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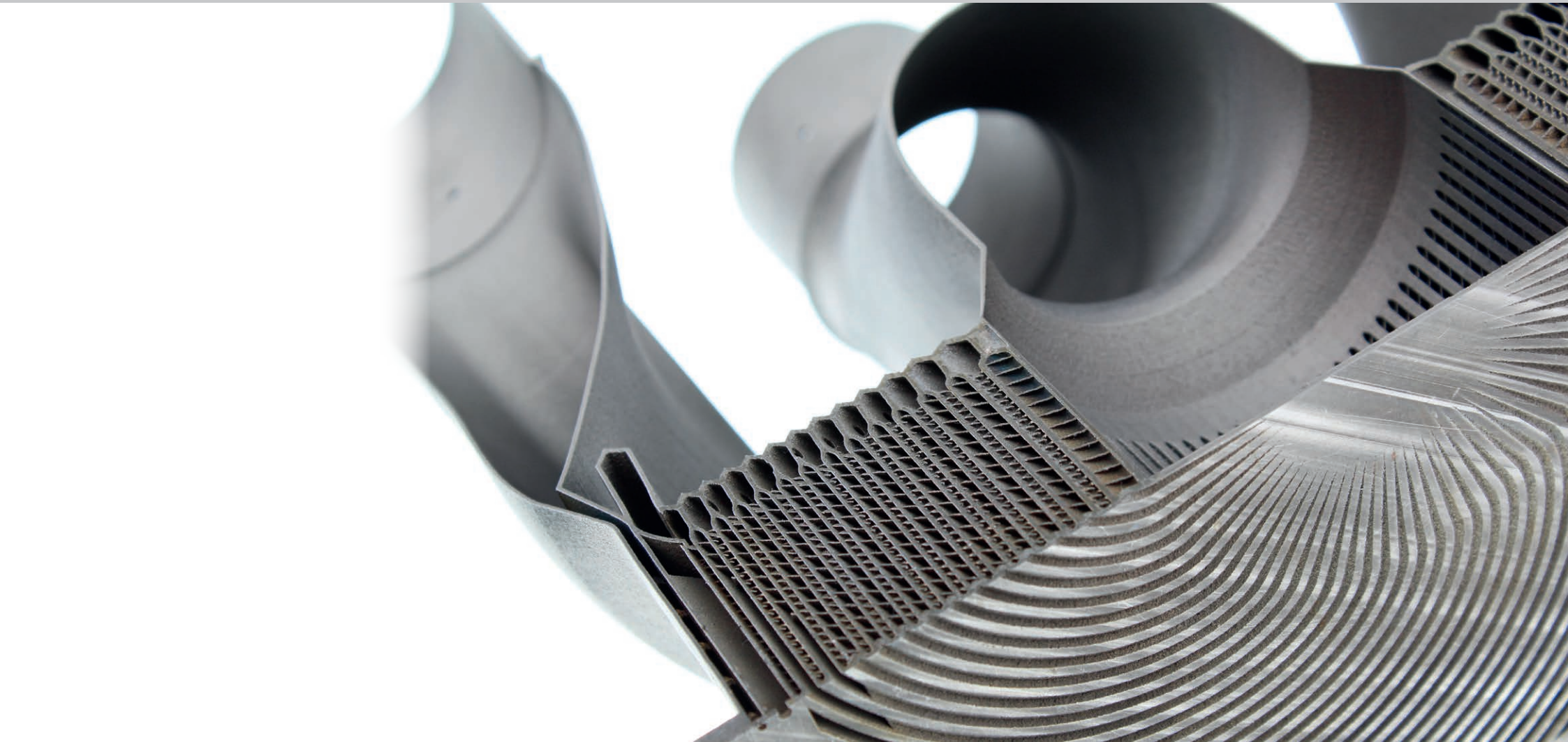
Metal additive manufacturing



