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3D Metal Printing: Driving the World of Manufacturing Forward

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Executive Summary

3D printing technology is probably one of the greatest inventions of our lifetime. Given its potential "to revolutionize the way we make almost everything,"[1] it is developing rapidly. That evolution has repositioned this once prohibitively expensive resource as affordable, making it accessible to many, manufacturers and consumers alike. The immediate challenge that people new to 3D printing face is distinguishing between its different processes and materials. In fact, the term 3D printing is actually an umbrella term that encompasses a variety of 3D printing processes. This paper will focus on 3D metal printing.

The 3D metal printing market is projected to grow from $590.4 million in 2018 to $2 billion by 2023. This growth is being driven by the increasing use of metal 3D printing processes in the aerospace, defense, medical and dental industries.[2]

North America was estimated to hold the largest share of the metal 3D printing market in 2018. Asia Pacific is expected to experience significant growth driven by the automotive industry in countries such as Japan, China, and South Korea.

Brief History of 3D Printing

The history of 3D printing goes back further than we may expect. In 1983 an engineer named Chuck Hull discovered a process called "stereolithography." [3] Stereolithography was the first 3D printing method. He used "photopolymers," which are liquid, acrylic-based materials that solidify when cured with a UV light. In 1986 he received a patent titled "Apparatus for Production of Three-Dimensional Objects by Stereolithography." This invention led to the creation of 3D Systems which, today is one of the largest publicly traded 3D printing companies. In recognition of his pioneering efforts, he was inducted into the National Inventors Hall of Fame in 2014.[4]

Many saw this as the wave of the future and companies followed suit with their own innovations, including the development of new manufacturing methodologies, materials, software and hardware. Some of the major new firms in this space included Stratasys, Makerbot, Shapeways, Formlabs and Carbon 3D. Traditional manufacturers also entered the market, such as General Electric ("GE") which formed GE Additive in 2016. GE soon purchased Arcam and SLM for $1.4 billion and has become one of the key players in metal 3D printing. Their main products are parts used in manufacturing airplanes and jets. The aerospace industry sees real opportunities in 3D metal printing, giving companies like GE a competitive advantage.

Hewlett Packard ("HP") is the latest company to take the metal 3D printing scene by storm. This tech giant unveiled their HP Metal Jet during the 2018 International Manufacturing Technology Show (IMTS). This advanced metal 3D printing technology is capable of creating production-grade metal parts at a high volume. They claim that this machine will provide users with up to 50 times more productivity at a significantly lower cost compared to other metal 3D printing methods.[5]

Other key players operating in the 3D metal printing market include EOS GmbH (Germany), Materialise NV (Belgium), Renishaw plc (UK), Voxeljet AG (Germany), (US), Sandvik AB (Sweden), Hoganas AB (Sweden) and others.[6]

What is 3D Metal Printing?

3D printing, also known as additive manufacturing, encompasses a wide range of technologies, materials, hardware and software. Additive manufacturing is a method that builds objects in successive layers.

It starts with a computer-aided design (CAD) model or digital scan of the object that is to be printed. Next, the design is processed with software that divides the object into thin cross sections which are eventually printed out or layered on top of one another. The layering continues until the 3D printed object emerges. It is the opposite of subtractive manufacturing, whereby computer numerically controlled (CNC) machines use rotary bits to remove material from sheets or blocks of raw material, or laser cutting where high powered CO_2 lasers cut through or engrave sheets of material.

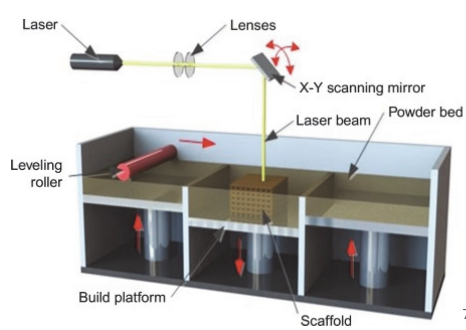
Metal is one of many different materials used in 3D printing and has become increasingly popular in the last few years. The 3D metal printing market uses titanium, nickel, stainless steel, aluminum and others. Titanium is used for manufacturing engine parts and airframes in the aerospace and defense industries due to its excellent corrosion resistance as well as its inherent strength. Titanium alloys are heat resistant and lightweight, so mainly used in the aerospace industry. Titanium is also a biocompatible material, which is widely used in medical implants. Stainless steel is another preferred material for metal 3D printing in the end-user industries. It is also biocompatible with high strength.

