Innovation
Additive manufacturing

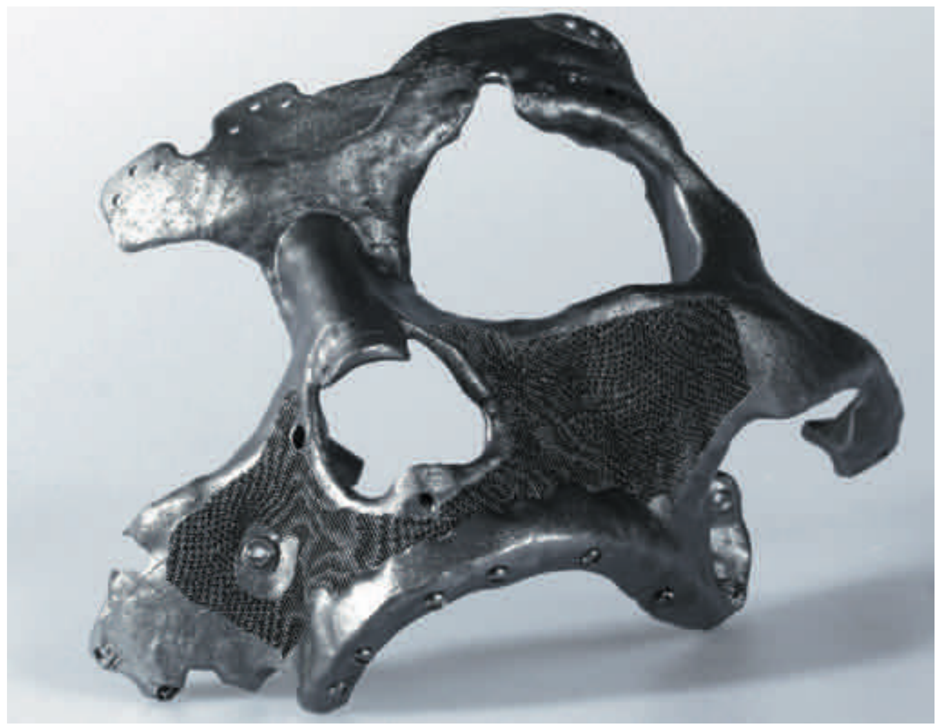
3D printing has proved invaluable in prototyping but has yet to make it big in volume manufacture. For that to happen, the failure rate has to be reduced. **Ben Sampson** reports

Airbus is known for innovation. It uses the latest propulsion technologies and simulation software to make its aircraft more efficient. The company pioneers advanced manufacturing, researches new materials, and pushes the boundaries.

So in the broader scale of aerospace innovation, the unveiling of a new internal dividing wall for the A320 last month was a bit unexciting. A wall, after all, is a wall.

Except this wall was developed in partnership with US software company Autodesk using what it calls "generative design" and 3D printing. Generative design automatically devises thousands of design iterations according to the parameters you input into the computer and chooses the best one. You tell the computer what you want, the size and structural constraints, and it churns out the best design.

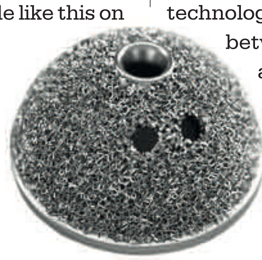
The design the computer produced was biomimetically inspired by the growth of algae. The strange variation in the spacing of the internal supportive struts is due to the structural constraints imposed by the flight attendants' seats and stretcher bench that attach to the wall. Then, on a microscale inside the struts, the generative process produced even smaller lattices, fine-tuned to save weight and provide structural integrity.



Upping the build speed

The process reduced the weight of the wall from 65kg to 35kg, exceeding engineers' expectations. Bastian Schäfer, innovation manager at Airbus, says: "The wall is the first prototype. We are working on improving the printer speed, especially with the microstructures. We have quite low build speeds now, five-and-a-half days, but we believe that printers on the market in three years' time will be quick enough. We will see more components made like this on aircraft from the early 2020s."

Effectively the design is being held back by manufacturing technology, and this situation is replicated across several sectors. Many large companies have small pockets of 3D printing, used for prototyping, but few have been brave enough yet to back the technology for manufacturing. The gap between 3D printing a prototype and additively manufacturing a component or product, even at the low volumes required by the aerospace sector, is vast.



