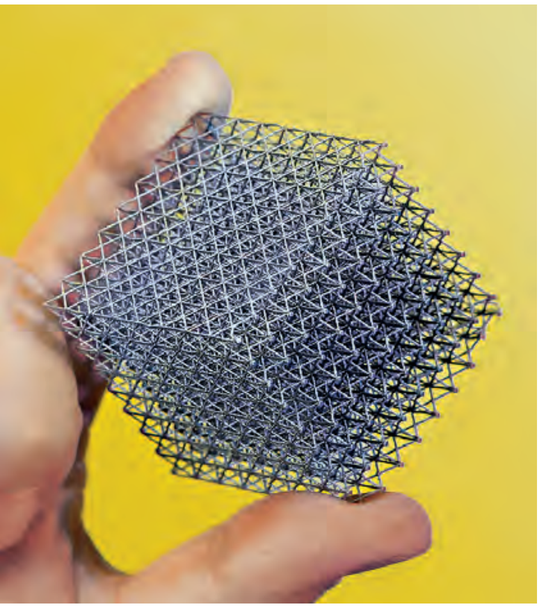
3D printing – future of manufacturing?

Many of the best tool steels require molybdenum to increase hardenability and toughness, and to form hard, wear-resistant carbides in the matrix. These attributes make molybdenum-containing tool steels the industry standard.

People have manufactured things since the beginning of civilization, and revolutionary changes in how things are made have dramatically changed the course of society's development. Examples include the first use of tools, shifts in materials from stone to bronze to iron, the introduction of the printing press and mass production. Today is an exciting period with the advent of 3D printing, enabling the printing of things in addition to words.

What is 3D printing?

3D printing, or additive manufacturing (AM), is a method to manufacture three-dimensional objects using a computer-controlled 'printer'. It has been used to make products as diverse as biomedical tissue and rocket parts. Using a digital file, for example a CAD (Computer Aided Design) drawing, the printer builds up individual parts layer upon layer, allowing drying or solidification time between layers, thus the term 'additive manufacturing'. This is unlike machining, for example, a technique that removes layers ('subtractive manufacturing') from a larger block of material. 3D printers can use a variety of materials including metals (e.g. stainless steels, nickel alloys, aluminum, and titanium), plastics, ceramics, and even living tissue.



This intricate object has been produced out of powdered metal using a laser melting process – a technique that can quickly manufacture even very complex parts. © www.siemens.com/press

3D printers have been under development since the mid 1980s, working at first mostly with plastic products but also with metal sintering. Early on, the method was mostly used for one-off parts such as prototypes during product development. Throughout the ensuing decades, engineers developed the technology to manufacture actual production parts. Some industrial metal applications began to reach commercial scale over the last few years. Today, it is estimated that more than 20% of 3D-printer output is final product, and some predict this number will rise to 50% by 2020.

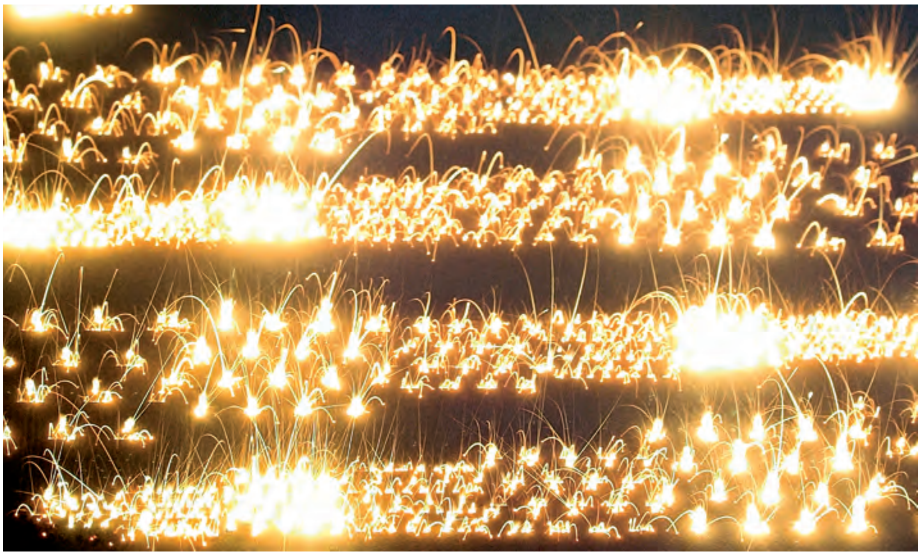
3D printing makes it unnecessary to produce thousands of parts in order to cover the fixed costs of tooling and storage, thereby reducing cost and lead-time. If spare parts for an old washing machine can be printed when needed, as an example, the management of spare part inventories can be greatly simplified and warehouse space reduced. It enables a great deal of product customization, and allows production of complex parts that cannot be made in any other way. These factors have the potential to change the whole concept of mass manufacturing. Some see customers in the future downloading an electronic file for a product, as they do now for music or movies, to print the product at home or at a local 3D production center. While this may be a faraway dream for the mass market, it is already happening for some enthusiasts. A new industrial revolution may be on the way that reduces risk, lead-time and cost.

