a pre-mated joint or existing crack. The water-thin solvent wicks into the part surface, which improves the strength of the repair or bond. Several solvents can be used, but the recommended product is SAME STUFF from Micro-Mark. This method produces bonds that are stronger that those of many adhesives. Like super glue, the process is simple, and the bond sets in seconds. Another similarity is that it can be applied to hard-to-reach areas since the solvent will wick into a seam or fracture. An advantage over super glue and epoxy is that after evaporation the bonded part will contain only FDM material. Although the bond sets in seconds, parts should be allowed to cure for at least eight hours. Also note that if the part is subjected to temperatures exceeding 176 °F (80 °C), surface blistering may occur. Solvent welding is not suitable for bonding PPSF or ULTEM 9085. These FDM materials are chemically resistant, so there is little reaction to solvents.

Hot Air Plastic Welding: Hot air welding of plastic is similar to oxy-acetylene welding of metal. However, a jet of hot air replaces the jetted flame, and a filament of FDM material replaces the filler rod. To bond parts, a hot air welding tool is slowly drawn along the joint. The heat melts the filament, which then fills the seam. This method produces bonds that are stronger than those of all other methods. It is also fast and inexpensive. Parts can be put into service as soon as they are cool to the touch. Since the bonding material is a small piece of FDM plastic, the cost is negligible. Another advantage of using the FDM material as the bonding medium is that there is material continuity. The bond has the same properties and characteristics as the part. For best results, hot air welding should not be used on thin-walled sections. Also, the process requires some skill, so the results will be dependent on the experience and technique of the technician.

Ultrasonic Spot Welding: This technique is widely used in production processes when creating a permanent bond between plastic parts. The ultrasonic spot welding tool uses sound waves to melt localized areas of the joint. With the availability of handheld ultrasonic welders, this method can also be used in low-volume prototyping or direct digital manufacturing applications. Compared to other bonding methods, there are few, if any, disadvantages to ultrasonic welding beyond the need to purchase the welding tool. Welded areas are stronger than the surrounding material, yet, the tensile strength is not as great as that of hot air welded or unbounded parts. The ultrasonic welder's horn and horn tips are often interchangeable. A variety of horns and welding tips are available, which will determine the thickness of material that can be welded, the diameter of weld, as well as the type of weld created.

Since no material is introduced into the joint, there is little change to the accuracy of the part or its properties. This makes ultrasonic welding ideal for medical applications that must consider the quality of the part as well as its suitability of human tissue contact. When higher strength is needed, ultrasonic welding may be used in combination with other methods. Tack weld individual pieces to fix their position and then apply adhesives, solvents or other bonding agents. This approach is especially useful for bulky or awkward assemblies. Ultrasonic welding is fast and very inexpensive. Once the welding operation is complete, the part can be immediately put into service. And since there are no consumables required, the only expense is that for direct labor.

Fasteners (Mechanical): Although this approach is a joining method, not bonding, it can be an effective alternative. There are a large number of mechanical fastening approaches and hardware options that can be used when joining FDM parts. One unique approach to mechanically join sections is to insert fastening hardware in the FDM part during its build process. When it emerges from the Fortus machine, the fasteners are integrated within the part.

Customer Story

"We should want to own and drive a clean, energy-efficient car," said Jim Kor, president and senior designer for the Winnipeg-based engineering group of KOR EcoLogic. His passion for the environment led him to design the principles of sustainability into a new car code-named Urbee, created with the production capabilities of Stratasys. The two-passenger Urbee, which stands for urban electric with ethanol as backup, was designed to use as little energy possible. It is capable of reaching more than 200 mpg on the highway and 100 mpg in the city. And now, it is the first prototype car ever to have its entire body printed with an additive process.

When evaluating options, Kor discovered that building the prototype body panels using fiber-reinforced polymer (FRP) or fiberglass would involve building a 1:1 scale plug for each of the body panels – first creating a strong framework of wood or MDF and covering it with dense foam that could be hand-carved into shape. Alternatively, the plug could be carved using a CNC milling machine to produce a more precise surface. "A fiberglass body would have taken a long time," said Kor. "And we would have had to deal with draft, or the ability of the part to come out of the mold."

After one of KOR's industrial designers recommended Stratasys to Jim Kor, it seemed the team had found its solution. Conversations with Stratasys representatives led Kor to believe that all exterior components could be created and bonded together using Dimension 3D Printers and Fortus 3D Production Systems at RedEye on Demand (in-house rapid prototyping and direct digital manufacturing services at Stratasys).

Kor and his colleagues transformed the scanned computer model of the car into nine logical body panels, first creating a 1/6th scale model to verify the exact fit of all the individual parts. This gave the team the confidence that the large panels would be trouble-free. Together with Stratasys, the team selected ABS as the material of choice and began to build the car. Several major body panels were built at Kor within weeks of receiving the go-ahead. The full-scale door and side panels were completed first. "These were big panels," said Kor. "The parts fit together perfectly." The remaining body panels were built and bonded by Stratasys.

"Stratasys can build a fender and place the plastic exactly where it is needed," he said. "That is just so powerful, it's unbelievable. It is good for the environment, it reduces cost, and it doesn't sacrifice safety. We simply don't need to put material where we don't need it. FDM technology made it easy and efficient to make design changes in the Urbee along the way," said Kor. "It also helped us meet our environmental goals by eliminating tooling, machining and handwork. If you can get to a pilot run without any tooling, you have advantages." Kor marveled at the speed of FDM production technology. "To have body parts that take days or weeks to make is pretty fast," he said. "Other methods are months away."

Jim Kor on bonding FDM for the Urbee: "A full-scale car skin was produced from ABS plastic for functional testing of the Urbee model. Some of the parts were too large to build as a single piece, so they were sectioned into pieces to be built on the Fortus 900mc. After the parts were built, the sectioned components need to be bonded together. We used the hot air welding method. The sectioned parts were fixtured into place using dovetail sectioned joints, clamps and vise grips. Then the sections were tack welded into place. Next, all outer joints and internal ribbing were bonded using the same hot air welding method. The inner non-structural ribbing was bonded using a solvent bond – ProWeld. To finish the outer surface for aesthetics and functional testing, the welds were sanded smooth."

How does Stratasys compare to traditional prototyping methods for KOR EcoLogic?

METHOD	COST	PRODUCTION TIME
Fiber Glass Overlay	$99,800	85 days
FDM Prototyping + Bonding	$75,300	36 days
Savings	$24,500 (25%)	49 days (57%)

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