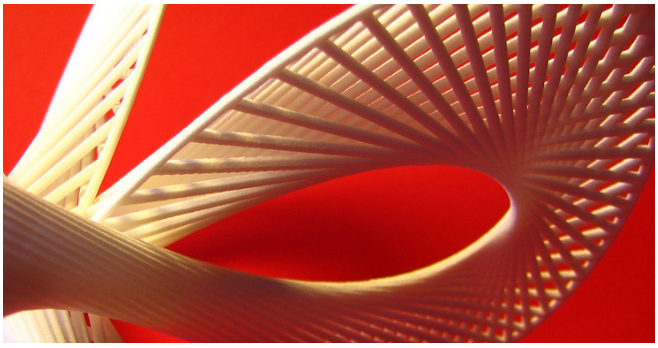
PUBLISHED DECEMBER 2013

3 A NEW ERA OF MANUFACTURING

BY STEPHEN FOULGER & COLIN WEBSTER



"[3D printing] has the potential to revolutionise the way we make almost anything"
Barack Obama, State of the Union address, February 12 2013

1. The shape of things to come?

3D printing feels like a revolution tantalisingly beyond our reach; close enough to see and to excite us in anticipation, yet the technology still seems far enough away to remain a hypothetical manufacturing nirvana. There is something rather science-fictiony about 3D printers; they appear to make something from nothing, making corporeal shapes that previously only existed in the mind of their creator and on the hard drive of a computer. The revolutionaries ask: could these be the instruments of a complete reconfiguration of our relationship with manufactured products? Will they bring manufacturing 'back home'? And do they allow small-scale producers to take on the major manufacturers by eliminating economies of scale?

2. What is 3D printing?

3D printing builds up three-dimensional objects one layer at a time following digital designs loaded into their memories. The process of adding material to build up an object is known as 'additive manufacturing', and it is in contrast to 'subtractive manufacture' in which material is cut away to produce a final piece. As a result, waste is almost completely eliminated from the making process. Most traditional craft and industrial production uses subtractive techniques such as carving, milling and grinding to produce finished objects, even if they start with cast or forged pieces.

3D printers tend to use various polymers as a feedstock, including acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polylactic acid (PLA), high-density polyethylene (HDPE), PC/ABS, and polyphenylsulfone (PPSU). They work by spreading a thin layer of powdered metal or plastic over a working bed. A laser or electron beam then selectively melts the powder, which then quickly hardens to produce a solid layer in places specified by the computer design.

Photo: Flickr user Digitas

Continued

There is a range of large-scale industrial machines, each costing tens of thousands of pounds that use 3D printing techniques. Metals are often used as the feedstock at an industrial scale. Complementing this industrial use is a thriving hobbyist scene featuring smaller machines costing just a few hundred pounds and easier to handle materials. It is the existence and interplay between the industrial and hobbyist fields of 3D printing which may give rise to some truly game-changing possibilities for manufacturing in the future.

3. Additive Manufacturing and economics

Professor Richard Hague of the University of Nottingham views Additive Manufacturing and 3D Printing as two separate technologies on the basis of scale: 3D Printing is, in his book, the small-scale relation of Additive Manufacturing, and is mostly concerned with prototyping. Additive Manufacturing, he believes, offers the greatest economic possibility.

The first point of note for additive manufacturing is the elimination of economies of scale: the marginal cost of a producing a second object is no different to the marginal cost of producing the 100,000th. This fact alone makes it viable to produce objects on demand, rather than in anticipation of demand. On top of that, new or small firms no longer have to spend money on costly moulds they can barely afford. The reduction (or elimination) of the cost of capital equipment can simplify supply chains and reduce lead times. And, at the same time, the elimination of waste removes a potential regulatory burden for business, on top of the obvious shared benefits of a cleaner production process.

Professor Hague cites the cost minimisation of Boeing's Additive Manufacturing programme in his 2013 speech to the Institution of Engineering and Technology[1]. He explains that Boeing F18 fighter jets are printed in one go, rather than built in parts and then assembled. F18 have been built this way for the last 14 years and they are yet to have a failure. While they did not cost less to produce, they are cheaper to maintain because they don't have to be disassembled at every service point.

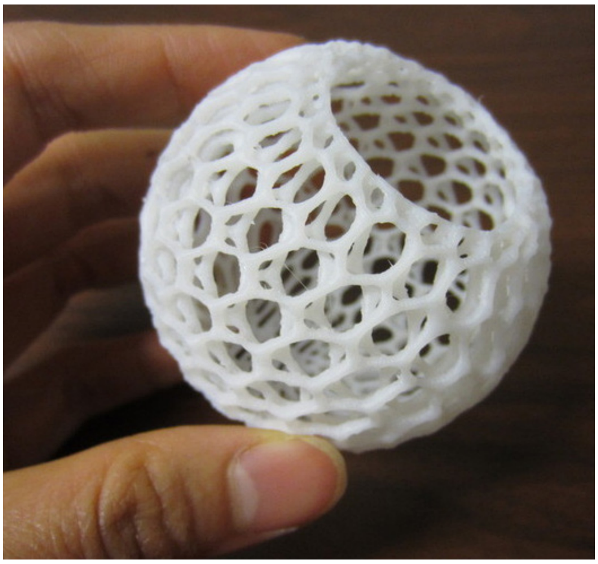
3D printers can produce prototypes without the need for time consuming and expensive retooling and often use cheaper materials such as plastics rather than high performance alloys. At the Military Air and Information Division of BAE Systems, rapid prototyping has reduced product development from six months to two weeks[2]. Once departments have experience with 3D printing, they can find increasing numbers of applications for it. The BAE Systems team built themselves some new tools including gauges for checking door alignment.