Steve Hobbs, director of development of advanced manufacturing at Delcam, which supplies CADCAM software, says that even when something is additively manufactured eventually it has to undergo a subtractive process: "People are focused on the finished part and how they get there with additive manufacturing, but they forget about how they are going to finish it. You need to think about the entire process

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chain, or you will make it more complicated and costly than it needs to be. We want to ensure people use these additive tools in the most productive way possible."

According to Hobbs, 70% of additive manufacturing fails because of the complexity of the design, bringing the design to the machine or because of weaknesses in the materials. The main challenge is with the interface between the machine and the CAD software, which needs to be able to reliably capture the complexities of a design and consider the materials. Hobbs says: "We should do better than creating an STL file in the 21st century. We don't rely on an STL file with 3D printing machines, we have to directly control the machine to avoid failure.

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Time to build in reliability

Benjamin Schrauwen is director of the Spark 3D printing platform, which offers standards for 3D printing software, hardware, materials and services, and aims to improve the process of designing and additively manufacturing. He says: "There are multiple reasons why failure rates are so high. The machine makers haven't been around that long and they've been making prototype-grade machines. A lot of these technologies were invented in the 1990s. They are old-school manufacturing."

An early adopter of additive layer manufacturing (ALM) is GE, which uses it to produce jet nozzles for aeroengines. According to Schrauwen, the company's engineers buy million-dollar machines, take them apart, rebuild them and recalibrate them before they are used in manufacturing. "It's early days – the hardware needs to become more reliable. The process is poorly understood," he says.

"The workflow to drive these machines has hundreds of parameters that are very process dependent, on the machine, the temperature, the material. That needs to become more productised. A lot is software, and the machines need to become more reliable. But the newer technologies will blow away these problems. Things like multi-material jetting with polymers in a closed-loop process."

Hobbs agrees that more research is needed to understand the fusion process so that the software can maintain paths and certain melt characteristics. He says: "The physics of the process is important. We are incrementally casting. These things are being made over tens of hours, the bottom is cold, the top is hot and it bends – sometimes they tear themselves apart. You have to balance those stresses out or engineer a solution around it that maybe involves heat treatment."

The materials used in 3D printing are at least as important as the process itself. One of the challenges with composites is that it is difficult to see when damage has occurred to the material. Researchers are developing ways of overcoming this.

An area being enabled by ALM is the production of functionally graded objects. The concept takes its cue from nature, where materials that have compositions that vary spatially are commonplace, from bones and beaks to palm trees. Man-made materials are almost always volumetrically homogeneous because they are easier to produce that way. When combined with advanced design methodologies, such as Autodesk's generative design technique, 3D printers that use types of concrete and UV-curable polymers can create products that are lighter yet stronger.

Adoption of ALM also does not necessarily have to be straightforward. Researchers are finding benefits in the development of so-called hybrid machines that combine subtractive and additive technologies.

One application for additive manufacturing is remanufacturing. "For some repairs it is quite a neat solution," says Hobbs. An example that uses Delcam's CADCAM software is a machine produced by Hamuel Maschinenbau. The machine can use five technologies – five-axis CNC milling, laser cladding, robot polishing, inspection and laser marking. Any of these processes can be combined, as required. Changeovers between each process can take less than 10 seconds.

The Manufacturing Technology Centre in Coventry was responsible for the 3D laser cladding element of the machine. Laser cladding is a welding-based method of additive manufacturing, which allows high-integrity material to be deposited onto the part being repaired. Typical applications include the repair of worn blades on impellers, where it is possible to remove the damaged area by milling off the worn material and then to build the material back up using the cladding technology. A second machining operation then produces the final shape, with a smooth transition between the original part and the new material. Polishing and laser marking can be undertaken to complete the component, if required.

However, Hobbs says the usefulness of such machines is undecided: "The jury is still out on whether building hybrid machines is a good idea. One of the biggest concerns is the throughput possible." ■

IN FOCUS **3D PRINTING** CHALLENGES

One of the biggest technical challenges for **3D printing in manufacturing** is that existing machines are too slow. Carbon3D's polymer-based 3D printing machine uses a photochemical reaction triggered by **UV light instead of a mechanical process**. The company says production speeds can be increased by up to 100 times compared to existing 3D printers.

Carbon3D, which is backed by **$100 million investment from Google**, plans to release its first 3D printer to use its patented technology this year.