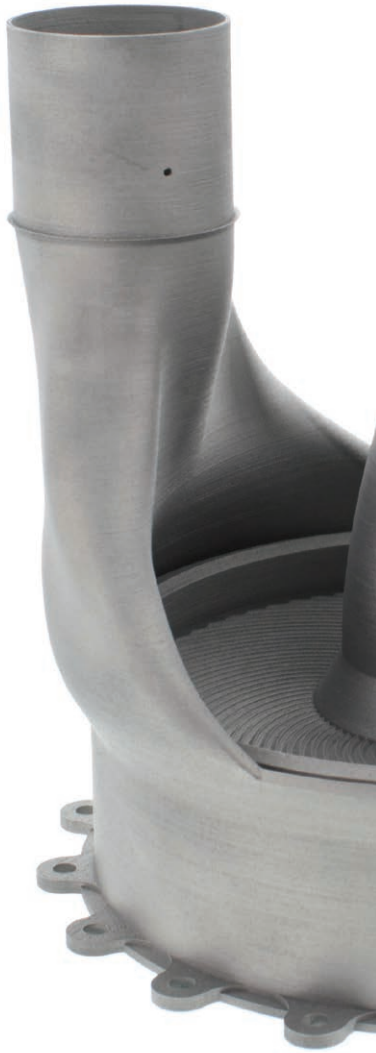


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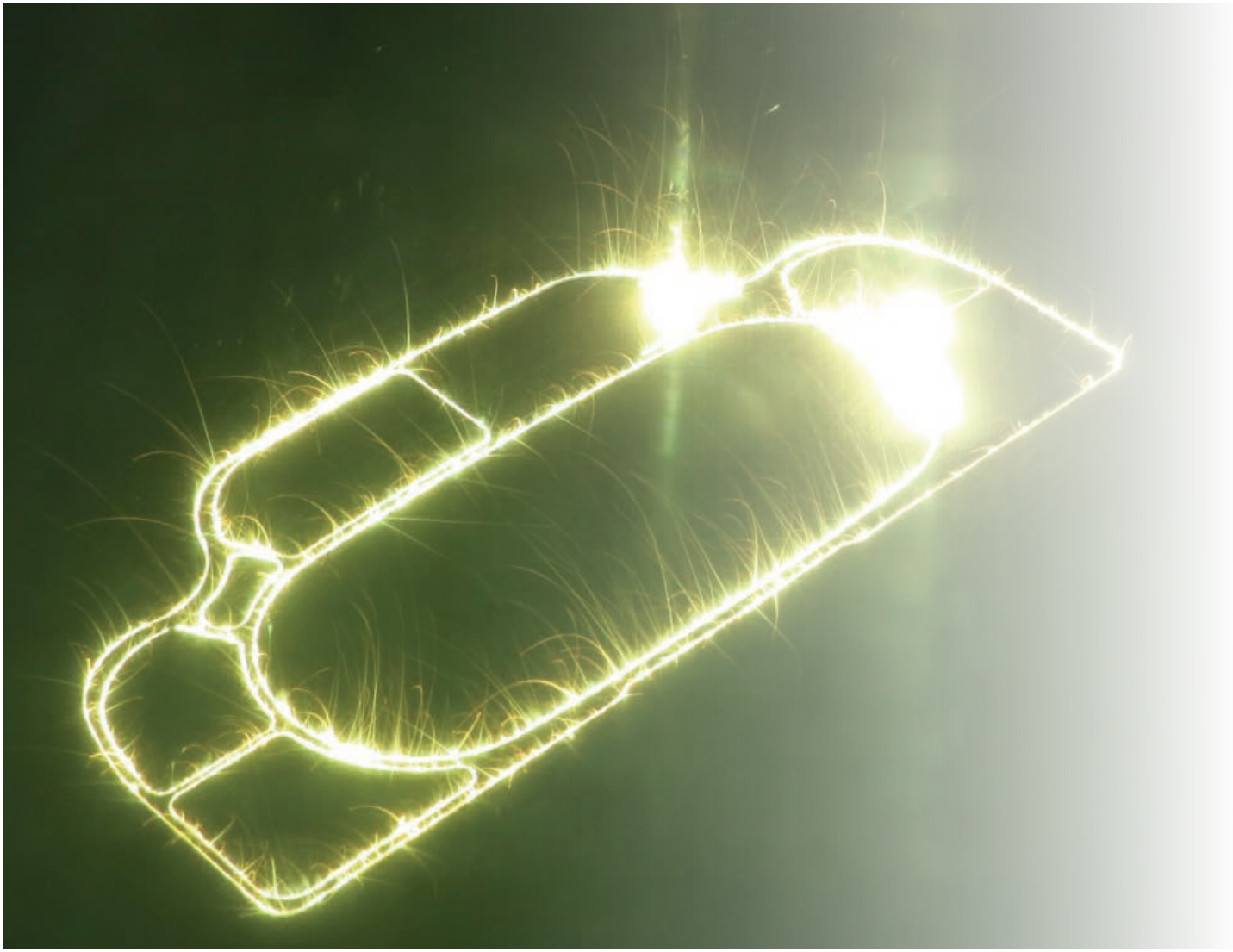
Table of Contents

Front cover, page 2 and page 3 part designed and manufactured by HiETA Technologies Ltd on a Renishaw AM system. An Annular Radial Flow Recuperator for a Microgas Turbine System developed in the Innovate UK supported SLAMMIT project in collaboration with Delta Motorsport Ltd.

Introduction to metal additive manufacturing

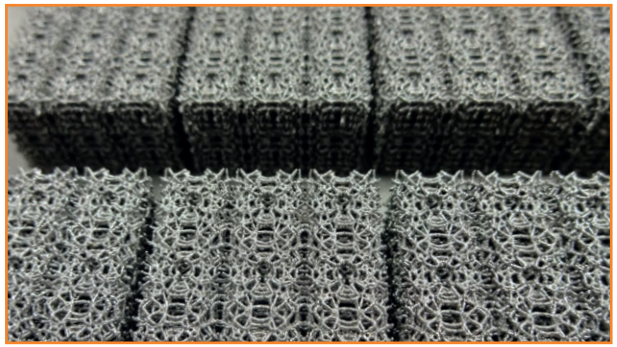


Metal additive manufacturing is the process of creating a 3D object from a CAD model by building it up from thin layers of metal powder, one by one.

The technology can produce complex shapes that are not possible with traditional casting and subtractive techniques, such as machining or electrical discharge machining.

Renishaw designs and manufactures metal additive manufacturing systems, for manufacturing parts in a variety of metals, using a process called laser powder bed fusion.

Metal additive manufacturing highlights

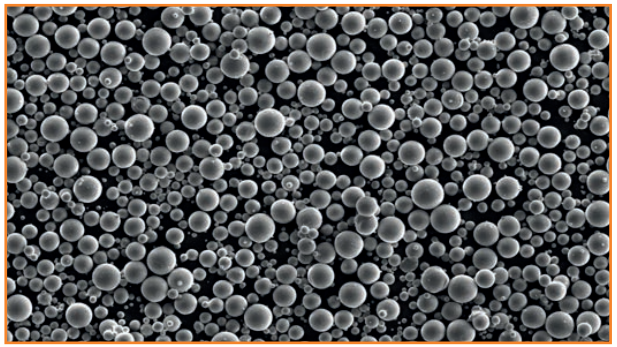


Benefits of metal additive manufacturing

Build complex metal components directly from 3D CAD models.

Renishaw Solutions Centres

Lower the barriers to metal additive manufacturing adoption for your business.

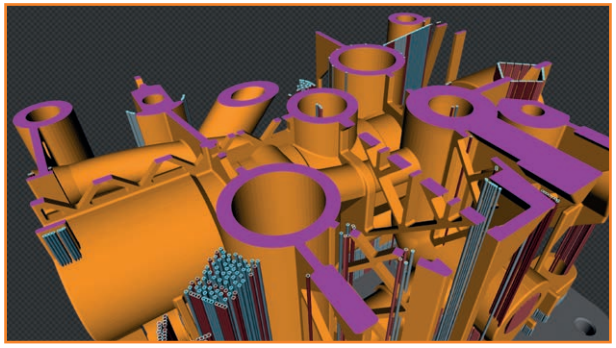


Materials

Renishaw provides a range of high quality metal powders that have been extensively researched and tested.

