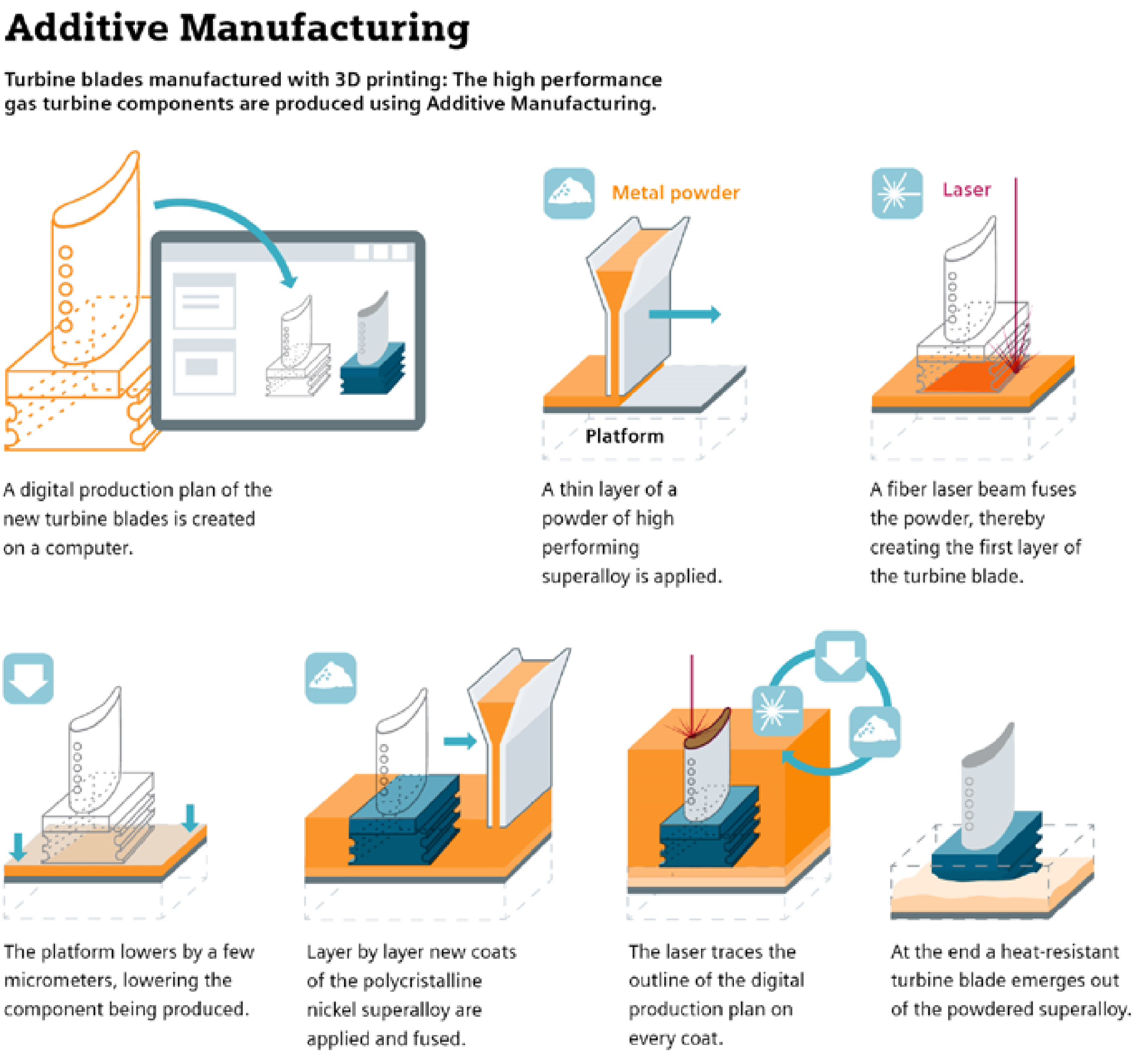
# MicroCT for metal 3D printing

*By Anton du Plessis. Images courtesy of the CT Scanner Facility, Stellenbosch University*

Most people have heard of 3D printing by now, but not everyone knows it can be done with metals. It is actually possible to produce custom and complex designs, similar to plastic 3D print models, in solid metal. This is known as additive manufacturing, and while it is not something for your hobby room or garage, it has been introduced globally in many big companies and is starting to be used in real applications – for example, in Formula 1 racing cars and fighter jets!

