THERMOPLASTICS: THE BEST CHOICE FOR 3D PRINTING

Why ABS is a Good Choice for 3D Printing and When to use Another Thermoplastic

By Fred Fischer, Stratasys, Inc.

The majority of today’s consumer products -- and many commercial ones -- are composed of thermoplastics. When designing a new product, engineers can best predict its end performance by prototyping with a material as similar to it as possible. That’s why 3D printing with thermoplastics is so widely practiced. Using Fused Deposition Modeling (FDM®) machines, engineers have the option of making parts with the most commonly used thermoplastics, such as ABS, polycarbonate, a variety of blends, as well as engineered thermoplastics for aerospace, medical, automotive and other specialty applications. When using 3D printing for the production of finished goods, using a thermoplastic is all the more important, and it may be the only choice for many applications.
Materials characterize manufacturing processes. In turn, manufacturing processes influence the material properties of the final product. Additive manufacturing is no different. The technologies are identified by the materials they use, and the quality of the output is controlled by the processing methods. In the case of FDM the materials are industrial grade thermoplastics.

Additive manufacturing uses a layer-based process to convert computer models into plastic parts. Direct from computer-aided design (CAD) files, automated machines add layer-after-layer of material, which makes very complex parts easy to produce. The FDM process creates functional parts by extruding and depositing the materials.

Using the same types of raw materials found in injection molding facilities around the globe, FDM makes plastic parts with properties suited for applications from concept modeling through product development and manufacturing. As with molded parts, there are a variety of material options; each with unique characteristics designed to meet the application needs.

SELECTING A THERMOPLASTIC

For production of finished goods, there are no shortcuts. Material stability and long-term performance is paramount. So, you will carefully consider the mechanical, thermal, electrical and chemical properties and any changes that result from aging or environmental exposure. However, because parts created with an FDM machine share many of the characteristics of the molded thermoplastics, you can leverage what you already know.

For all other applications, including functional prototypes, patterns, tooling and manufacturing aids, the selection process is much simpler. The key is having an understanding of the characteristics that make each FDM material unique. What you will consider are the following qualities:

- Material characteristics
- FDM machine availability
- Support material type
- Color

To pick the best material, seek the best combination of these material traits while placing priorities where they belong. As you review the material options, you may find the choice is simple because of a critical performance standard (e.g. chemical inertness) or personal preference (e.g. no-touch post processing).

All FDM materials have a lot in common. Each material is similar in terms of loading and building parts, office compatibility, and is safe enough to handle with no protective gear. Also, parts produced by each material are dimensionally stable and durable enough for demanding applications.

FDM MATERIALS

Since its early days, FDM Technology™ has been identified by industrial thermoplastics, and the process was originally known for ABS (acrylonitrile butadiene styrene). But materials for FDM have advanced and evolved. Today, there are four versions of ABS, each tougher than the original formulation. And the FDM material family has expanded to include nine options, including two engineered thermoplastics.

ABS

ABS, one of most commonly used thermoplastics, has been the foundation for FDM for many years. Measured by annual consumption, it is the most widely used material in FDM machines. It is so widely used that it can be labeled “general-purpose,” which is accurate but misleading. The ABS materials are an excellent choice for models, prototypes, patterns, tools and end-use parts. Forty to seventy percent stronger than the FDM materials of just a few years ago, today’s thermoplastics for FDM machines offer greater tensile, impact, and flexural strength.

ABSplus or ABS-M30 is available on every new FDM-based machine. The Dimension 3D printers build with ABSplus while the Fortus 3D production systems manufacture with ABS-M30. In
raw filament form, these are identical materials with equal mechanical properties. However, as you review the data sheets for ABSplus and ABS-M30, you may be surprised to see a difference in finished part material properties. As with molded parts, processing makes a difference. Developed for manufacturing applications, the Fortus 3D production systems have advanced hardware and software controls that process the materials differently. By doing so, the material characteristics achievable from ABS-M30 are improved. While ABSplus produces tough parts, ABS-M30 is generally stronger in all categories.

Both materials will produce parts that are stable, strong, and durable. Both come in a range of colors that include white, black, red, blue, green, fluorescent yellow and more.

Another common quality that makes these two materials the workhorses of FDM is that they are easy to finish. As with most additive manufacturing processes, FDM machines use a sacrificial support structure to build the part, but the ABS materials have something few others do: no-touch support removal. A soluble support material eliminates manual labor. Parts are placed in a tank and the supports are dissolved away.

The surface finish of ABSplus and ABS-M30 parts is more than adequate for concept modeling, functional prototyping, and creating manufacturing tools. If the application is for master patterns, marketing models, or finished goods, and the user wants a surface finish similar to that of injection molding, FDM has an optional hands-free smoothing process in the form of the Finishing Touch Smoothing Station that can smooth parts in under a minute.

Good material properties and simple post processing are the reasons that ABSplus and ABS-M30 are the most-used FDM materials. But two materials can’t meet the demands of every operation and every application. For more demanding or specialty applications, there are seven additional material options. These materials are compatible only with Stratasys’ Fortus 3D Production System line.

