3D PRINTING – A REVOLUTION IN THE MAKING

The emergence of multifunctional 3D Printing has the potential to create high-value products and enable a new manufacturing revolution.

As a manufacturing technology, 3D Printing is based on the principle of adding material, hence it is also referred to as 'Additive Manufacturing'. A relatively recent approach to the manufacture of end-use components, it is based on creating parts and products directly from raw material in powder, liquid, sheet or filament form and digital 3D design data. This process works by depositing material, usually layer-by-layer, without the need for moulds, tools or dies.

By operating entirely without such tooling, Additive Manufacturing has two key advantages over other, more conventional, manufacturing techniques. Firstly, it enables the manufacture of products without many of the limitations that are normally placed on designs by conventional manufacturing processes involving tooling such as moulds. Secondly, Additive Manufacturing enables the cost-efficient production of bespoke low-medium volume products, which can be highly complex and tailored for a particular function or user.

In terms of established manufacturing thinking, the current focus often lies on large numbers of identical products originating from elaborate global supply chains. The key advantages of Additive Manufacturing allows this to be challenged: it is now possible to create efficiently complex and advanced geometries in a single, integrated, manufacturing step with the added possibility of each unit of output being different. This has led to considerable interest among manufacturing experts and sparked the imagination of the media and the wider public.

Prototype prosthetic arm and hand

As illustrated by current commercial applications of Additive Manufacturing in the medical and aerospace industries, perhaps the most fundamental potential offered by Additive Manufacturing technology is the ability to produce designs that would not have been possible using traditional processes such as casting or machining. These include products with complex internal channels and pathways or with intricate lattices and honeycombs which can replicate some of the strongest materials that occur in nature, such as bone. In the aerospace and automotive industries, Additive Manufacturing could enable the weight of structures to be reduced by up to 40%, while improving strength and using significantly less raw material in production.

At the Additive Manufacturing and 3D Printing Research Group (3DPRG) at the University of Nottingham, researchers led by Professor Richard Hague are investigating ways of taking this to the next technological level: by depositing more than one material within a single build process, it will be possible to print entire working systems instead of individual parts and components. These could, for example, contain embedded electronics, chemical agents or even biological structures.

This special research focus is why the 3DPRG is recognised as the world's leading research group in the field and is helping to set the global research agenda.

Work at the University of Nottingham has shown that the step away from the single material case to multi-material Additive Manufacturing allows users to move beyond structural applications and create functional systems rather than passive individual components. The possibilities of creating added functionality and user value – through the embedding of 3D structures within structural materials such as engineering polymers or metals – appear immense. Such functional structures that may be built directly include electrical circuitry, optical tracks, sensors, conformal batteries, solar cells, LED screens, antennas and other interfaces.

The embedding of functional structures through the Additive Manufacturing process results in an ability to generate efficiently complex and tailored product solutions. As a fully digital manufacturing process, this aspect connects Additive Manufacturing to the ongoing debate about the consequences of decreases in marginal costs enabled by digital technology. Think, for example, of the impact that electronic media have had on the publishing industry. The possibility of integrating complex and customised functionality direct within products at (almost) no additional cost may produce staggering effects in manufacturing industry. This is likely to lead to manufacturers and designers increasing the levels of functionality of their products.

Operating a selective laser melting system

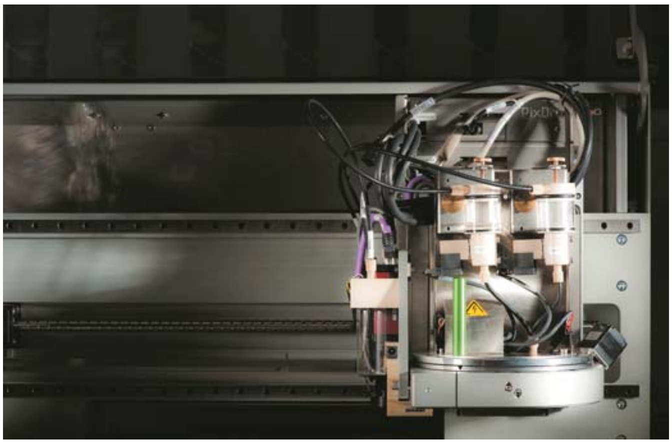
Especially where multifunctional Additive Manufacturing is used, this also promises to have important consequences for the underlying design approach. This is because low cost sensors and electronics, embedded directly within the component during multifunctional Additive Manufacturing, will be able to provide a wealth of data on a product's useful life. These data can then be used to support design optimisation techniques or customisation approaches, leading to refinements for the following generations of products.