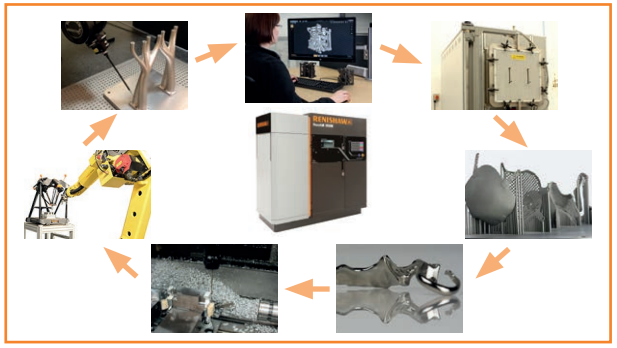
Systems

A range of metal additive manufacturing systems to suit the needs of your organisation.



Software

Renishaw build preparation software – orientate, support, layout and review models before building them in metal.



Renishaw end-to-end engineering

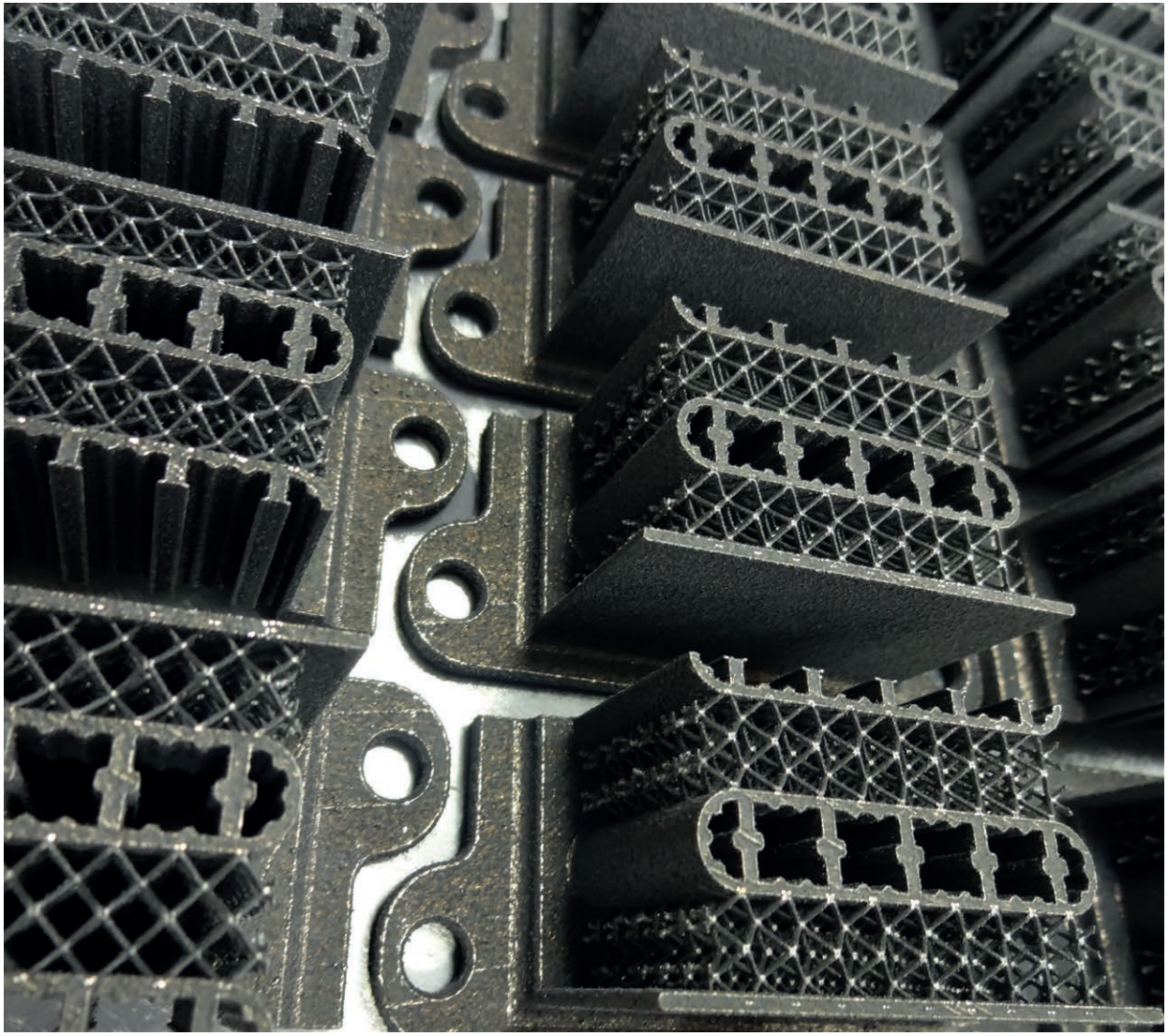
Over 40 years of engineering experience including machining, inspection, gauging and finishing.

