Photo courtesy Nike

In February, Nike Football debuted the Nike Vapor Laser Talon with a revolutionary 3D printed plate that will help football athletes perform at their best. It is specifically designed to provide optimal traction on football turf and to help athletes maintain their "drive stance" longer.

Additive Manufacturing: Going Mainstream

2013: Trends, myths, and investments in additive manufacturing

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Additive manufacturing is receiving unprecedented attention from the mainstream media, investment community, and national governments around the world. This attention reached a pinnacle when 3D printing was mentioned by President Barack Obama in his February 2013 State of the Union address. (Many, including us, use the terms "additive manufacturing" and "3D printing" interchangeably.) AM, just 25 years old and still a relatively small industry, has completed a transformation from obscurity to something that many can't stop talking about.

One of the top companies in the AM industry monitors the number of articles on the subject. In 2011, about 1600 articles were found. In 2012, that number ballooned to around 16,000—a tenfold increase. 3D printing has also developed into a darling of the crowd-funding world. Three of the top ten all-time Kickstarter technology projects are 3D printers from Formlabs, Printrbot, and RoBo 3D.

With all the attention 3D printing has attracted, it's important to point out where the technology works and where it is going. Prototyping has been the technology's biggest application, thus the name rapid prototyping, and it remains a key category. The fastest-growing application, however, is in the actual manufacturing of parts for final products. In just 10 years, this important application has grown from almost nothing to more than 28% of the total global product and service revenues, according to our research for Wohlers Report 2013. The manufacturing of final parts, rather than prototyping, is where the manufacturing money is, and it is the most significant part of AM's future.

Photo courtesy Mykita

The evolution of MYLON frames by MYKITA began with a new production process, laser sintering, in which a polyamide power is turned into an object layer by layer. MYKITA has developed a complex process that creates a sophisticated finish in six steps and gives the frames a unique visual and tactile appeal. MYKITA named the new material MYLON and has since won recognition for the development process in the shape of the 2011 iF material award.

Morris Technologies Inc., a Cincinnati-based company with 21 metal powder bed fusion systems, has been a trailblazer in developing complex and high-value metal parts made by additive manufacturing. GE Aviation acquired Morris Technologies and its sister company, Rapid Quality Manufacturing, in November 2012. Earlier in the year, GE announced its intention to produce fuel injector assemblies for its next-generation LEAP jet engine by additive manufacturing. The acquisition illustrates GE's optimistic view of AM, and essentially "locks up" Morris's vast knowledge and experience for GE only.

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GE Aviation also plans to use AM to produce the titanium leading edges for the LEAP engine's fan blades. Meanwhile, German company EOS GmbH, a leading manufacturer of metal powder bed fusion systems, estimates that 15,000 dental copings are made in the company's machines every day. A coping is the metal structure for dental crowns and bridges. What's more, an estimated 80,000 acetabular (hip) cups have been manufactured using electron beam melting powder bed fusion systems from Sweden's Arcam AB. These are standard, off-the-shelf products that come in a range of sizes. More than 30,000 of these parts have been implanted into patients.

AM technologies are also making inroads into the consumer products industry. The sporting goods company New Balance is developing custom 3D-printed soles for its track spikes and running shoes. In January, a professional runner wore 3D-printed shoes for the first time at the New Balance Games in New York. The cleat plate of Nike's new Talon football shoe is manufactured by 3D printing. The ultra-light Talon's cleat plate was designed to provide optimal traction and help athletes maintain their "drive stance" while sprinting, according to Nike. Two manufacturers of eyeglasses, Mykita and pq, offer products with 3D-printed nylon frames. The Corbs line from pq, designed by Ron Arad, features one-piece frames with hinging action created by a series of scores in the material.

Fact vs. Fiction

Despite many examples of growth and progress, a considerable amount of hype surrounds AM, and many myths and misconceptions associated with the technology have developed.