Other metals that can be 3D printed include brass, copper, bronze, silver, gold and platinum. Each offers a unique combination of practical and aesthetic properties to suit a variety of products from high-end parts used in jet engines, medical and dental implants to jewelry and kitchenware.

Metal 3D Printing Technologies

There are many different types of methods and technologies used in additive manufacturing. In 3D metal printing, the processes can be classified into three major groups.

- Powder Bed Fusion (PBF) - This is the most popular metal 3D printing process. The metal powder is layered or spread onto the powder bed through a roller or vibrating blade. Thermal energy from a laser or an electron beam (e-beam) is used to sinter and fuse the metal powder layer. The powder bed is lowered, another successive layer is applied and then sintered, which fuses the layer to the prior layer. This process continues until the 3D object is fully printed.



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The main representative processes are selective laser sintering/melting (SLS/SLM), direct metal laser sintering (DMLS) and electron beam melting (EBM). Both SLS/SLM and DMLS use metal powder and a high-power laser to sinter together a part. The difference between the two is SLS/SLM uses polymers or coated metal powders, while DMLS uses uncoated pre-alloyed metal powders as the sintering material. The EBM technology process is similar to SLS but uses an electron beam instead of a laser to heat and fuse the successive layers of powder metal. Overall, the PBF processes are slow and require a careful design approach. However, they surpass the other methods of 3D metal printing for strength and durability.

- Directed Energy Deposition (DED) – This is a powder-fed system where highly concentrated metal powder streams through an extruder. The extruded material is directly sintered by a laser which fuses it to the prior layer and eventually forms the part. The accuracy of this system is exceptional, which makes it the preferred method to repair broken parts.

- Metal Binder Jetting – This method uses a liquid binding resin, which is applied onto a powder metal material. This relatively inexpensive and fast technology can be used to create large structures. However, the resulting strength and densities of the printed structure is inferior compared to the other two methods. The build process is accomplished on a layer by layer basis using Powder Bed Fusion technology.

Advantages & Disadvantages of 3D Metal Printing

Metal 3D printing offers a number of manufacturing advantages such as:

- Manufacturing parts with highly complex geometries – This by far is the most significant advantage of metal 3D printing. It allows for the production of parts with highly complex geometries and design that cannot be made using existing production methods. Typically, in conventional manufacturing, the object's degree of complexity correlates to its production cost. The higher expense is due to the additional manufacturing steps and tooling. With metal 3D printing, adding complexity to an object's design does not proportionately increase costs. However, increasing the size or dimension of a 3D printed object is more likely to increase its cost than complexity.

- Manufacturing stronger and lighter parts - The additive manufacturing aspect of metal 3D printing has the potential for producing parts that may be stronger and lighter than parts manufactured using traditional CNC processes. There is consequently a significant market for the manufacturing of small parts using metal 3D printing, especially in the aerospace industry. GE is one of the leading manufacturers of metal 3D printed parts as they are able to use unique geometric forms to optimize weight and strength for parts used in airplanes and jets. Metal 3D printing, as a manufacturing process, was so critical to GE, they spent $1.4 billion to acquire several firms in this space.[8]

- Design cycle iterations – The metal 3D printing process inherently enables for faster design cycle iteration. It allows designers to quickly produce prototypes and enable them to see what the object will look like or feel like. Changes can be made rapidly and at a minimal cost compared to conventional machining methods.

- Material cost savings - Unlike subtractive manufacturing, there is significantly less material waste with metal 3D printing. The additive manufacturing process only uses material as necessary.

Metal 3D printing also has a number of disadvantages such as:

- Speed and volume of production – As it is an additive and layering process, 3D metal printing is inherently slower compared to conventional metal production technologies. It works well for prototyping, but is not ideal for large volume or mass production due to its slower speed and higher per unit cost.

  Size constraints - There are size constraints and limitations associated with 3D printing. Parts that have large dimensions or volumes require significantly more material and time to manufacture using 3D printing processes. From a cost perspective, this can result in an exponential increase in the price of the product, thereby making 3D metal printing impractical for such products.

Metal 3D Printing Applications

The most common market segments utilizing metal 3D printed parts include the aerospace, defense, medical, dental, automotive and jewelry industries.

Metal implants for medical and dental applications are being 3D printed. They are the best available option for patients, as they are custom printed for that individual-.

The aerospace and defense industry is becoming more dependent on this method of manufacturing. Aside from GE, an Italian company named Ge-AvioAero prints 3D metal components for the LEAP jet engine. It is the first full 3D printing factory in the world.