The benefits of metal additive manufacturing

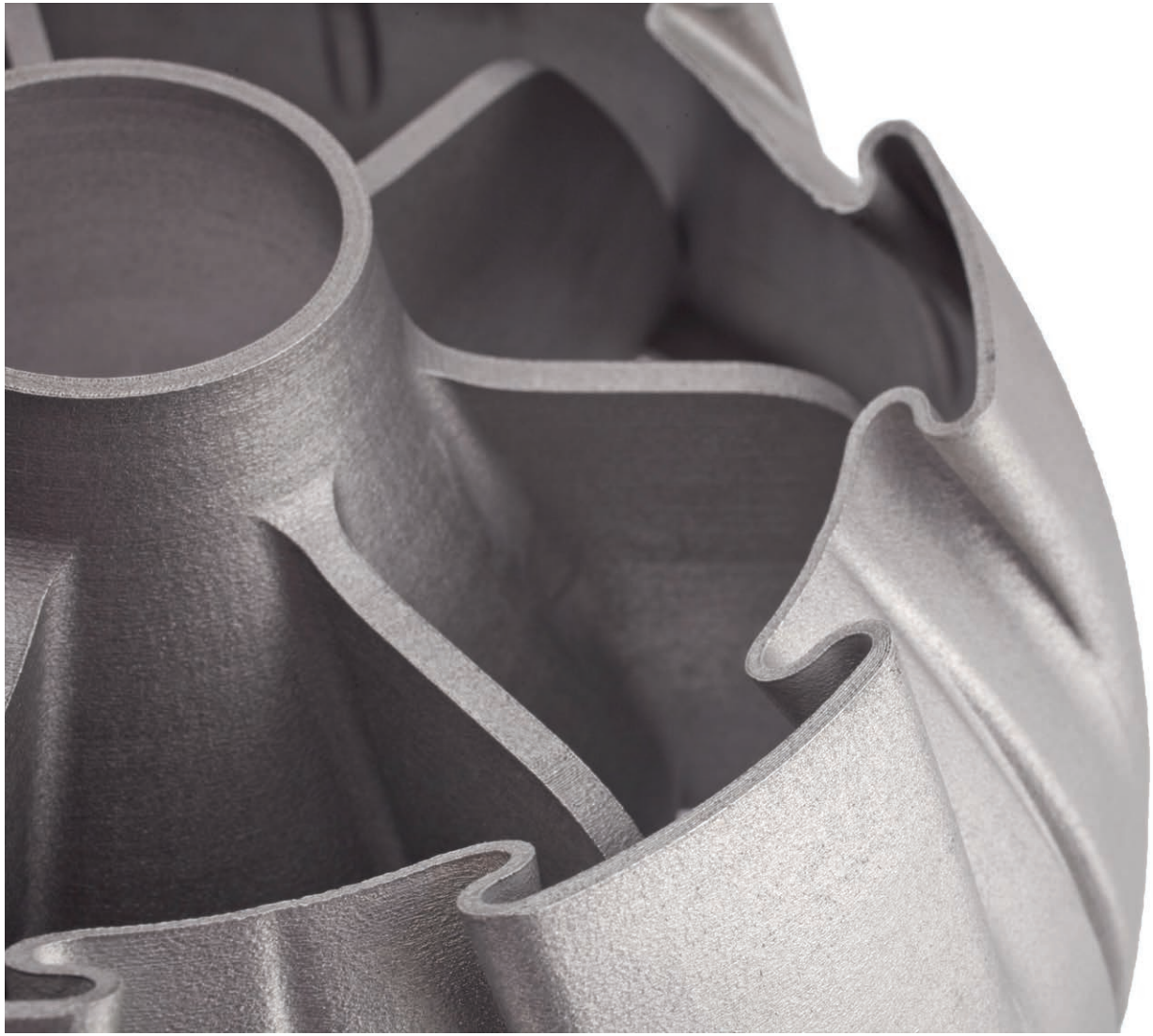
Metal additive manufacturing technology enables the production of highly complex geometries due to the fact that is not constrained by the same rules associated with subtractive machining and other traditional manufacturing techniques.

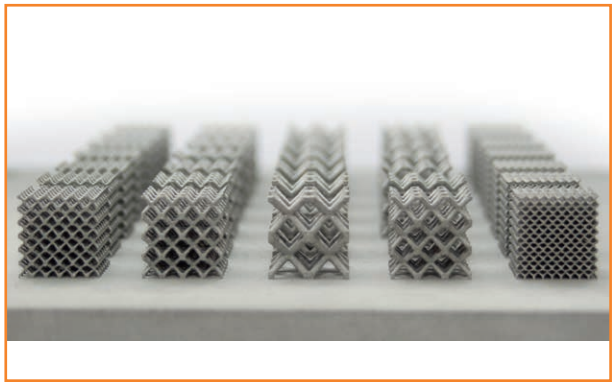
Benefits at a glance:

- Produce complex geometries such as lattice structures and conformal channels to improve performance
- Consolidate multiple parts into single or fewer components to improve reliability and reduce inventory
- Complementary tool – can be integrated into current manufacturing processes to reduce steps, time to market and cost
- Create fully bespoke or customised components to improve performance
- Light weight – only build material where it is needed, reducing waste
- Reduced tooling costs – parts can be manufactured directly without the need for tooling
- Rapid design iterations right up to manufacture