The process works by using a focussed high-power laser that is scanned across a surface to melt fine metal powder in a single layer, according to the 3D model. This is followed by lowering the solidified layer, and then adding the next layer of powder and melting this layer on top of the previous one and so on, until the entire model is created in solid metal, surrounded by powder. The part is removed from the powder and processed further to ensure it has acceptable mechanical properties.

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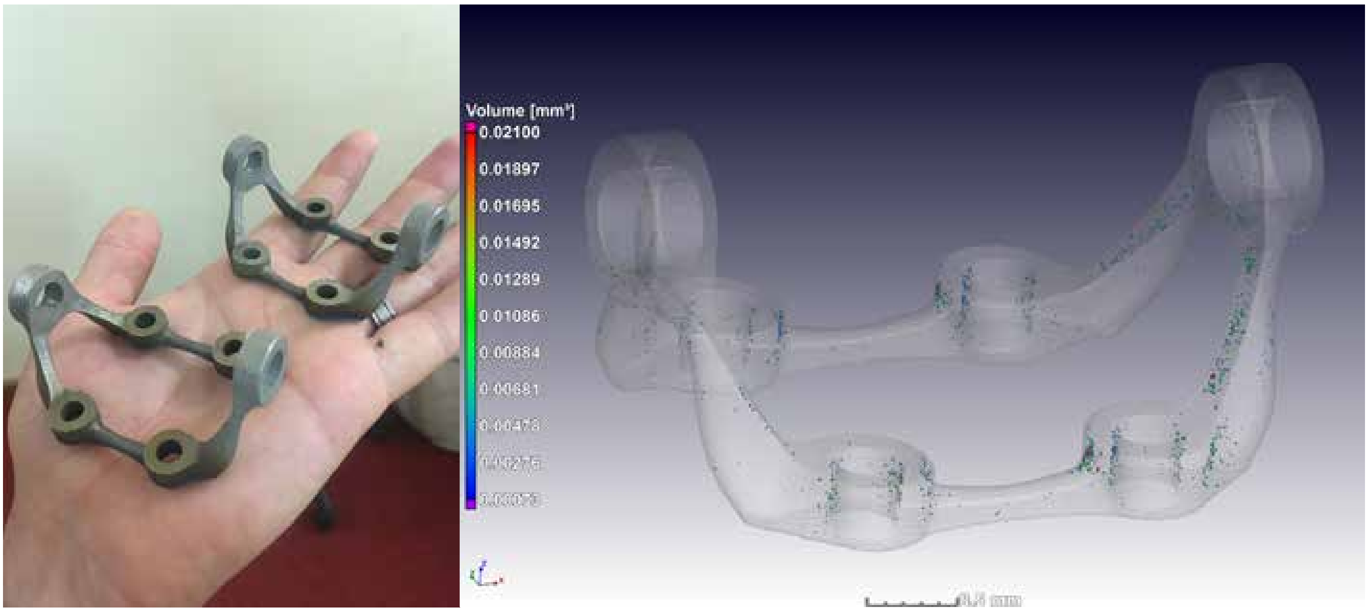
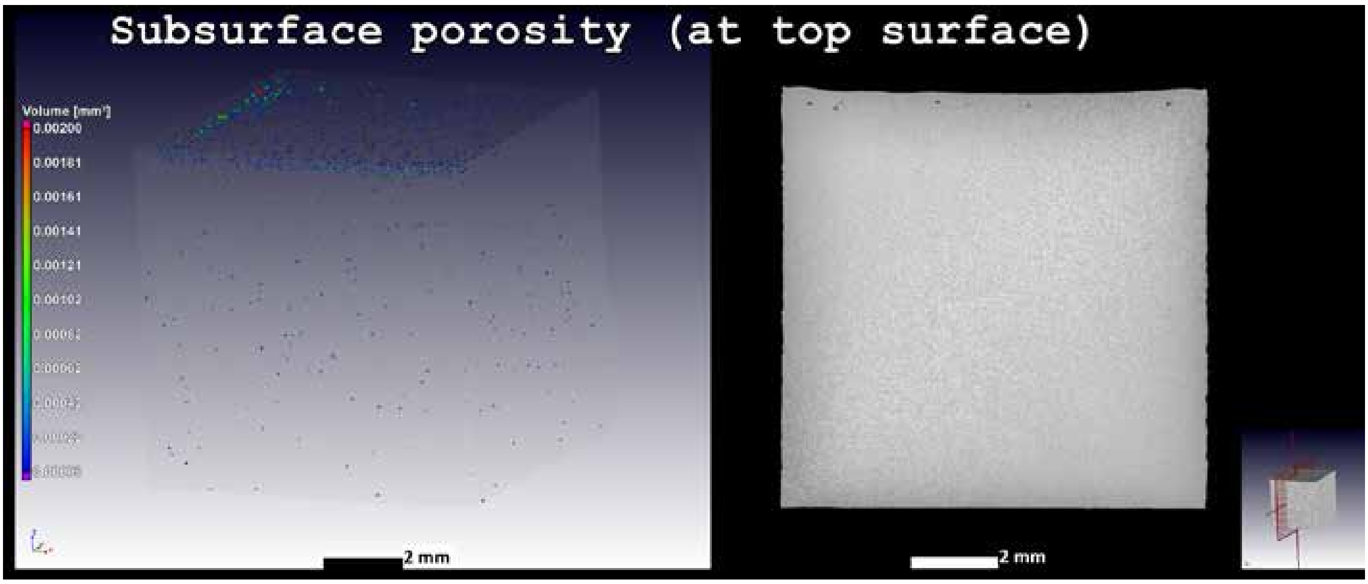



