

No one seems to know whether 3D printing (or additive manufacturing) is the future of technology or an overhyped exercise in gimmickry, but footwear designers are seizing the opportunity to create unusual shapes, faster prototypes and customised components.



Victoria Spruce's 3D-printed designs. CREDIT: COURTESY OF VICTORIA SPRUCE

Breaking the mould

Getting a call from Selfridges, the famous London retailer, out of the blue to display one of your first collections would be pleasing for any up-and-coming designer, but for Victoria Spruce it produced a problem: one of the shoes had been broken during a recent fashion shoot. Made from resin, it would not merely be a question of fixing – the whole shoe would have to be made from scratch in a tight time frame. Luckily, she had designed the collection with 3D printing in mind, which meant a scan could be taken, scratches removed from the computer-aided design file (CAD), and then the entire thing printed again in a short space of time.

"If I had chosen a more conventional route, I wouldn't have been able to solve the problems so easily," she says. "We were able to mirror the data to create both a left hand and right hand shoe and could scale the shoes to the exact size."

Ms Spruce is one of a number of footwear designers looking seriously at the benefits of 3D printing and what it can offer in terms of freedom of shapes and time to manufacture. "It allows designers to create sculptural shapes that aren't possible with other techniques," she explains. "It's perfect for designers who want to create something new and forward thinking."

She uses the technique to create her unusual shapes and designs, and hand-finishes them, fitting leather to the 'printed' shoe base. Her latest collection went on show at the London department store in January, alongside a video showing how

they were made. "Shoe designs are getting crazier and more experimental thanks to new ways of working with materials and form which is why shoe designers are among the first to adopt new technologies," she adds.

Mountain or molehill?

3D printing is nothing new; engineers and scientists have been using it for more than a decade, but the process is still very much in its infancy and elicits polarised views on its relevance. On one side are those who think it will revolutionise how we live: we will be able to make our own dishwasher parts, chairs and cutlery after downloading a pattern. Scientists in the US have been developing ways of creating intricate cell structures using sugar to create new organs – potentially groundbreaking for transplants. On the other side are those who say the industry is in its infancy; it can only make simple, flimsy objects at a high cost, over a long time frame and its significance has been blown out of proportion.

In essence, the tools are similar to ink-jet printers in that they deposit layers of material until a three-dimensional object is built – an additive process, rather than the traditional 'subtractive' manufacturing. There are a number of different ways to do this: SLS (selective laser sintering) and SLA (stereolithography) are two that are favoured by the footwear industry. The design is created on CAD software, or the printer can take a 3D scan of an existing object and translate it into a

'map' to make another one.

"Media exposure has made a lot more people aware of the process, and more importantly the capabilities, and the result has been that it's no longer just engineering companies that are involved," explains Barry Assheton, sales director at CRDM, a UK-based provider of rapid prototyping and tooling services. "Artists, young inventors, small businesses and clothing and shoe designers are taking a much larger slice of the market that was previously dominated by engineers in manufacturing."

One of the benefits is the ability to manufacture in small quantities. "3D printing is fantastic for footwear designers as it gives them far more freedom of design for low-volume production and removes the manufacturing barriers," adds Mr Assheton. "In addition, it allows a prototype of a shoe to be made very quickly 'to prove the design concept' prior to normal manufacturing starting."

Heavy metal

US designer Bryan Oknyansky is further down the line with 3D printing. Unlike Ms Spruce's designs, the former architect's creations are sturdy enough to walk in – customers buying his inaugural Heavy Metal designs have their feet 'mapped' and then a pair 3D printed in metal to their exact measurements. "Architecture and footwear share the same brief: It must be beautiful, and it can't kill you," he says. "Besides, if you can't stand up straight, what's it all for?"

His Spider Heels and Caged Heels are made from titanium alloy using direct metal laser sintering (DMLS), and were prototyped in time to launch at what became a very successful showing at Berlin Fashion Week. The Spinneret Heels and Canti Heels were sampled using the SLS process and 5-Axis CNC Milling, a subtractive, sculptural machined process. This design was prototyped from a solid cube of automotive-grade aluminium by a British luxury concept car manufacturer and the designs translated into instructions for a robotic drill bit to sculpt.

His latest line was featured in the spring-summer London Fashion Week Fashion Fringe and helped Chinese designer HaiZhen Wang to win first prize. Split Heels feature a 3D printed platform and are the first that customers could, in effect, print at home. "The day the 3D Touch 3D printer arrived at the studio I powered it up and immediately started printing prototypes of Split Heels," says Mr Oknyansky. "This is my first design that I could make completely from my studio without outsourcing production. One month later I had 13 cutting-edge high heels ready for the catwalk at a fraction of the cost."



Bryan Oknyansky's Split Heels complemented HaiZhen Wang's collection. CREDIT: COURTESY OF BRYAN OKNYANSKY

The need for speed

Sportswear groups have also been experimenting. Both Nike and New Balance have recently created custom footwear with 3D printed elements. In February, Nike launched what it claims is the world's first 3D printed plate for an American football boot – although a similar custom soccer boot appeared as early as 2006.