The metal additive manufacturing process



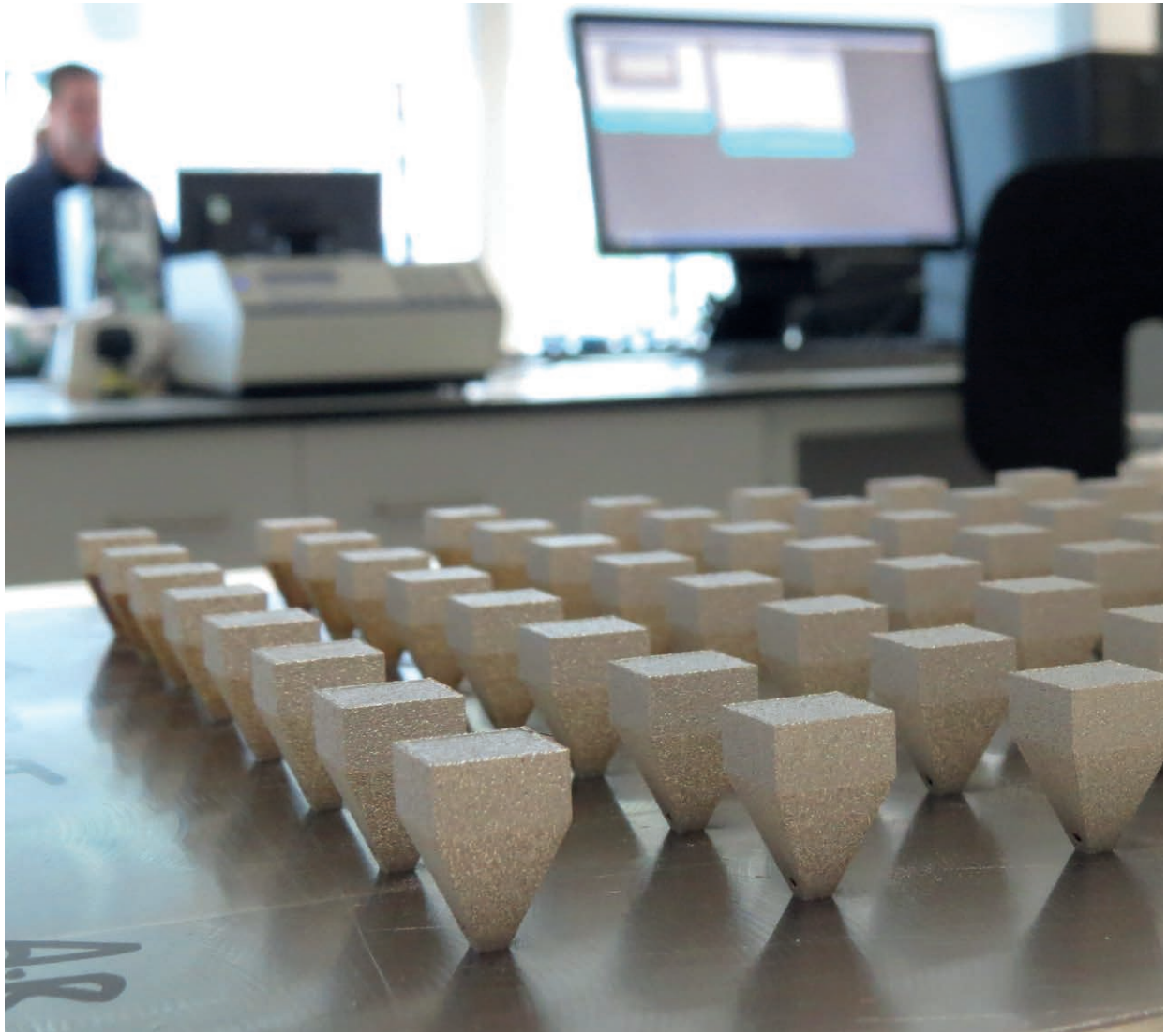


Renishaw's additive manufacturing systems use laser powder bed fusion to build up solid metal components from fine metal powders.

Metal additive manufacturing process at a glance:

- The existing 3D CAD model of your component design is sliced into 2D layers usually between 30 µm and 100 µm thick using specially developed QuantAM software from Renishaw
- A thin layer of powder is spread across a build plate, and a laser selectively melts areas of the powder corresponding to a 2D slice of the CAD data for the part
- The build plate moves down, another layer of powder is spread over the first layer and the process is repeated until the 3D metal component has been built
- The component is post processed as necessary, for example: bead blasting, heat treatment, tumbling and light machining of critical features

Why Renishaw for metal additive manufacturing?

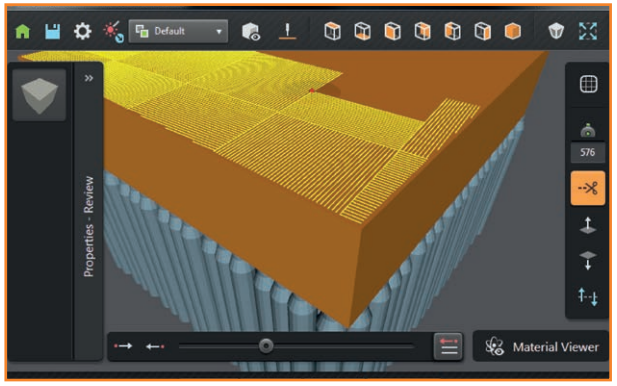


We offer a comprehensive solution for metal additive manufacturing from additive manufacturing systems, metal powders, ancillaries and software through to an expert advice and support service and our Solutions Centres.

Advanced metal additive manufacturing systems are designed, manufactured and optimised by Renishaw to fulfill a range of industry applications where durability, customised parts and precision are key.

Why Renishaw for additive manufacturing at a glance:

- Over twelve years experience designing and manufacturing additive manufacturing systems
- Class leading inert atmosphere generation and low argon consumption
- Vast process development experience, including our own healthcare production facility certified to ISO 13485
- Open parameter ethos, and the software tools to support and exploit this



Renishaw expertise in metal additive manufacturing

Renishaw has more than twelve years experience in the metal additive manufacturing industry.

Our expertise in process development and our experience in using the technology in our own manufacturing operations enables Renishaw to provide turn-key and optimised metal additive manufacturing solutions for a broad range of applications, including industrial and healthcare sectors.

Talk to Renishaw to find out more about metal additive manufacturing systems and services for your industry.

Renishaw additive manufacturing expertise at a glance:

- Applications engineers and engineering support
- Design for additive manufacturing support
- Metal powder development, specification and supply
- In-house powder analysis and metallography laboratory
- Research, design, development and manufacture of systems
- End-to-end process chain manufacturing
- Software