**ABS-M30i**

Medical, pharmaceutical and food handling equipment have stringent regulations to protect consumers from illness and disease. Regulations include standards such as ISO 10993 and USP Class VI, which classify a material as biocompatible. ABS-M30i meets these criteria so it can be used for products that come in contact with skin, food and medications.

ABS-M30i blends strength with sterilization capability – another criterion for products that come in contact with our bodies and the things we ingest. ABS-M30i can be sterilized using either gamma radiation or ethylene oxide (Eta) sterilization methods.

**ABSi**

ABSi’s advantage is translucency. Although it has good mechanical properties, it excels in lighting applications. It is widely used for functional evaluation of lenses for items such as automotive lighting. The popularity of ABSi for lens application is apparent through its color options: red, amber and natural.

It is also useful for monitoring material flow in applications that process or transfer material in powder or bulk solid form.

**PC**

Stratasys is serious about production applications, so it doesn’t ignore the most widely used industrial thermoplastic, polycarbonate (PC). PC is available on all Fortus 3D production systems, and when parts come off these machines, they are accurate, stable, and very durable.
PC has excellent mechanical properties and heat resistance. It has the second highest tensile strength of all FDM materials and a high heat deflection temperature of 280 °F (138 °C). This is a serious material for tough applications—functional testing, tooling or production.

**PC-ABS**  
*(polycarbonate and ABS blend)*

There’s a good reason for the blend of polycarbonate and ABS. It gives the most desirable properties of both PC and ABS materials. It has the superior mechanical properties and heat resistance of PC, including one of the highest impact strength ratings of all the FDM materials. Meanwhile, it has good flexural strength, feature definition, and surface appeal of ABS.

Like all versions of ABS for FDM, PC-ABS offers the no-touch finishing option with soluble supports.

**PC-ISO**

Like ABS-M30i, PC-ISO is a biocompatible (ISO 10993 and USP Class VI) material, which makes it the other FDM alternative for medical, pharmaceutical and food packaging industries. Another trait shared between them is that it is sterilizable using gamma radiation or ethylene oxide (EtO) methods.

Characteristics that distinguish PC-ISO are its higher tensile and flexural strength, and its higher heat deflection temperature. In these categories, its values are 33% to 59% higher than those of ABS-M30i.

**ULTEM® 9085**  
*(polyetherimide (PEI) resin)*

This thermoplastic is a product of SABIC Innovative Plastics, and it is found in many aircraft and aerospace products because it meets stringent safety requirements. ULTEM 9085 is FST rated, which means it satisfies flame, smoke and toxicity standards. When processed in a Fortus system, ULTEM's FST characteristics are unchanged. So, transportation companies that must adhere to rigorous demands often use ULTEM 9085.

If your application doesn’t demand FST rating, don’t overlook this FDM material. You will still want to consider ULTEM 9085 for its strength, durability, and resistance to heat and chemicals. It is a tough material that can take a beating. Of the nine FDM materials, ULTEM 9085 has the highest tensile and flexural strength. In terms of sales, it is the fastest growing material for FDM.

**PPSF / PPSU**  
*(polyphenylsulfone)*

The first engineering thermoplastic available for FDM was PPSF (also called PPSU). This super material was added for under-the-hood and other advanced applications, where other plastics can succumb to heat and chemical attack. PPSF has the highest heat resistance (372 °F/189 °C heat deflection temperature) and chemical resistance of all FDM materials. It is mechanically superior to other FDM materials, except ULTEM® 9085. PPSF is resistant to oils, gasoline, chemicals, and acids.

Like ABSi and ABS-M30i, PPSF is sterilizable. But because of its temperature and chemical resistance, you can use other sterilization methods, such as steam autoclave, plasma, chemical, and radiation sterilization.
CONCLUSION

The nine FDM materials share many characteristics that make them well-suited for in-office modeling as well as low-volume manufacturing. Yet, each has unique properties that distinguish them from one another. Their unique properties include transparency, biocompatibility, FST certification, chemical resistance, thermal resistance and strength, and it is these that make a material selection a fairly simple task.

In manufacturing, materials define the process. In additive manufacturing, FDM is recognized as the process that offers a selection of properties from range of thermoplastic materials.

Stratasys takes seriously market feedback about which materials are important to users, and it is always exploring options for future material releases. It will continue to research and develop new thermoplastic material formulations for use in its FDM machines.

<table>
<thead>
<tr>
<th>Fortus Material</th>
<th>Key Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSi</td>
<td>Translucent</td>
</tr>
<tr>
<td>ABS-M30</td>
<td>Versatile, tough</td>
</tr>
<tr>
<td>ABS-M30i</td>
<td>Biocompatible</td>
</tr>
<tr>
<td>PC</td>
<td>Strong (tension)</td>
</tr>
<tr>
<td>PC-ABS</td>
<td>Strong (impact)</td>
</tr>
<tr>
<td>PC-ISO</td>
<td>Biocompatible</td>
</tr>
<tr>
<td>ULTEM 9085</td>
<td>Mechanically well-rounded. FST certification</td>
</tr>
<tr>
<td>PPSF</td>
<td>Resistant (thermal/chemical)</td>
</tr>
</tbody>
</table>