Myth #1: AM is a low-labor content, "pushbutton" technology. While it's true that AM often runs overnight in lights-out operations, a lot of work occurs before and after the actual production of the parts. Data needs to be prepared at the front end, which may require CAD expertise, the repair of the models, and optimization of support structures. (Most AM systems require that structures are designed to support overhanging features and other areas of parts.) Build parameters, such as layer thickness, temperature, build speed, and a number of other options may need to be adjusted for a particular part, group of parts, or type of material. Thermal AM processes require pre-build chamber heating and post-build chamber cooling and this can take hours, even tens of hours, for large parts and large build volumes. And post-processing steps, including the removal of support material, stress relief, and finishing, can be quite labor intensive.

Myth #2: Additive manufacturing is fast. AM systems build parts by depositing, fusing, curing, or laminating consecutive layers of material. These layers are typically 0.001 to 0.010" (0.025–0.254 mm) in thickness, so parts often require thousands of layers. Defining the perimeter and solidifying the area of each layer for large volumes can be quite time consuming. The period between layers also adds time. Processes that operate with a heated build chamber take time for preheating and cooling cycles. With all the required steps, some jobs take several days.

Global athletic leader New Balance in March announced a significant advancement in the use of 3D printing to customize high performance products for athletes. At the New Balance Games in January 2013, Team New Balance athlete, Jack Bolas, became the first ever track athlete to compete in customized, 3D printed plates.


Photo courtesy New Balance

Myth #3: AM is greener than conventional manufacturing. At one time, many hoped that one-off, distributed manufacturing would result in more energy-efficient products. However, the studies completed to date—mostly in Europe—do not necessarily support this theory. AM processes consume more electrical energy per unit mass of material produced compared to conventional processes. When combined with new design capabilities, less material, fewer parts in inventory, and the elimination of tooling, the picture improves. This is especially true when compared to waste-intensive processes, such as CNC machining. In the aerospace industry, the environmental benefits of AM-enabled weight reduction are clear, because weight reduction results in substantial fuel savings. We know now that assessing the environmental benefits of AM is a very complex exercise that requires an analysis of the entire life cycle of a product, from raw material processing to the product's end of life. The industry will need to embark on thorough, cradle-to-grave assessments of AM's energy efficiency.

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Myth #4: AM systems can produce anything. The adage "if you can design it, you can build it" is generally true, as most AM processes are blind to the complexity of a part and can successfully build shapes that cannot be fabricated easily or at all using conventional methods of manufacturing. However, AM processes also have limitations. One is minimum wall thickness. Another is the requirement for supports and anchors on down-facing surfaces, which can be difficult or sometimes impossible to remove. Material that is trapped in internal channels can also be difficult or impossible to remove, and the size of the internal channels impact the degree of difficulty in removing unwanted material.

Myth #5: With AM, it's just as efficient to build one part at a time as it is to build many. Depending on the process, packing the build volume with parts makes a significant difference in the per-part build time, cost, and energy consumed. AM comes with economy of scale, especially with powder bed processes, where the entire build volume can be filled, and stacked, with many parts. A similar myth is that it's just as efficient to make 50 custom parts as it is to make 50 copies of a single part. In reality, while build time and expense may be the same, the pre-build file preparation and post-build part finishing may be considerably more time-consuming when each part is unique.

Myth #6: AM systems and materials are inexpensive. It's true that some 3D printers for hobbyists and do-it-yourselfers are inexpensive. The least expensive 3D printer, the Maki-Box, lists for $200. The list price of Concept Laser's X line 1000R metal AM system in Europe is €1.4 million. Generally, industrial AM systems are more expensive than CNC machining centers. And materials are far more expensive. Plastic materials for AM can be 53 to 104 times more expensive than plastic materials for injection molding.

Photo courtesy New Balance

For the production of the custom plates, New Balance uses laser sintering to convert powder materials into solid cross-sections, layer by layer using a laser. SLS printing enables the customization process by allowing for complex designs that could not be achieved through traditional manufacturing methods.

Myth #7: AM will replace conventional manufacturing. AM has disrupted and forever changed several niche manufacturing applications, including in-the-ear hearing aids, dental restorations, orthopedic implants, orthodontics, and environmental control system ducting for aircraft. However, AM will not displace conventional manufacturing methods for high-volume, low-complexity parts any time soon. Think of common mass-produced items, such as injection-molded stadium seats, trash cans, and disposable drinking cups, or the ubiquitous 12-ounce aluminum beverage containers. These products will continue to be made by conventional methods because it is much faster and more cost-effective to do so.