Metal 3D printing

Metal 3D printing uses, among other processes, focused laser or electron beams to melt fine metal powders. The powder is added to the process chamber in dimensionally controlled layers and melted to build the part in an inert atmosphere to minimize oxidation. Layers are added until the finished part is complete. Each individual layer is between 20 and 100 microns thick, so it is an easily modelled building block. Unused loose powder that remains can be collected, screened, and used again.

Depending on the material and the process, the properties of the final part can be similar to as-cast material or better. For many applications this is sufficient, though there are some high-end applications (e.g. turbine blades), where the resulting properties are not yet good enough to replace traditional manufacturing techniques.

Molybdenum is playing a very important role in metal 3D printing as can be seen from the alloys supplied by EOS, one of the leading companies in this field. The powders include Type 316 stainless steel with a minimum of 2.25% molybdenum, maraging steel with 4.5% molybdenum, cobalt-chromium alloys with 5% molybdenum and nickel- based alloys ›



Lasers fuse metal powder during 3D printing. © www.siemens.com/press

such as UNS N06002 (Hastelloy®-X) or UNS N06625 (Inconel® alloy 625), both with at least 8% molybdenum. Key industries that are already using metal 3D printing routinely, include medical and dental, tool making and aerospace.

Design and applications for metal parts

3D printing's advantage over conventional manufacturing is its ability to make virtually any shape and internal complexity without subassemblies. This allows designers to think far beyond the design limitations of subtractive manufacturing, a huge advantage when it comes to high-tech metal parts. These are parts normally built from multiple subcomponents using expensive alloys, which are difficult and costly to manufacture by conventional methods. It allows designers to optimize the weight of a part, omitting any material that is not strictly necessary for its function. This way extreme lightweighting with weight savings of up to 80% is possible. In the future, it will also be possible to print a part wherever there is a suitable 3D printer, allowing the printing of spare parts on site or at local centers instead of waiting for replacement parts to be shipped from a different continent. Engineers even dream of taking 3D printers on space missions to produce the parts necessary for any repairs right on board.

The aerospace and gas turbine industries are understandably enthusiastic about 3D printing. Weight and material costs play an important role here, as turbine parts are usually machined from solid input stock of very expensive super alloys. In some cases, 90% of the input material is machined away. The left over chips and turnings must be sent back to the alloy producer for remelting. In contrast, 3D printing can recycle surplus powder, and the parts may use as little as 10% of the raw material required in conventional processes. Researchers also envision parts made from new alloys and ceramics that cannot be produced by traditional technologies.

All the major gas turbine and jet engine manufacturers are actively developing 3D printed components. Siemens is using 3D printing to make a complex multi-element gas turbine component in a single piece, which can only be achieved by AM. They are also using the technology in the repair of gas turbine burners. 3D printing the new Hastelloy X tip onto the old burner, allows them to cut the repair time from 44 weeks to only 4 weeks and to upgrade the part to the latest design. GE is building the world's first dedicated 3D printing facility for jet engine parts, where they plan to produce fuel nozzles for the CFM LEAP engine starting in 2015. Over 6,000 of these engines are already on order, each requiring 19 cobalt-chromium nozzles. The current nozzle has twenty separate parts whereas the 3D printed nozzle, five times more durable and 25% lighter, is made in only one. Cobalt-chromium alloys with 5% molybdenum have been used for years for dental implants and replacements joints. Today, millions of crowns and bridges are produced through AM every year.

GE is also a leader in reaching beyond its corporate borders to spur development of 3D printing by sponsoring challenge grant projects. Their interest in refractory metals is underscored in the 3D Printing Production Quest. This program challenges participants to produce complex high-precision parts from refractory metals for the X-ray based medical imaging arena. 3D printing can produce complicated geometries in almost any metal, even a high melting-point metal like molybdenum. IMOA member company Plansee has recently announced that they have perfected the AM process for tungsten and molybdenum products over the last few years.

This new technology faces many challenges. It is comparatively slow, so it lends itself mostly to prototypes and smaller production runs. Surfaces tend to be rough and require polishing or other finishing for high-flow applications. It is also limited in the size of parts that it can produce. The largest metal component produced as of this writing using 3D printing, an aluminum gear part, measures 474 x 367 x 480 mm. These numbers will continue to grow in the foreseeable future.

›

3D printed cobalt-chromium can be used to make a complicated fuel nozzle in one part instead of 20… © GE Aviation

…and to make the metal part of very intricate partial dentures. The production stages from left to right: partial denture directly after 3D printing on its support structure, support structure removed and polished and after completion. © EOS

What will the future bring?

The future of 3D printing looks bright. The technology can reduce development time and cost for complex parts, make optimized designs possible that cannot be manufactured with conventional means, and may reduce lead time and cost for small production runs and spare parts. The process offers the world a new manufacturing method that will supplement present technologies and help stimulate economic growth. It will make the dream of spare parts on demand anywhere in the world possible.

The potential for metals, molybdenum included, is very high. Much of the research work on 3D printing is focused on high-value, high-performance, difficult-to-machine alloys and pure metals. Molybdenum is frequently an important component of such materials, and thus is likely to play an important role in existing material needs as well as in new alloy development focused specifically on 3D printing. (Alenka Kosmac)