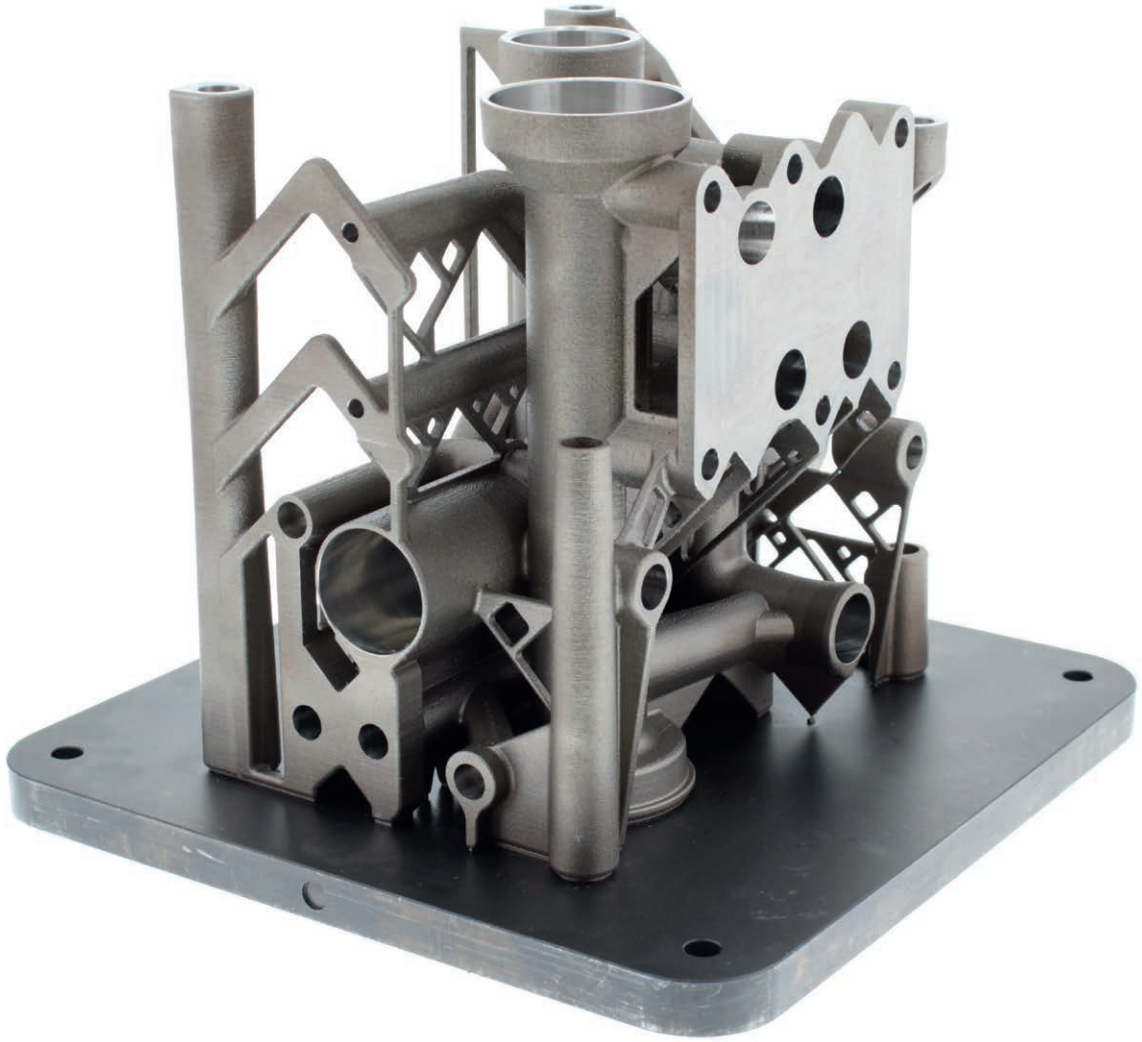
Design for additive manufacturing – DfAM

To achieve best results with any manufacturing process, design engineers must balance the requirements of the application against the limitations of the process. Additive manufacturing is no different, and while there is significantly greater design freedom afforded by laser powder bed fusion, this freedom is not limitless.

DfAM is a subset of a wider DFM quality approach that aims to reduce lead-time, material waste and the number of design revisions necessary to bring a product to market. The ability of AM to generate near-finished parts directly, allows a significant reduction in tooling design and manufacture requirements – thus speeding up development cycles. There remains, however, a need to consider down-stream processes such as: heat-treatment, machining, surface finishing, anodising etc.

Products that have been designed for additive manufacture:

- Have build-orientation taken into account early in the design
- Have minimal over-hanging surfaces in need of further support
- Consider down-stream processes
- Offer significant benefits over designs produced using any other manufacturing process



In-source not out-source

For Renishaw, research and development has always been at the heart of our business, typically investing between 13% and 18% of sales turnover on R&D and engineering to maintain our leadership position.

At a glance:

- Technology – additive manufacturing systems fully designed and manufactured by Renishaw in the UK
- People – strong apprentice and graduate recruitment schemes, with year-on-year increases in recruitment numbers
- Innovation – long term commitment to invest heavily in research and development, to deliver innovative new products
- Partnerships – strong research and development relationships with several universities and research institutes

Renishaw Solutions Centres – lowering barriers to metal AM adoption

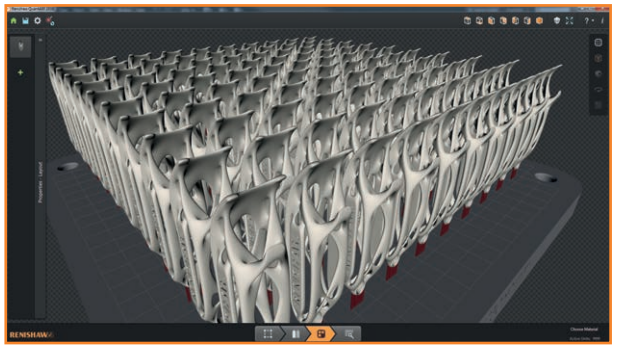
Renishaw Solutions Centres aim to lower the entry barrier to metal additive manufacturing by providing a secure development environment in which you can build your knowledge and confidence using metal additive manufacturing technology.

Equipped with the latest Renishaw metal additive manufacturing systems, and staffed with skilled, experienced and knowledgeable engineers, Renishaw Solutions Centres offer you a fast and accessible way to rapidly deploy this exciting technology within your business.

The pathway to innovative additive manufacturing products:

- Design for additive manufacturing concept – the concept embodies additive manufacturing benefits
- Proof of concept – benchmark components show tangible benefits
- Process validation – optimise the process and verify components
- Process capability – demonstrate process stability
- Production deployment – additive manufacturing and finishing processes to make saleable products

For the brochure, visit **www.renishaw.com/solutionscentres**



Renishaw Solutions Centres – lowering barriers to metal AM adoption

Renishaw will support you throughout your investigation and business case development process, helping you to optimise your design, build your confidence in the metal additive manufacturing process, and gain the evidence you need to make investment decisions.