Myth #8: AM can print guns. Of all the media attention AM has drawn, the most unsavory has been the hype around the 3D printing of guns. Here are the facts: some noncritical parts of a semiautomatic rifle were made on a 3D printer. The gun broke after it was fired six times, which confirms the premise that a plastic 3D printed firearm does not hold up to the heat, impact, and ballistic energy of rapid firing. The gun is more of a danger to the person shooting it than to anyone else. The US is the most heavily armed country on the planet, with about a third of the world's guns, so market demand for a new way to manufacture guns simply does not exist. Also, we know of many ways (e.g., basic machine shop tools and materials) that are better for making gun parts. The focus on 3D printing guns is a red herring, and the media and AM industry would be well served to move on to more productive subjects.

Myth #9: Every household will own a 3D printer. This assumption draws on the parallel between personal computers and 3D printers. There was certainly a time when the claim that every household would have a computer was met with skepticism. However, the analogy for 3D printers simply does not hold up. Before computers, people would write, publish, communicate with others, present information, manage documents, listen to music, organize photos, and do accounting and research. People continue to do these things, but now with the support of computers. Most people are not designers of products or inventors, so the widespread availability of 3D printers will not change their behavior. The more likely development will be the rise of local 3D print shops, similar to today's document printing service companies, and online transactions for parts and products, similar to the way many of us use Amazon and other sites to purchase products.

A Vibrant Future

Despite the hype and half truths, additive manufacturing is gaining steam around the world. In fact, a number of national governments have committed sizable resources to the development and advancement of the technology.

In August 2012, the National Additive Manufacturing Innovation Institute (NAMII) was created as the pilot institute for the National Network for Manufacturing Innovation (NNMI). The NNMI is a proposed investment of $1 billion in up to 15 institutes across the US, each serving as a regional hub of advanced manufacturing and innovation. NAMII was launched with $30 million in funding from the Departments of Defense, Energy, and Commerce, and the National Science Foundation. Industrial and academic partners in NAMII have more than matched this initial investment with $40 million in cash and in-kind contributions. In March of this year, NAMII announced awards for seven applied research and development projects in AM, totaling more than $9 million in funding. A second call for R&D projects is expected in June of this year. As of mid April, 76 organizations across the US had become members of NAMII.

The government of Singapore announced plans to invest an impressive $403 million over five years in advanced manufacturing and 3D printing technologies. The investment is part of the government's Future of Manufacturing program, intended to get manufacturers to embrace disruptive technologies and help the country's competitiveness with neighboring countries. As part of the program, the government expects to consider building a 3D printing industry ecosystem.

Photo courtesy Smith Dentistry

German company EOS GmbH, a leading manufacturer of metal powder bed fusion systems, estimates that 15,000 dental copings are made in the company's machines every day. A coping is the metal structure for dental crowns and bridges.

The central government of China plans to pour about $240 million into AM research, development, and commercialization. The emphasis on AM is expected to last seven years, but the funding is for the first three, which means each funded project must become self-sustaining after three years. The funding is part of a concerted effort in China to develop a high-tech industrial infrastructure, complete with universities, research institutes, and advanced manufacturing capabilities. Provincial and city governments are expected to invest even more money and resources into AM.

The European Union and many national governments in Europe are funding projects on additive manufacturing. The European Space Agency, for example, recently launched a 4.5-year, €1.88 million project titled Additive Manufacturing Aiming Towards Zero Waste and Efficient Production of High-Tech Metal Products. The project seeks to produce defect-free metal parts that measure up about 78" (1981 mm) in size, with close to zero waste. Another objective is to reduce cost by 50% for finished parts, compared to traditional processing. The parts will be for the aeronautics, space, automotive, nuclear fusion, and tooling industries.

This is truly an exciting time for additive manufacturing. The fast-growing industry is enjoying unprecedented levels of attention, interest and investment—as well as hype—around the world. With so much being published on the subject, it can be difficult to maintain an objective perspective on AM's importance and future. Despite the misinformation, misconceptions, and uncertain future, AM is poised to some day become one of the most valued forms of manufacturing ever. **ME**