3D printing has found a natural fit in the medical sector where highly customised items are required in relatively low numbers. GN ReSound produces batches of 40 individualised hearing aids in 90 minutes using photo cured plastics[3]. Other uses include modelling and producing replacement orthopaedic parts. In some areas, reducing costs by reducing production stages has stimulated uptake of 3D printing. Hip replacements must be forged, machined, then given a coating to encourage bone growth into the replacement, yet a 3D printed part can be formed in one process with the density varied at the surface to make it porous.

Photo: Flickr user 24874528@N04

Continued

The accessibility of the technology means that start-ups can come from nowhere to generate a huge profit. FreshFiber – a company making personalised iPhone covers – started with nothing but were worth $36million in 18 months. The intriguing thing is that they never owned a machine: they simply sold the data. Perhaps the future of manufacturing is partly about the product and partly about access to it.



4. Design considerations

Additive Manufacturing can allow us to develop what Professor Hague calls 'topology optimised' designs: *'natural'* shapes which create a more streamlined object with a reduced weight, by focusing on the different layering options for any given portion of the object. Some 20 to 40% of the weight of an object can be reduced by making designs reminiscent of a Gaudi creation. This approach is not quite cost effective yet, but the potential has been demonstrated and further development of the idea should bring down costs.

Likewise, we can now produce lattice-like internal structures, reduce weight further still. We are no longer limited to drilling in straight lines thanks to Additive Manufacturing and the associated software. However, it is not all plain sailing: we presently can only really construct using one material, although it is anticipated that multiple-material technology is on its way[4].

5. Localised 3D printing

Some have claimed that 3D printing could democratise manufacturing by allowing parts and products to be printed at home – or in a local print shop – which would cut back transportation costs and delays, whilst allowing us all to become the designer, or the user of readily available designs (for replacement parts, etc). Of course, we don't all have the inclination to be a designer, nor the skillset or free time, but the potential is there. Need a new cover for your laptop? Design one – or choose someone else's design – then print it off at home. Is a part on your vacuum cleaner broken? Download the data for that part and print it out.

Hobbyists are already finding 3D printing to be to their liking. Traditional hobbyists, designer/makers and artists form a community that share ideas and open source designs for 3D printers and objects. This open environment is ideal for producing further innovations in 3D printing. While 3D printer ownership continues to rise, it remains to be seen whether it will spread out to a further circle of less technically adept potential users.

The technology allows us to speculate about the return of major manufacturing to Western countries. By eliminating economies of scale and much of the assembly line, regionalised manufacturing makes sense from the perspective of being closer to the market, thus reducing transportation costs.

6. What does this all mean for a circular economy?

Our prediction is that manufacturers will design and produce products for longevity, for repair, remanufacture and resale. 3D printing theoretically allows individuals to do some of that work themselves, by allowing for the endless customisation of products. This, in turn, extends their useful life, keeping them in circulation for longer while possibly allowing the user to develop a closer relationship with the product. Fine for a record player, you may think, but how close a relationship do you want with your washing machine? In that product's case, the usefulness of 3D printing lies in the repair of broken parts and panels. Imagine a repairperson visiting your home, identifying the problem part, then printing it out in situ.

Photo: Flickr user fdecomite

Continued

There are many savings to be made by the manufacturer as the flexibility of a 3D printer makes the technology an alluring alternative to traditional manufacturing. A 3D printer can generate complex shapes at the same cost as simple ones; the weight of items can be drastically reduced with biomimetic design principles; the lead-in time is reduced through a print-on-demand approach; a single 3D printer can make many shapes (limited only by the printer's size, material feed and the designer's imagination), whereas many traditional machines exist to perform a specific task; 3D printing produces next to no waste; and 3D printing can produce objects which require no disassembly[5]. That final point represents a challenge for a circular economy: will non-assembled products lead to end-of-life, rather than disassembly and repurposing?

7. Biological feedstock

One potential great leap forward for 3D printing and the circular economy would be the production of a material that fits into the biological cycle. Janine Benyus, author of *Biomimicry: Innovation Inspired by Nature*, states that, rather than following a treat-beat-heat process, which is both energy intensive and wasteful of materials, *"nature uses life-friendly chemistry, which is nontoxic and water-based, and which does not require high heat"*[6]. Benyus asks that we look to nature for inspiration in our designs, and she is particularly enthused by the possibilities offered by 3D printing. She told the Ellen MacArthur Foundation's CE100 Global Summit[7]:

"Life is going to teach us a lot about composites. Abalone shell is twice as tough as our high-tech ceramics... it's mineral and then polymer: a very gummy kind of thing... and then mineral again. The ability to print out layer by layer with different materials gives us the opportunity make things as tough as abalone."

Nature also tends to only use a small subset of the periodic table, yet creates...everything. In mimicking nature we can now print out foams to be very strong, as well as reduce the weight of our printed objects, and create structures that were impossible before. If 3D printing is really going to revolutionise manufacturing then perhaps it is the biomimetic approach which will make this dream become a reality.

References

1 *3D Printing The Future of Manufacturing?,* Richard Hague, The Institute of Engineering and Technology, October 24 2013
2 *Exploring the 3D printing opportunity,* Jane Bird, The Financial Times, August 08 2012
3 *Exploring the 3D printing opportunity,* Jane Bird, The Financial Times, August 08 2012
4 *Faster 3D printing with multiple materials,* Megan Hazle, Futurity, November 21 2013
5 *Industrial revolution?* Maybe, Melba Kurman,
6 *Improving 3-D Printing by Copying Nature,* Brian Clark Howard, National Geographic, July 07 2013
7 Video, Janine Benyus at the Circular Economy 100 Annual Summit, June 2013