The plate is crafted using SLS, a process that allows Nike's designers to make updates within hours instead of months. They prototyped a plate and traction system within a fraction of the traditional time frame and at a fraction of the weight. "SLS technology has revolutionised the way we design cleat plates—even beyond football—and gives Nike the ability to create solutions that were not possible within the constraints of traditional manufacturing processes," says Shane Kohatsu, director of Nike Footwear Innovation. The Nike Vapor Laser Talon weighs a mere 5.6oz and is designed for optimal traction on football turf by helping athletes maintain their "drive stance" longer.

Similarly, New Balance has developed a process to customise its high-performance spiked shoes for athletes. Its research and design teams used race-simulation biomechanical data collected using a force plate, in-shoe sensors and a motion-capture system. Advanced algorithms and software translated the data into 3D printed spike designs, which were then created using a SLS process and fused to a standard upper.

"Using our Team New Balance athletes to develop the customisation process was extremely helpful," explains Sean



Nike's Vapor Laser Talon is designed to improve acceleration

CREDIT: NIKE



New Balance's spikes are customised to each athlete.

CREDIT: NEW BALANCE

PRECISION ENGINEERING: SLS VERSUS SLA

There are a number of ways designers are making use of additive manufacturing, choosing from a range of 'inks' including thermoplastics, polylactic acid or polycarbonate, or metallic powders or clays. All additive processes use the same basic principle of melting and fusing fine powder layers, which are cooled and set, sometimes using chemicals, and then finished.

The Nike designers use SLS, a process that cures powder in very fine layers, directed by a computer-guided mirror. For CRDM's nylon offering, "the inert nitrogen environment stops the nylon oxydising when heated by the laser beam. The temperature inside the chamber is maintained at 170°C, just below the melting point of the polymer powder, so that as soon as the laser makes contact with the surface particles they are instantly fused by the 12°C rise in temperature."

For SLA, the method Victoria Spruce uses, the model is built using a liquid ultraviolet curable photopolymer resin and an ultraviolet laser. The laser traces a cross-section of the pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern and joins it to the layer below. After the pattern has been traced, a resin-filled blade sweeps across the cross section, recoating it with fresh material. The parts are cured under UV light.



Machine detail of a 3D printer.

CREDIT: SHUTTERSTOCK/BABICH ALEXANDER

Murphy, New Balance's senior manager of innovation and engineering. Jack Bolas, a 1,500 metre runner, in January became the first track athlete to compete in customised 3D printed plates, according to the company. By tailoring the spikes to each athlete it says it can offer a more refined experience.

In addition to printing semi-rigid parts, the company is working on softer SLS printed components that mimic the cushioning properties of foam midsoles, which it says will bring the customisation process to a wider customer base. CEO Robert DeMartini says: "We believe this is the future of performance footwear and we are excited to bring this to consumers. Developing our printing capabilities could ultimately help us by adding highly technical positions to our already skilled labour force in Massachusetts and Maine."

Drawbacks

One of the problems companies envisage with the increasing use of 3D printers is that of intellectual property infringements. If CAD drawings are available, the fear is that people will illegally share them and print their own products. It has been suggested it could go the way of the music and film industry, where piracy and file sharing has meant increasing lawsuits as well as writs that force site providers to remove material. Experts warn that policymakers need to consider the implications that 3D printing presents sooner rather than later.

The current limitations also mean that the shoes are, in the main, not strong enough to be worn. Mr Assheton says it is a matter of time before this is resolved. "The strength and quality has improved and will continue to do so. The process of additive manufacturing doesn't only apply to plastics, but also to metal. These parts have even been used on Formula 1 race cars – the ultimate test of their performance."

"I'm in discussion with CRDM to create a shoe that would be robust enough to last," adds Ms Spruce. "To get the necessary strength I am developing a new collection

using injection moulding instead. Once the materials are strong enough to withstand the pressure that a shoe takes then I think 3D printing can be applied to all areas of footwear design."

A third factor is cost. A printer can only make one object at a time, so would be of no value for high-volume manufacturing, and the materials are relatively expensive, which would need to be factored into the cost to the customer. "The costs have largely fallen over the past 10 years and, as the volume of parts required grows, the prices will continue to fall," says Mr Assheton. "This is because the material costs will reduce and the machines will become faster in production."

A global movement

It is not just Western companies that are plugging into 3D possibilities. There are factories in China making everything from toys to jewellery; the time it takes to produce a mould for a car has been reduced from months to a couple of weeks. One of the country's largest printers is housed at Beijing University where it is being employed to make large and complex parts for China's commercial aircraft programme.

"People once said mobile phones were too big and heavy and had limited capability, but now they are commonplace in many people's lives," says Mr Assheton. "Eventually, 3D printing will undergo the same transformation as the machines become cheaper, the quality improves and the knowledge of their capabilities continues to spread."

With the UN's World Intellectual Property Organization forecasting the 3D printing business to be worth \$3.7 billion by 2015 and \$6.5 billion by 2019, the implications for the footwear industry are as far reaching as any other. Mr Oknyansky is currently looking for opportunities to develop new products for scaled manufacture in markets all over the world. "It's a real game-changer and it will soon change how shoes are made and sold," he concludes. 