Technology

The Unique Challenges and Solutions in Metal 3D Printing

Kip Hanson | Feb 27, 2018

What You Need to Know:

Metal 3D printing is making inroads in aerospace, automotive, medical and other industries, and the market is expected to grow to $12 billion over the next 10 years.
Not only are the build speeds with metal 3D printing glacially slow compared with machining, but the parts are also not particularly accurate.
Lasers and electron beams heat particles of titanium, aluminum, stainless steel, cobalt chrome, tool steel and dozens of other alloys to their melting points, which can exceed 2,700 degrees.
Several new technologies including hybrid metal and polymer materials are edging into powder bed territory, promising lower costs, greater accuracy and much faster build speeds.

Metal 3D printing is not without its practical challenges and opportunities. Get a deeper understanding of where to expect snags—and how to deal with them. Plus, learn about emerging technology that could shift the market's direction.

The future has arrived in metal 3D printing—and its price of entry could be making headwinds. The big boys of manufacturing are in this area pretty deeply—and they may need a ***smaller specialty shop's help***. What does it take to adopt 3D and metal together? Embracing new engineering approaches and getting used to new materials such as metal powders, for starters.

SpaceX builds key parts with it. So do NASA, Boeing, Lockheed Martin and GE Aviation. These and other ***manufacturers are 3D printing*** metal parts for use in the aircraft that carry us from city to city, the spacecraft that bring astronauts to near-Earth orbit and the rockets that launch red Tesla Roadsters to the asteroid belt. Medical firms are also getting in on the additive manufacturing game with 3D printed implants for hip replacements and skull repair plates for accident victims. Automotive and consumer products are also lining up.

If you're a ***subcontracted manufacturer*** to one of these major aerospace firms, you already understand the challenges that accompany this complex technology. While it's not going to replace traditional or many CNC machining and fabricating processes in our lifetimes, it is changing the landscape of available manufacturing options.

Look at the numbers: Market researcher IDTechEx ***forecasts*** that 3D metal printing will grow to a $12 billion industry by 2028—up from roughly $2.5 billion in 2018. A 2016 ***EY study*** found 52 percent of companies surveyed choose metal in 3D printing over every other material. The next closest material, polymer, garnered 31 percent of the demand—with 6 percent hoping to print ceramics.

“Companies choose it [metal] because it allows products to be printed from precious metals, titanium, tool steel, stainless steel and aluminum alloys,” says EY in the report. “Among companies already using metal 3D printing, companies from two industries top the lists: aerospace and automotive companies. Sixty-five percent of these companies use metal 3D printing; this high ratio is due to the huge number of metal components in products from these sectors.”

Be Prepared to Wait and to Clean Up Metal 3D Printed Parts and Components

Before jumping into the 3D printing business, prepare yourself. It may sound obvious, but building parts in this manner is nothing like hogging out a block of aluminum or turning a cobalt chrome shaft. The tool is a laser, the material is a pile of metal powder and the fixture is a flat metal plate. Load the program, hit cycle start—and hours or days later, your part is ready. Almost.

Here’s the rub: Not only are the build speeds with metal 3D printing glacially slow compared with machining, but also the parts aren’t necessarily completed when processed, nor are they completely accurate. Whether you know it as direct metal laser sintering, electron beam melting or selective laser melting, typical tolerances using powder bed fusion are around +/- 0.005 inches with a surface finish comparable to an investment casting (figure around 125 Ra, in the best case). This means machining is usually necessary to clean up any critical surfaces, bore holes, cut threads and more.

What’s more, powder bed fusion requires structures like scaffolding to support the workpiece during processing. That means grinding, bead blasting and additional machining may be needed to remove these supports.

Do you want a more fundamental background on why and how 3D has made an impact? Check out “*The Case for 3D Printing in Manufacturing*.”

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When It Comes to Metal 3D Printing, Safety First

There's plenty more to be aware of with powder bed fusion, especially for those operating the machines. The build chamber, for example, is filled with inert gases such as argon and nitrogen. Both are nontoxic, but they do displace oxygen, so proper safety precautions must be taken to avoid asphyxiation.