3D printed prototyping has been a longtime practice at companies such as BMW and Audi, and they are now considering using metal 3D printers for actual parts. There will continue to be expansion in other industries as well, which will increase the demand for metal powder significantly. In addition, manufacturers of metal 3D printers are developing and designing new printers with a larger print box, enabling the customer to print larger components and structures.

Additionally, advancements in metal 3D printing technology are allowing manufacturers that previously used plastic 3D printing to switch to metal process. For example, jewelry manufacturers that previously used resin 3D printing in the past are now switching to metal 3D printing.

The Price of Innovation

Since its invention, the cost of metal 3D printing continues to decline, fueling demand for this technology. This has broadened its availability and affordability to businesses as well as to home-based business owners and hobbyists. With the increased use of this technology, especially by people who may be less familiar with operating this equipment, the material/structural integrity of finished 3D printed parts, or with copyright infringement laws, suggests a greater exposure to a new set of liabilities and legal issues.

A metal 3D printed object can have material and/or structural flaws. These flaws may stem from a defect of the raw material, the product design, the CAD and layering process, or the underlying manufacturing process.

The most common manufacturing defect is called “vapor depressions.”[9] These are cavities produced when the laser drills into the metal and pockets of gas become trapped into the layers. This causes imperfections that could lead to cracks or other defects in the final product, compromising its integrity and resulting in a potential financial loss.

If a loss occurs then what are the ramifications? If a metal 3D printed part fails, who would be responsible and liable? Would it be the entity that designed the part or its production, or is it the manufacturer of the 3D printer or the developer of the 3D printer CAD software? Given the rapidly evolving state of this new market, it may not be easy to clearly delineate the responsible party and liability in such cases.

From an insurance perspective, the types of claims and loss scenarios that could result from metal 3D printing exposures include:

- Workers Compensation - Employees could be exposed to printing materials with proprietary ingredients that could have a latent occupational disease exposure, or they may injure themselves operating certain equipment.

- Intellectual Property Rights (“IP”) - IP enforcement issues may occur as anyone with a metal 3D printer is able to print replicas of patented devices and/or copyrighted parts?[10] These concerns are further heightened for more complex and technical products such as parts used in airplanes and in medical applications.

- Products Liability - There could also be issues with the metal 3D printer itself. The printer may have a manufacturing defect, or erroneous or missing instructions and warning labels. These could lead to typical products liability claims against the printer manufacturer stemming from property damage and/or bodily injury to individuals that use the metal 3D printers.

  Additionally, with the metal 3D manufacturing of medical products, specifically implantable components and devices, there is exposure from contamination, metal leaching, product failure and product recall.[11]

  The first 3D product printing litigation is a class action suit against the 3D printer manufacturer Makertbot. According to reports, they were alleged to knowingly selling faulty printers with poor printing quality and recurring problems.[12]

  To date, metal 3D printing product liability cases have been limited, as the technology is relatively new and in limited use. How liability is apportioned to the various parties in this manufacturing chain is evolving. What is certain is that the law will need to adapt as metal and other forms of 3D printing become more available in the marketplace and relevant in the supply chain.

Conclusion

3D metal printing is here and revolutionizing the manufacturing world. It offers a myriad of benefits, such as allowing the production of highly complex objects that cannot be handled by traditional methods. Metal 3D printed parts are also proven to be stronger, lighter and more precise. This process accelerate modifications to prototyping with low marginal costs, bringing new concepts and designs to fruition faster than the traditional method.

But the technology is also not for every project due to its drawbacks. It is not cost-effective for mass production. Additionally, as a relatively new technology there could be legal issues, particularly in the area of product liability. Entities using and manufacturing this technology need to be aware of these issues and protect themselves from potential liability exposures by developing strategies to manage their product risks.

In the 2014 CNN interview with the inventor Chuck Hull, he was asked if he thought there were limits to what 3D printing can do. He responded that "There's limits to everything. So, the kind of traditional limits of 3D printing have been: material properties, speed, making millions of things. But all the competitive companies are just constantly pushing those limits, so if you're projecting the future, it looks like these limits are going to be beat down over the next couple of years."[13] And it certainly has!

Contact Us

To learn more about how OneBeacon Technology Insurance can help you manage online and other technology risks, please contact Dan Bauman, VP of Risk Control for OneBeacon Technology Insurance at dbauman@onebeacontech.com or 262.623.6558.

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