Almost any fused filament fabrication printer can build metal parts

Filament is designed to work with low- to high-end equipment

Coils of Filamet on the shelves behind Brad Woods, owner and material developer, and Tricia Suess, president, of The Virtual Foundry, are ready for shipping.

By Sue Roberts

Let's make 3D printing important. That was the reaction to 3D printing that ended up immersing Brad Woods in the development of metal filament for use in existing fused filament fabrication (FFF) printers.

"A friend literally bought me a printer and said I had to try it. I figured out how to print a part and decided that to be important in many applications we needed to print with materials in addition to plastics," Woods said. "That's what set me off on the quest to find a way to print metal without using heat and working with hardware that was readily available. Achieving that goal became a hobby. Now it is my hobby and my job."

Many hats came along with adding the "job" part to his quest. Woods, a self-taught computer scientist, became the founder, principal, and key materials developer of The Virtual Foundry (TVF), a company that started in his basement in 2015. About three years ago TVF took over a 4,500-square-foot storefront in downtown Stoughton, Wis., shifting storage space into production space. And, it is ready to expand production—again.

Metal Filamet like the stainless steel 316L can be used with any FFF/FDM 3D printer.

Woods is passionate about creating printable materials highly loaded with nonplastic elements, particularly metal, that function like plastic during the printing process. His experimentation has led to printable materials and the development of the proprietary equipment that produces the filaments and pellets.

A Little More Metal

"Basically, I look at how much metal we can get into the plastic and still have the printers handle it. Since I started the company, I've continually moved the bar up, adding a percentage of metal at a time, identifying that maximum, and then pushing it a little further," said Woods.

TVF products include an ever-expanding line of Filamet™, metal filaments that work with virtually any low- to high-end printer, and Filamet

Copper Filamet pellets are used in large-format printers that employ a cone-shaped hopper to funnel the material to the printing bed.

pellets for large-format printers. Both printing media comprise metal powders encased in bioplastics, PLA (polylactic acid)-compliant binders. In stock, ready-to-ship materials include stainless steel 316L, copper, bronze, and iron. More than 30 other alloys — along with some materials that deviate from metal, such as sand, glass, and ceramics—are available by special order.

Then there are custom requests that comprise about 25 percent of the business. Woods creates filaments from almost any metal that can be sintered. A recent example is a high-carbon ferro-magnetic iron filament, used to build parts often used in electronics and motors. The material itself isn't magnetic but it is attracted to a magnetic field. Woods said, "This is a material I wouldn't have thought of working with myself, but a customer asked for it. Some of our business is steered by requests."

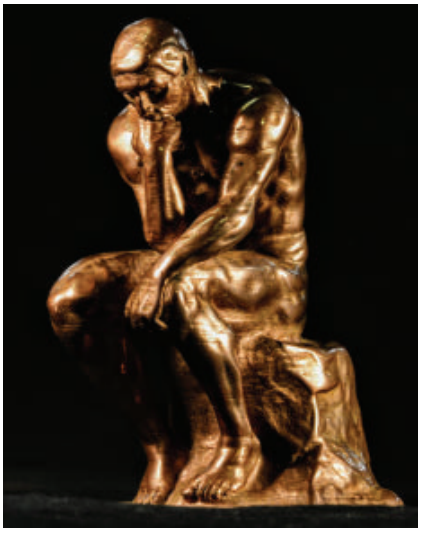
Tricia Suess, TVF president, said, "Creating filaments from different materials is a continual process. An experiment with bismuth is coming soon. Filaments incorporating tool steels are another popular request. We haven't gotten to them yet, but some titanium is on order for us to work with so it might be the next new material for the printers."

Although still considered under development with ongoing research conducted at TVF, educational institutions, and by customers, the metal filaments have achieved worldwide distribution.

Sinter to Densify Metal

Sintering is a part of the overall process. It burns off the encasing plastic to leave a printed piece that is about 99.9 percent metal that, Woods said, behaves like its origin metal and has mechanical properties very similar to those made through a metal injection molding process.

Before sintering, filaments and pellets are typically about 90 percent metal and 10 percent plastic.



Unsintered filament like the stainless steel used for "Colossus" and copper for the "Thinking Man" can achieve a near mirror finish.

During sintering, a part built from Filamet will shrink about 7 percent with minimal distortion, Woods said. By controlling the sintering process, he added, the density of the part can be somewhat controlled. "A person who wants to intentionally densify a part can sinter it longer to help get the output they are looking for. It will continue to shrink."

In some cases, sintering is bypassed and a part is polished or finished in its green state. Jewelry, art objects, and props for the movie industry's special effects companies are some of the items often polished to a near mirror finish and completed without sintering.

Parts requiring tight specifications are printed to the near net shape, sintered, and fine-machined to reach final tolerances. "You can get quite close to achieving specs with most printers," Suess said, "but you get much closer if you use a high-end machine. To really satisfy tight tolerances there will be some extra work."

Some FFF and SLS Differences

There are differences between an FFF-printed component and one printed using selective laser sintering (SLS), Suess said. A binder jet part, she added, will be very similar to an FFF-printed part because the processes are similar.

