TECHNOLOGY

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3D Printing and the Metal Finishing Industry

3D printing creates a three-dimensional solid object of virtually any shape, using a laser beam to melt the raw material and laying horizontal cross sections to build the part based on information supplied by a digital model. 3D printing for industrial applications is commonly called *additive* manufacturing because of its additive process. Traditional machining techniques mostly rely on the removal of materials by methods such as cutting and drilling (*subtractive* manufacturing). 3D-printed parts tend to be lighter than traditionally forged parts because they don't require welding, and the process generates less scrap material. A 3D printer is a limited type of industrial robot that is capable of carrying out an additive process under computer control.

NOW THAT GE AVIATION and Pratt & Whitney are using 3D printing to make metal jet engine components, it's time to think about the impact 3D printing could have on the shot peening and blast cleaning industries.

If you're surprised to read that 3D printing has progressed this far into mainstream manufacturing—albeit aerospace is a leader in manufacturing innovation—here are few examples of how the futuristic technology is progressing.

Aerospace Components

In the spring of 2013, The University of Connecticut (UConn) and Pratt & Whitney announced the opening of the new Pratt & Whitney Additive Manufacturing Innovation Center at the university. A press release from UConn cited that it is the first additive manufacturing facility in the Northeast United States to work with metals rather than plastics. The press release quoted Paul Adams, Pratt & Whitney's chief operating officer, as saying, "Additive manufacturing is complementary to traditional methods by enabling new innovation in design, speed and affordability, and is necessary to build the next generation of jet engines. We are currently using additive manufacturing to build complex components with extreme precision for the flight-proven PurePower® commercial jet engine."

When MIT Technology Review publicized additive manufacturing as one of the "10 Technology Breakthroughs of 2013," the magazine featured GE Aviation in the related article. GE made their top 10 list because "…the decision to mass produce a critical metal alloy part to be used in thousands of jet engines is a significant milestone for the technology."[1] The critical parts in the spotlight are 3D printed jet engine nozzles—GE Aviation is committed to supplying more than 85,000 3D-printed fuel nozzles for its new LEAP jet engines by late 2015 or early 2016. To help GE realize the potential of additive manufacturing, GE Aviation purchased Morris Technologies and Rapid Quality Manufacturing in 2012. Both companies specialize in additive manufacturing.

3D-printed components aren't earthbound: NASA and Aerojet Rocketdyne of West Palm Beach, Florida recently announced that they have finished testing a rocket engine injector made through 3D printing. "NASA recognizes that on Earth and potentially in space, additive manufacturing can be game changing for new mission opportunities, significantly reducing production time and cost by 'printing' tools, engine parts or even entire spacecraft," stated Michael Gazarik, NASA's associate administrator for space technology in Washington, D.C., in a press release. "3D manufacturing offers opportunities to optimize the fit, form and delivery systems of materials that will enable our space missions while directly benefiting American businesses here on Earth," said Mr. Gazarik.

Medical Implants

"3D printing is becoming more commonly used in the medical industry, specifically in product development as a way to create fast prototypes for design feasibility testing," said Scott Hatfield, Manufacturing Engineer with Medtronic. Mr. Hatfield added, "It is also used in the creation of prototype and custom manufacturing fixturing and gaging." Medtronic divisions—Medtronic-Diabetes for example—are already using 3D printing for rapid prototyping. Medtronic's new Customer Innovation Centre in Galway, Ireland has 3D printing facilities to prototype new ideas along with extensive training and education facilities.

3D printing is also developing rapidly in medical implant manufacturing. At Peking University Third Hospital in Beijing, Liu Zhongjun and his team of surgeons started clinical trials with 3D-printed titanium orthopedic implants last year. A typical usage is repairing a fractured pelvis with a titanium implant that fits perfectly with the anatomical structure of the pelvis. "3D printing technology has two very nice features: 1) It can print specific structures 2) It is capable of producing porous metal," Liu stated in article on his team's accomplishments. He explained that pre-clinical studies have indicated that bone can grow into the metal pores, and enhance the strength of the implant. "In the past we used clinical titanium mesh, but with the growth of bone, titanium mesh could easily stick to the bone and cause collapse. 3D printed implants fit the bone completely. And as a result, not only the pressure on the bone is reduced, but it also allows the bone to grow into the implants."[2]

Restoration of Worn Metal Parts

GE scientists have developed a 3D-printing technology they call "Cold Spray" that can rebuild worn parts without machining or welding. The additive technology is closer to 3D painting than 3D printing. According to a press release on www.worldindustrialreporter.com, metal powders are sprayed onto a worn part at high speeds to rebuild the worn elements of the parts. Spray technologies will be especially conducive to the repair of large components and have the potential to transform repair processes for industrial and aircraft components including rotors, blades, shafts, propellers and gearboxes. (You can watch a YouTube video on Cold Spray at tinyurl.com/coldspray.)