**These titanium brackets were 'additively manufactured' using metal 3D printing and then tested using microCT. The small coloured dots represent porosity of different sizes. These are gas bubbles inside the metal that need to be minimised for optimal quality of the part.**

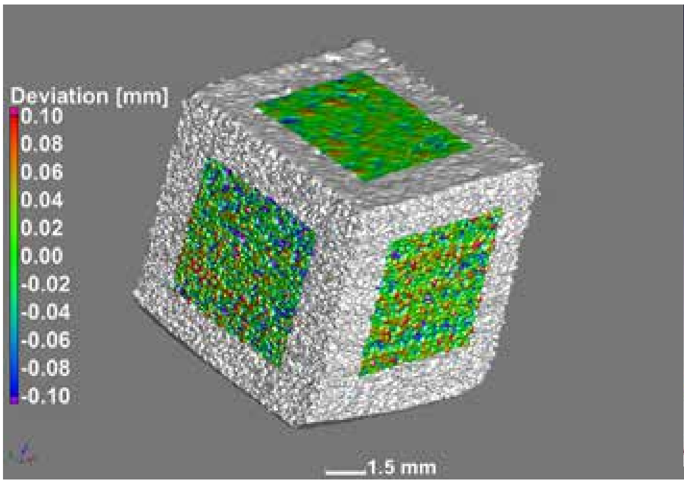
Obviously this is a complex process, with expensive equipment and powder, and many things that can go wrong. In traditional manufacturing, various well-known quality-control tools are used to ensure structural integrity and quality of the final parts. These include dimensional measurements, density measurements, surface-quality measurement, 2D X-ray inspection (digital radiography) and sometimes even 3D X-ray inspection (microCT). By contrast, additive manufacturing relies heavily on microCT, because many of the traditional quality-control tools are difficult to use for these parts. In additive manufacturing the parts are more intricate, so some areas are not accessible, and the internal pores, cracks and other flaws that can occur are smaller. The high-detail imaging capabilities of microCT make it very useful for checking these parts quickly for major flaws.

Besides final quality checks for parts, microCT is also very useful and cost-effective for optimising all the various parameters in the additive manufacturing system before starting to build the parts – in other words, fine-tuning the machine. It allows for easy checking of which parameters result in the minimum porosity and crack formation, with 3D images indicating what could be wrong in the process. During the laser melting of the powder particles, gas bubbles can form in the molten metal region under the laser spot, and then get trapped in the solid metal due to the rapid cooling as the laser spot moves. It can also happen that the laser moves too fast and does not melt enough metal powder, so layers on top of one another do not weld together sufficiently, and even have spaces called 'lack of fusion'. Obviously these two errors have different resulting 'pore shapes', which can be easily seen in microCT images.

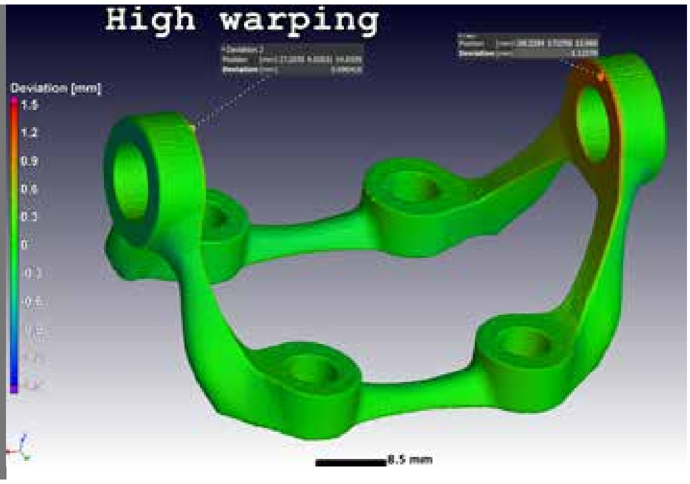
In general, no production method is perfect, and gas bubbles are also present in other traditional parts such as metal castings. In the case of additive manufacturing,