"Sintering is part of an SLS printing process so a part doesn't need to go through a second process to achieve density, but the process has some limitations that ours won't. For example, an SLS part can't have an enclosed, hollow interior. An FFF part built using our filament can," Suess said.

"When it comes to material usage, there is less waste with the FFF process. You don't have any powder spatter with our filament because the powder is encased in plastic. We also don't use any chemicals so there are really no safety issues."

Multiple-material components can be printed by quickly changing from one spool of material to another. More than one metal also can be included in special-order filaments, but it can be tricky if the part is going to be sintered, Suess said, because different materials sinter at different temperatures.

Although metal behavior during sintering isn't the main focus of the company, TVF performs continual sintering trials to help its customers with their applications and provide the most current sintering information possible. The company also acts as an information hub, collecting and disseminating tips that are shared by the hobbyists, manufacturers, educational institutions, and

organizations like NASA currently on their customer list.

"We are pretty open to sharing with people. We don't expect them to take our materials home and have perfect parts every time so we want to help. In some areas our customers are starting to outpace us," Woods said. "It happened when we decided to release aluminum before perfecting the sintering process in-house. Our customers were willing to pick up the project and run with it. We're all still learning."

Ongoing Research

Research is ongoing with established materials, filaments still in development, and the printing and sintering processes themselves.

Educational institutions in Wisconsin and across the globe are currently working with Filamet as part of their additive manufacturing curricula. Findings from their labs contribute to the materials' databases.

"Colleges, universities, and tech schools all want to have some type of additive manufacturing program, but very few of them can afford to purchase a powder bed fusion printer. Using a less expensive printer along with metal filaments does the job for their training needs," Woods said.

"There has been a little flurry of research papers coming out of universities that deal exclusively with our filaments. This all helps us discover the best way to work with the materials."

A group of graduate students at the University of Wisconsin-Madison, one of the University's Capstone Teams, is working with TVF. The group's focus is on the sintering process. Woods said they take a part, sinter it, then use a scanning micron microscope to analyze the resulting material. Some mechanical testing also is part of the project.

3D printing large components is another area of cooperative research.

"We have a customer that works with companies like oil refineries and needs large parts. They are taking our concept, using pellets, and experimenting to see how large a part they can print," Woods said.

"We had a large, meter cubed, custom furnace built for them. Once the process is situated to build parts that fill that space, the company wants to go many times larger. Using this strategy, the cost of 3D-printing large metal parts can be pretty reasonable."

Quintuple Growth

Looking ahead, Woods said he doesn't know where the company will be in five years because technology, materials science, and customer requests are changing quickly, and TVF will adapt to meet the new needs. He said that five years ago he had no idea that TVF would be where it is today with product array, distribution across all seven continents, and positioned to grow again.

"Our customers continue to come up with interesting applications and requests so our path has largely been determined by what it takes to help them solve their problems." At the moment, Woods added, his life work includes planning how to scale the company's growth. In the next six months he expects to increase monthly production by at least five times.

Suess said, "The 3D printing technology is in a place where people have accepted and embraced it. Now they are researching and proving out the metal filament technology. Once they've discovered how to fit it into their work processes, they will shift into the category of customers with standing orders. We are poised for that growth. It is an exciting space to be in."

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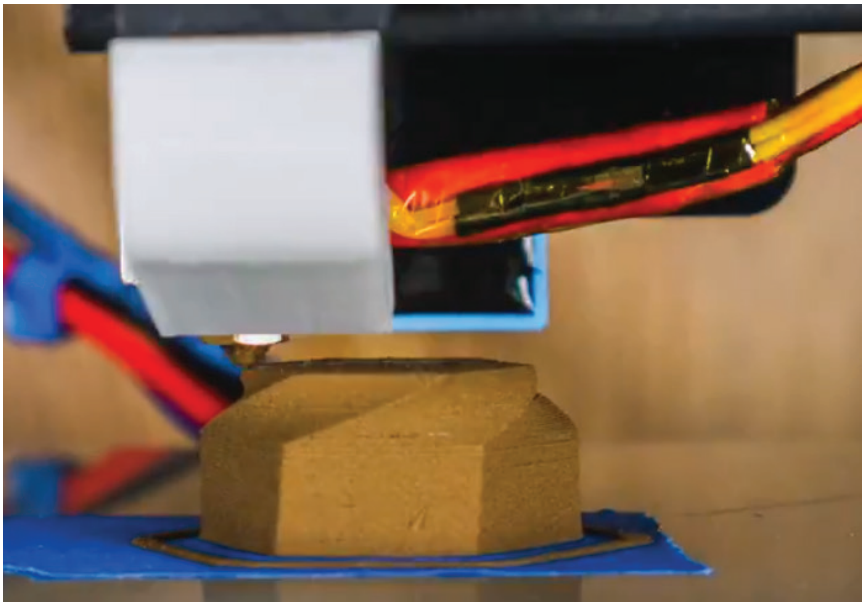
The Virtual Foundry, www.thevirtualfoundry.com



An Anet A8 printer builds a bronze swirly cone.