Solutions Centres capabilities include:

- Additive manufacturing systems and expertise
- Applications engineering expertise
- Finishing, including heat treatment, machining and inspection
- Incubator cells
- Private offices
- Materials laboratory
- Powder management
- Pre-production
- Process development
- Dedicated machine operators

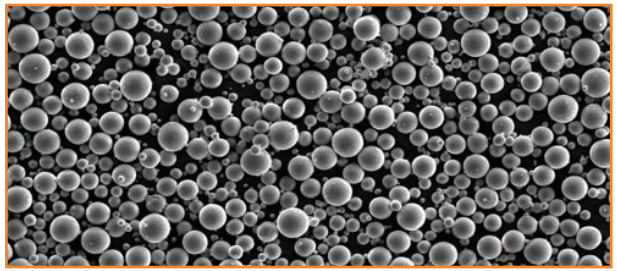
Materials

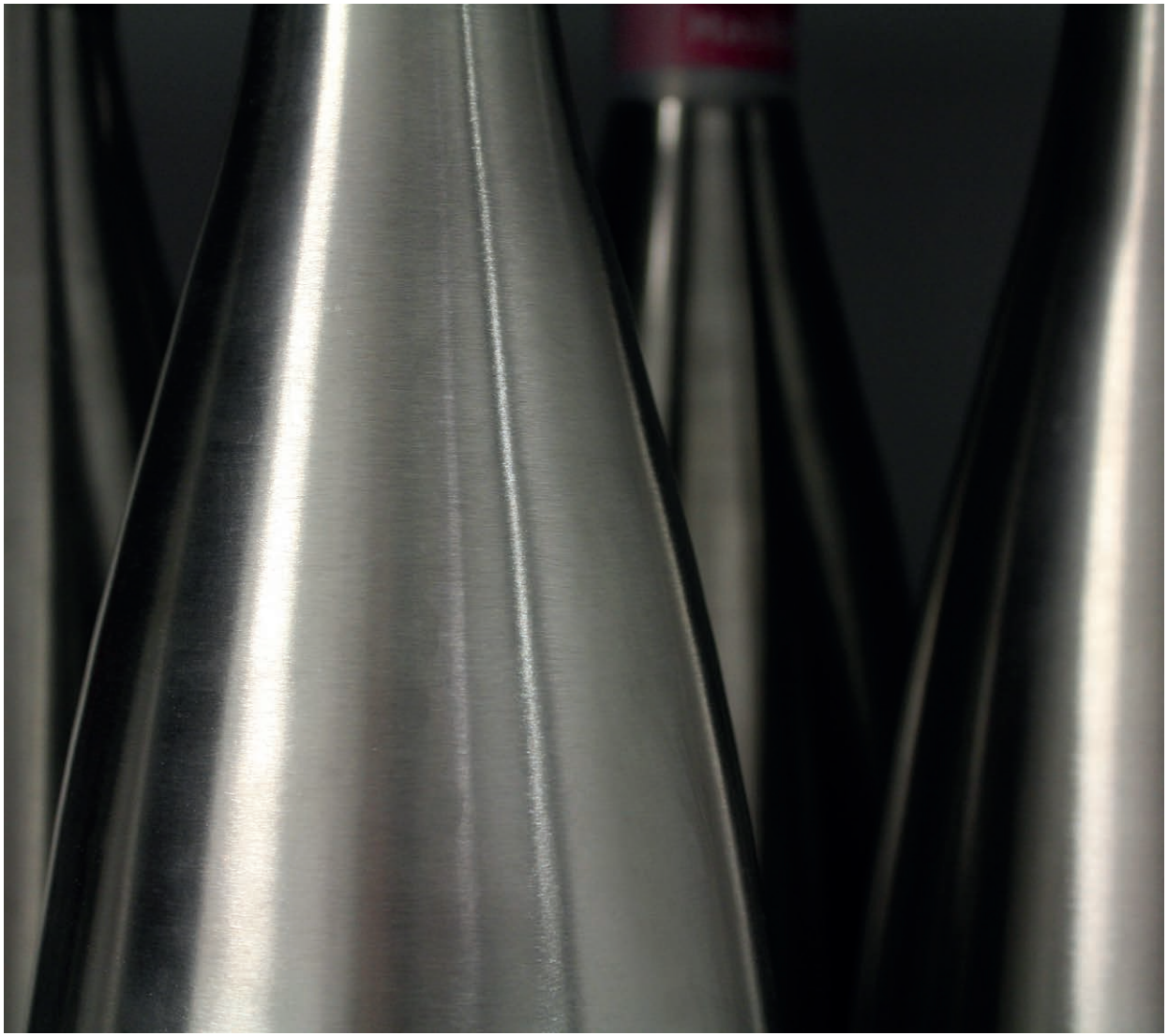
For optimum performance of Renishaw additive manufacturing systems, Renishaw recommends use of its extensively researched and tested range of metal powders, these include:

- Aluminium alloy – AlSi10Mg
- Cobalt chromium
- Maraging steel
- Nickel alloys – INCONEL® 625-2 and 718-6
- Stainless steel – 316L
- Titanium alloy – Ti6Al4V

Powder characteristics are very important for successful laser powder bed fusion. Renishaw makes sure that the powders supplied for their additive manufacturing systems are of the highest quality. Good flow, close packing of particles and spherical particle shape are all important characteristics that lead to consistent and predictable powder dosing and fusion. Renishaw's laser powder bed fusion systems use metal powders with particle sizes that range between 15 microns and 45 microns.

Renishaw supports open system and powder specifications, which can be supplied upon request, to enable you to develop your own system parameters for the application you are developing. Renishaw can also support your own material supply chain development activities.





Healthcare

To help support the adoption of additive manufacturing in healthcare, Renishaw actively uses additive manufacturing systems in the production of healthcare products in an ISO 13485 environment. This helps us understand the challenges and demands of a production environment.