New Metal Alloys

Additive manufacturing will give product designers the ability to create new shapes and components because they won't be hampered by the limitations of today's casting and machining technology. They will need metal alloys to meet their design parameters. According to Martin LaMonica in his article on additive manufacturing for MIT Technology Review, "GE engineers are starting to explore how to use additive manufacturing with a wider range of metal alloys, including some materials specifically designed for 3D printing. GE Aviation, for one, is looking to use titanium, aluminum, and nickel-chromium alloys. A single part could be made of multiple alloys, letting designers tailor its material characteristics in a way that's not possible with casting. A blade for an engine or turbine, for example, could be made with different materials so that one end is optimized for strength and the other for heat resistance."

What Our Industry Experts Are Saying

Industry leaders share their opinions on 3D printing and its significance to the shot peening and blast cleaning fields.

Scott Hatfield, *Manufacturing Engineer for Medtronic*
If 3D printing makes shot peening obsolete on a medical implant, then that implant didn't need shot peening in the first place. Medical implants are shot peened to create a layer of residual compressive stress to increase fatigue strength. If this layer of residual compressive stress is needed to get the desired performance out of an implant, simply changing the method of manufacturing to 3D printing will not create a surface that is in a state of compression. It will still retain tensile stresses at the surface and will require the same secondary operations as they do now to facilitate the creation of residual compressive stresses to counter the inherent tensile stresses in the material.

Walter Beach, *Vice-President of Peening Technologies*
Peening Technologies is shot peening aerospace engine components manufactured with 3D printing. As far as blast cleaning, parts may still need post work to remove slag/residual material.

Kumar Balan, *Director, Global Sales for Empire Abrasive Equipment*
The threat to shot peening is minimal. At this stage, 3D printing is a complement to traditional manufacturing processes and together they increase efficiencies. If additive technology achieves the high production rates possible with current processes, it will be yet another type of manufacturing for the shot peening world. In other words, the tensile stresses produced by this manufacturing process will still have to be countered by compressive stresses provided through shot peening.

One could make an argument that being an "additive" process and not a "subtractive" process like current manufacturing, the tensile stresses created by 3D printing may not be a threat. I'm eager to see how our aerospace design engineers respond to that and will be very surprised if they eliminate a proven stress-countering process, especially given the time involved to update our stringent specifications and audits. It takes several years to approve the use of different and better peening media than established ones! In my mind, the larger threat to shot peening is alternative materials such as composites and exotic alloys of aluminum and titanium. That said, aerospace engineers that I've spoken with don't perceive these materials as replacing conventional materials.

Blast cleaning removes scale, rust and burrs and it etches, deflashes, and more. Although some 3D-printed parts may not require a step like deburring, blast cleaning is here to stay as long as the parts are metallic, especially because of heat treating. Metallic components go through heat treatment processes after forging, casting and other conventional manufacturing processes. A 3D-printed component will also have to be heat treated. Heat treatment produces scale, and components stored long enough oxidize to develop rust. These contaminants will have to be blast cleaned regardless of the upstream production process.

Blast cleaning is widely used in high-production automotive facilities. I don't see 3D printers advancing to the extent of being capable of producing large quantities; for example, 10-14 tons of brake drums or similar components an hour, much less at an operating cost that's competitive to a metal foundry. Given the amount of infrastructure and capacity being added to foundries and forge plants around the world today, and their constant search to reduce operating costs by adopting newer technologies, the limitations of 3D printing must be evident to experts in those industries. In addition, the large industry sector in raw sheet steel, structural steel and other weldment will still rely on blast cleaning to clean their stock before downstream fabrication processes. As a complementary process, however, I do see 3D printing shrinking the development time of tooling and patterns in foundries and forge plants.

Jörg Kaltmaier, *Project Planner with voxeljet AG*
Cast parts made from voxeljet models are like any cast parts. They need to be cleaned, blasted and machined. (voxeljet is a leading manufacturer of industrial 3D printing systems and operates what it believes to be one of Europe's largest service centers for the "on-demand production" of molds and models for metal casting.)

Are We Finished?
Not by a long shot…at least in the foreseeable future. While it's difficult to predict how emerging technologies will eventually impact us, for the most part, components that benefited from shot peening and/or blast cleaning after conventional subtractive manufacturing require metal finishing treatments after today's additive manufacturing. In addition, the new technology faces challenges before it will be widely accepted:

- High cost: The price of materials and equipment are out of reach for most manufacturers
- Slow speeds: The pace of 3D printing will need to increase a hundredfold to compete with conventional manufacturing in many applications[3]
- Lack of raw materials: Even though companies like GE are experimenting with new alloys specifically developed for additive manufacturing, only a few metals and plastics are currently suitable for the process
- Poor consistency: Parts are not always identical from machine to machine, or from day to day on the same machine[3]

Even more encouraging are the innovators in our industry that are already looking for ways to take advantage of additive manufacturing. "Peening Technologies is working with a 3D printer services supplier to develop polymer masks. The technology is very expensive now, but it will definitely have a place in creating very sophisticated and resilient polymer masks for aerospace components," said Walter Beach. "I can see purchasing a 3D printer in the future."

1. http://www.technologyreview.com/featuredstory/513716/additive-manufacturing
2. http://3dprinterplans.info/beijing-hospital-uses-3d-printed-titanium-orthopedic-implants-for-patients
3. Freedman, David H., "Layer by Layer," MIT Technology Review, December 19, 2011.