However, the greater concern is the powder itself. With particle sizes of 10 to 70 microns, which is about the size of pollen, inhalation is a danger. Always ***wear protective clothing, proper eyewear and a breathing mask***. Titanium and other metal powders are reactive, especially when blasting them with high-powered laser light, so follow the manufacturer's recommendations to avoid explosions.

Laser light is also hazardous. Build chambers are sealed to prevent leakage, though seals wear and operators have been known to disable safety interlocks. Be safe, follow the rules and don't become an OSHA statistic.

It's Hot: 3D Printing Stress on Metals

There's also thermal stress to consider. Lasers and electron beams heat particles of titanium, aluminum, stainless steel, cobalt chrome, tool steel and dozens of other alloys to their melting points, which can exceed 2,700 degrees. Once each layer is complete, fresh powder is added and the process begins again. As you might imagine, this repetitive heating and cooling creates tremendous stress that must be controlled during the build process, then annealed post-build through heat treating.

That's a lot to think about and manage. In addition, those pursuing a 3D printing strategy must look at scalability, modeling, layering and simulation.

Scalability

Until fairly recently, the largest 3D metal printer was barely big enough to print a toaster. Today, commercially available machines can build parts the size of a canoe and deposit 20 pounds of metal per hour. What size machine do you need, which technology is best and how big is your budget? You can figure it will cost $1 million or more, not counting the learning curve.

Modeling

One of the biggest obstacles facing additive manufacturers is part design. Engineers must learn to think differently if they're to be successful with this technology—and that means embracing complex geometries and "organic shapes" that were previously unable to be manufactured. Of course, it's up to the machinists and manufacturing engineers to figure out how to fixture the odd-shaped parts that are coming their way.

Layering

Once the design has been approved, the 3D printer programmer or operator has to design the support structures and determine the best way to position and build the part. The good news is that there are plenty of software programs designed for this purpose—and this task is nowhere near as difficult as it once was.

Simulation

The bed is filled with powder, the build plate is clean and the metal is ready to melt. Before pushing the button, though, it's important to evaluate the build process using software simulation. This will help identify areas where thermal stress may rear its ugly head, detect where support structures are needed (or unnecessary) and confirm if the existing part design is suitable for 3D printing.

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3D Printed Metal, Meet Your New Friend, Polymer

In the 3D metal printing world, powder bed fusion reigns supreme—at least for now. Several new technologies are edging into powder bed territory, including ***thermal spray*** and ***extrusion approaches*** promising lower costs (in the $120,000 range as opposed to $500,000 and above), greater accuracy and much faster build speeds. One of these works much like an ink-jet printer, except that the "ink" is made of metal powder mixed with a polymer binder.

The part is built up in a "green" state before being placed into an oven for sintering, which is a bit different from the decades-old metal injection molding process. Since it uses the same metal powder, it receives nowhere near as much metallurgical scrutiny as other additive powders. And like all metal 3D printing technologies, it produces fully dense parts.

Similar to the "binder-jet" technology used in some newer polymer printers, build speeds are reportedly 10 to 100 times faster than their competition. Machine costs are a fraction of those of powder bed or hybrid machine tools. There's little need for support structures, and the ones that are used can be popped off easily after sintering. And since there's no laser light—only UV to cure the binder material—and the metal is supplied in printer-friendly cartridges that any office worker would be familiar with, there are far fewer health and safety concerns.

"Adopting metal 3D printing for making end-use parts has been a step that some machining businesses have taken, but it wasn't something shops everywhere could do," notes Peter Zelinski, editor-in-chief of Modern Machine Shop, in the article "The Arrival of Low-Cost Metal AM?" "Now, lower-cost metal 3D printing might mean that shops will routinely employ both additive and subtractive methods for metal parts. And it might also mean that the range of metal parts suitable for additive is getting ready to expand."

Have you had any experience with metal 3D printing or any other additive manufacturing processes? What has it been like for you and your shop?