Design Focus - Make your own.
17 October 2007

Rapid prototyping is evolving as the machines improve, 3D printing becomes cheaper and direct manufacture becomes reality, says Ben Sampson.

Twenty years ago the first rapid prototyping machine was released, creating a niche area of design engineering. Since then the area has received as many new names as it has new machines. Free-form fabrication, additive manufacturing, 3D printing, desktop manufacturing - the list grows.

With its impenetrable jargon, it's hardly surprising that the area has remained niche. But as the digital age begins to take hold in the 21st century, rapid prototyping is moving in new directions and fulfilling its potential. At the bottom end of the market, 3D printers are being used by a wider range of people, while at the top end, high-spec rapid prototyping machines are pushing the boundaries and evolving into something completely different.

3D printers use similar technology to "traditional" rapid prototyping machines: an additive process (as opposed to subtractive) where objects are built up layer by layer. 3D printers are, however, cheaper and have a lower specification. New machines can be bought for £16,000, and bureaus able to print models from 3D CAD files have sprung up all over the country.

One such company is Cadventure, which has several **ZCorp** 3D printers in its London office. Tellingly, Cadventure initially provided 3D CAD programming services, but it has grown to offer 3D printing and even sells the 3D printers themselves. Senior consultant at the firm Stefan Ponur says: "The market was originally just product design but we're seeing more architects getting into the idea of 3D modelling now, mainly because it's become much more affordable."

Companies are less precious with the models because they are much cheaper to make, he says. The ability to print in colour quickly and more easily from CAD with the **ZCorp** 450 machine has also bought work in from engineers mapping FEA analysis and heat loss calculations on to models. The company's core market is architects, although it also does brisk business with engineers designing products, and even doctors and dentists who want models on which to practice operations.

"There is a whole generation to whom 3D printing and modelling is second nature," says Ponur. "If your work is at all design-oriented you will find one of these machines useful."

The symbiotic link between 3D printing and 3D CAD is evident at Cadventure. Without the latter 3D printing cannot exist, Ponsur explains, and without 3D printing there isn't much point to 3D CAD.

This is a point echoed by Prof Phill Dickens, associate dean of research and director of the Innovative Manufacturing and Construction Research Centre at Loughborough University. He goes further, crediting rapid prototyping as the main driving force behind the increased uptake of 3D CAD modelling. The Rapid Manufacturing Research Group at Loughborough works at the "top end" of the market, where machines can cost as much as £500,000. This is in contrast to bureaus such as Cadventure, which are using machines aimed more at the mass market.

Direct digital manufacturing, using additive processes to manufacture products and parts from CAD, has been the focus of research at Loughborough for more than 10 years. According to Dickens, rapid prototyping is a misnomer for the field. Prototyping can be carried out with alternative technologies, such as CNC machining, and prototyping machines can also make production standard parts.

Talk of direct manufacturing causing a second industrial revolution seems far-fetched, and images of banks of rapid manufacturing machines in workshops, churning out parts and products fantastic. But Dickens cites examples where it is happening. The technology is best suited to short-volume manufacturing, and companies such as Siemens are already using additive technologies to produce personalised hearing aids. He has also worked with automotive companies to integrate rapid manufacturing machines into production lines. "It's true just in time manufacturing," he says.

"There will be families of machines, producing maybe medical products, like tablets or human tissue. Then there will be a family producing plastic parts, one producing metal parts, one for ceramic. Then within that there will be large parts and small parts.

"It has fantastic potential, and I believe it is going to have a big effect on manufacturing."

However, it isn't full steam ahead for rapid manufacturing. There are still major engineering and business issues to be solved. For instance, there is a relatively small number of materials available to would-be rapid manufacturers, and most are unsuitable for use in final products or components. The biggest obstacle though, Dickens says, is repeatability.

"I can produce parts on the same machine in the same batch and they will be up to 50% different in terms of accuracy, mechanical properties and surface finish," says Dickens. "It differs because we don't have the control systems on the machine and don't understand the processes. In a way we're flying in the dark."

Whereas conventional manufacturing incorporates monitoring and feedback to enable the engineer to tweak and adjust to improve repeatability, rapid prototyping machines, designed to produce one-off models, do not require that level of control. "The problem is that most rapid manufacturing nowadays is done with rapid prototyping machines," Dickens says. "But designing a machine and process for manufacturing from the off will enable us to repeat repeatability."

The greater degree of control should come from machine makers within the next 10 years, he says. Meanwhile research at Loughborough has been focusing on increasing the speed and accuracy of existing rapid prototyping machines.

Selective laser sintering is a well-established rapid prototyping method which can produce highly complex shapes but it is slow and expensive. The inside of a laser sintering machine is extremely hot, around 270 deg C, and contains a bed of powder, usually polymer or metal. A laser is passed over the powder and adds the last bit of energy required to fuse the already hot powder into a solid layer. The bed then shifts down a level and the next layer is sintered, and the next, and the next, until the object is completed.

Researchers at Loughborough have been modifying old laser sintering machines by removing the lasers and replacing them with infra red lamps. Inkjets have been added, which spray a "radiation absorbent material" on to the powder bed. This marks out the shape of the layer, and soaks up the radiation-released by an infrared flash, causing the sintering. Dickens says the process will enable much larger machines and is up to 100 times faster than conventional laser sintering, with an 18-second cycle. The university has an international patent on the process and it is generating a lot of interest, particularly from the company whose machines they are modifying, says Dickens.

Even when the technological problems are solved, a viable business model still has to be developed for the deployment of the technology. The much touted customisation of products remains the most attractive initial route for this, says Dickens, and the technology and pricing is almost at the level where it will break through to affect the design process.

High-value areas such as sports products will be the first to benefit from direct manufacturing, Dickens predicts. Equipment and clothing can be tailored to suit the individual. "Top players are prepared to pay anything for that extra advantage," he says. Think extra yardage on customised golf clubs, or more spin on a kicked football. "By the 2012 Olympics we'll have made shoes here that will make our athletes run faster," he claims.

Aesthetic attributes on cars and tailor-made ergonomics, such as handles and seats, are also prime areas. The department has designed seats for rally drivers and RAF fighter pilots. Another potential early area is equipment for disabled people. High-end consumer goods, such as lamps and sculptures, which use direct manufacturing to produce complex geometric shapes impossible to produce with conventional methods are also attracting great interest.

"Direct manufacturing machines need to be as cheap as possible because people need to recover their investment. But what is most important is what you can do with them," says Dickens. "Most people want to make their prototypes on the same machine that produces the actual product. That way there is no incongruity between the two.

"The next five years will see a big push into metals, with more rapid processes using them. At the moment machines use mainly plastic stock, but a lot of companies want to produce parts in metal."

Meanwhile, at the other end of the market, he predicts that 3D printers will continue to get cheaper. A 3D printer for use in the home could retail for as little as £200 he says. "You will get machines in the home, but they will be for a highly specific market, such as kids' toys," he says. "A child could download the latest model and figure from the internet and produce the model on their own 3D printer."

Medical products will also start to get noticed, Dickens adds. The biological production of soft tissues and replacement skin and cartilage will become available to mainstream patients. Although slightly more macabre, the manufacturing process is very similar, it is just the materials - biological cells - that are different.

Rapid prototyping is evolving into rapid manufacturing, but how it will initially impact remains to be seen. The biggest machine makers are still relatively small compared to other engineering sectors, and he believes it will take a big player to push the technology into the mainstream. "Some big companies have been sitting back and watching the technology mature," he says. "Eventually they will come in and buy up companies and processes for a mass-market product."