Besides conducting a range of research projects, the 3DPRG has received funding from the Engineering and Physical Sciences Research Council (EPSRC) to host the Centre for Innovative Manufacturing in Additive Manufacturing. This is carrying out an ambitious programme of research worth in excess of £24m, designed to lay the foundations for the exploitation of multifunctional Additive Manufacturing technologies in the UK, enabling future commercial applications for the high value manufacturing industry. Highlights include:

- Development of novel design systems based on multiphysics optimisation
- Research towards structural materials supporting multifunctional Additive Manufacturing via ink jetting approaches
- Deposition of embedded conductive, optical or biological or otherwise functionalised structures from secondary materials
- Computational modelling of processes within multi-material additive deposition
- Micro-scale Additive Manufacturing based on two-photon polymerisation and optical tweezer technology

In terms of the technological approaches investigated, a special focus within the EPSRC Centre lies on the research of novel processes depositing materials via the jetting of droplets. Such processes are ideally suited to deposit a variety of materials at the same time. In a recent development, the group is proud to announce a pioneering project looking into the high temperature deposition of liquid metal via a materials jetting process.

The Centre was recently awarded an additional £2.7m from EPSRC to work with the University's School of Pharmacy on drug delivery through the Additive Manufacturing of pharmaceuticals. Their 3D printed tablets formed part of a landmark exhibition at London's Science Museum, ***'3D: printing the future'***. The printed tablets are structured to allow the release of pharmaceutical agents at varying speeds according to individual patient need. The University is a sponsor and adviser to the exhibition.



A multi-material jetting head in a PixDro materials printer

Student interns at Nottingham created another highlight of the exhibition – a demonstrator for a 3D printed prosthetic arm, illustrating how the technology could evolve to print customised prosthetics with embedded actuators, electronics and pick-ups for nerve endings (see image).

3D printing technology in action

Developing the next generation of researchers is a key strategic goal of the EPSRC Centre. It recently launched the £4.5m Centre for Doctoral Training (CDT) in Additive Manufacturing and 3D Printing. Further investment at the University of Nottingham Ningbo China gives activity a global perspective, building capacity within the world's biggest manufacturing economy.

Structurally optimised design, 3D printed in stainless steel

The commercial potential of Additive Manufacturing is immense.

In 2013, the size of the Additive Manufacturing industry was estimated at round £1.81 billion, with an annual growth rate of over 30%. This makes Additive Manufacturing a small but fast growing area in the manufacturing sector. What really captures the imagination of inventors, innovators and entrepreneurs however is the size of the business opportunity, and the scale of the potential market. As outlined in the Wohlers Report 2012, an annual industry publication, experts speculate that Additive Manufacturing has so far been adopted in only 1% to 8% of potential applications. At full technology diffusion and assuming that industry revenue corresponds to the potential market, this would equate to an industry size from at least £14 billion to over £110 billion in annual turnover.

Additive Manufacturing may also yield environmental benefits. The technology will enable many new supply chain configurations – possibly heavily decentralised – in which the creation of considerable product value is compressed into a single manufacturing process step. Due to excellent product performance, energy efficiency and the minimisation of logistics, it has the potential to reduce the environmental burden of manufacturing activity.

Identified as a key part of one of the government's 'eight great technologies' to drive UK growth, Additive Manufacturing has the potential to bring manufacturing back to high-wage economies around the world. University of Nottingham researchers are ensuring that UK companies will be at the forefront of that revolution.