**MicroCT of a 3D-printed titanium cube of 10 mm, shown in 3D with colour coding and in a virtual cross-section to visualise porosity. The pores, represented by black dots, occur mainly near the top surface.**




**Colour mapping of surface roughness of a 10 mm cube, showing side surfaces much rougher than the top surface.**

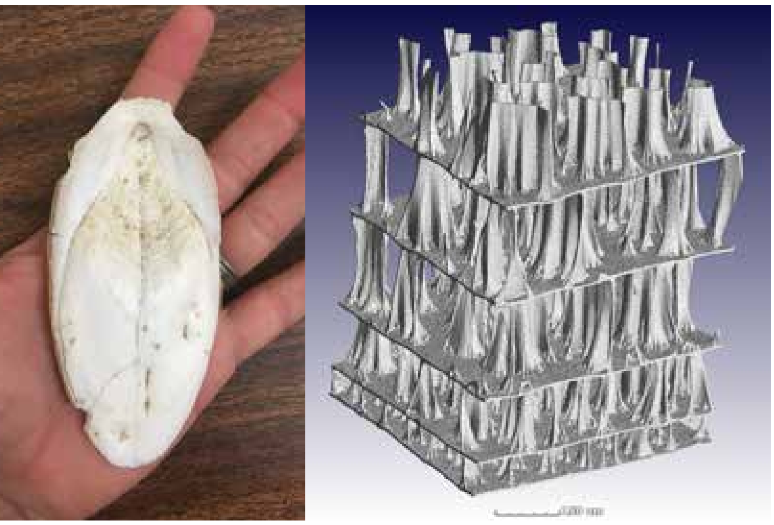



**Colour coding shows deviation of up to 1.1 mm on the right side of the part compared to the CAD design file.**

however, these flaws may be extremely small, while still affecting the properties of the bulk material. MicroCT is therefore crucial in helping to minimise this porosity by adjusting the laser power, scan speed, and other parameters of the additive manufacturing system. By fine-tuning the settings, highly dense parts can be produced with excellent properties.

Besides porosity, the surface quality varies from machine to machine, and even between vertical and horizontal sections on the parts. This can also be measured by microCT and can be used to assess requirements for post-processing, such as smoothing rough surfaces.

More importantly, microCT can be used to detect whether a part has been produced inaccurately compared to the design specification. The example shown here is a bracket that warped inwards by 1 mm on both sides. This happens during the layer-by-layer process if the heat input is not removed fast enough. Irregular thermal distribution results in stress in the material, which causes it to distort or warp and even crack in extreme cases. Although a 1 mm warping seems insignificant, it can be critical for a fighter jet!



**The internal structure of a cuttlefish bone may be a design inspiration for additively manufactured lightweight materials.**

In South Africa there are various facilities with metal 3D printers doing research into new processes and developing new applications, much of this R&D work being supported by the Department of Science and Technology through the Collaborative Programme in Additive Manufacturing (CPAM). These facilities are also making additive manufacturing available to local industry players that recognise the advantage of being able to produce extremely complex parts with exactly the shape needed for the application. These metal parts can have the same strength as a traditionally designed one, but with a fraction of the mass, which is very important for vehicle and airplane efficiency. MicroCT obviously assists in obtaining the best quality for such parts, but it can also help in designing them.

The parts are often visually impressive, with designs resembling natural structures, such as branch-like or spider-web connections. This is where microCT has another role to play – in the design of biomimetic parts.

Biomimicry is the practice of 'learning from nature' to design and produce materials, objects and systems. By allowing nature's designs to be visualised and analysed in full 3D, microCT can assist in the creation of engineering blueprints for new biomimicry applications, many of which could be implemented through additive manufacturing. The protective bony plates in reptiles or overlapping scales in fish, for example, might inspire the development of new kinds of body armour, from bullet-proof vests to shark-proof wetsuits!

- A thorough overview of microCT applications is available online in the open-access publication: Du Plessis *et al.* (2019) Advancing X-ray micro-computed tomography in Africa: Going far, together. *Scientific African* Vol. 3. https://doi.org/10.1016/j.sciaf.2019.e00061

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*For more information, including a variety of microCT case studies, see: http://blogs.sun.ac.za/ctscanner/.*