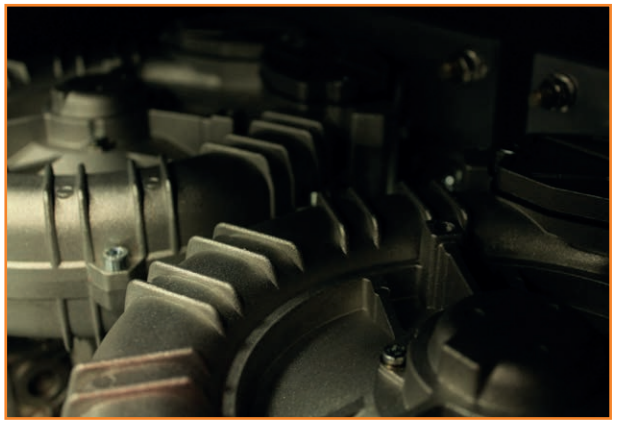
The capability of additive manufacturing to produce complex features and accurate parts makes it highly suited to the production of bespoke medical and dental components.

Orthopaedics and dental devices are just some of the areas in which additive manufacturing is being used, with many more applications possible.

Features at a glance:

- Biocompatible materials
- Complex geometries
- Customised, bespoke components
- Patient specific surgical guides
- Surface features which encourage osseointegration

Metal additive manufacturing systems



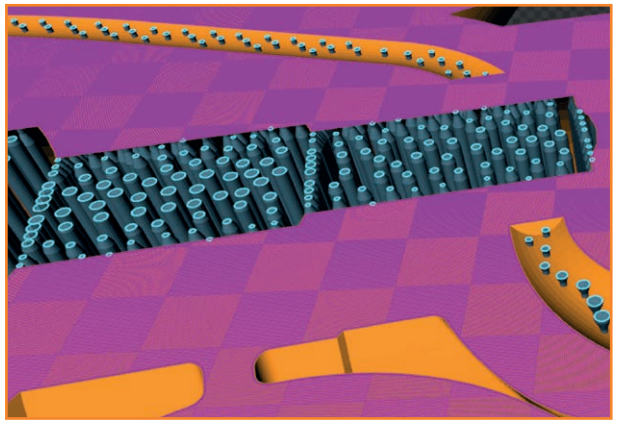
Renishaw offers comprehensive solutions for metal additive manufacturing, including software, hardware, peripherals and services.

Renishaw additive manufacturing systems feature: class leading low argon gas consumption, a small footprint, inert powder handling, an open parameter ethos, over forty years of engineering experience and a global service and support network – over 70 offices in 35 countries.

Systems at a glance:

- Metal additive manufacturing systems
- Ancillary equipment
- Expert advice
- Global support services
- Metal powder supply
- Systems software
- Training

Software



Renishaw's QuantAM file preparation software enables you to quickly and easily prepare CAD models for building in metal.

QuantAM also features powerful intuitive tools for process development and is tightly integrated with the system control software to provide easy access to process data.

QuantAM software guides you through the four steps of build preparation to create additive manufacturing system readable files to enable manufacture in a range of metals.

Build preparation steps at a glance:

- Orientation – set the angle of the component relative to the build plate
- Support – apply sacrificial material to support the component on the build plate
- Layout – rapidly arrange your components on the build plate to optimise space
- Slice – generate the machine code and, directly view scan paths and exposure data

Renishaw end-to-end engineering

Manufacturers in many fields apply Renishaw's world leading metrology systems to verify and control their processes.

As an experienced manufacturer itself, Renishaw has expertise in precision machining, finishing and treatment processes, which are essential complements to additive manufacturing.

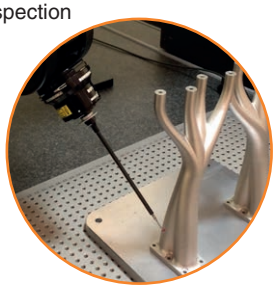
Our approach is to work with you and to develop an end-to-end process that optimises the performance and cost of your innovative new product.

End-to-end engineering at a glance:

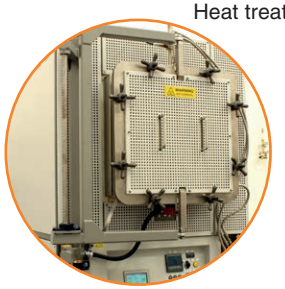
- Precision measurement and process control
- Position and motion control
- 3D laser scanning and measurement
- Healthcare
- Scientific
- Additive manufacturing
- Rapid prototyping

Design for process know-how

CMM inspection



Heat treatment



Metal additive manufacturing

Automated gauging

Supports removal

Machining

Polishing

Building partnerships

Renishaw has worked extensively with a large number of organisations across a range of different industries to help them understand how additive manufacturing technology can bring improvements to their products.

Renishaw also works with partner organisations, either as lead or participant, in funded or co-operative projects to show the benefits that additive manufacturing can bring.

Industries, projects and lead partners include:

- Aerospace – WINDY – Airbus
- Aerospace – Horizon (AM) – GKN
- Automotive – FLAC - HiETA Technologies Ltd
- Medical – ADEPT – PDR
- Science – Accelerated Metallurgy – Sintef
- Metallurgy – AMAZE – MTC (Manufacturing Technology Centre)

Global support

Renishaw believes the quality of support you receive is just as important as the quality of the products you buy. Renishaw is committed to supporting customers throughout the world via an extensive network of wholly owned Renishaw offices and distributors, with 70 offices in 33 countries.

If you are investing in your first additive manufacturing system, or if you are upgrading to the latest technology, Renishaw can support you. We've developed all elements of our own manufacturing processes, including additive manufacturing, enabling us to provide excellent technical service and support.

Renishaw account managers and service engineers are renowned for their pre and post sales support. Buying new equipment can be a major investment and keeping it running is often key to the profitability of a business, which is why Renishaw gives fast responsive support.

For more information or to tailor a support package to your exact requirements, please contact your local Renishaw office for detailed information on the options available.

For worldwide contact details, visit **www.renishaw.com/contact**

Renishaw ethos

"Renishaw fundamentally believes that success comes from patented and innovative products and processes, high quality manufacturing, and the ability to provide local customer support in all its markets around the globe."

Sir David McMurtry
Chairman and Chief Executive

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About Renishaw

Renishaw is an established world leader in engineering technologies, with a strong history of innovation in product development and manufacturing. Since its formation in 1973, the company has supplied leading-edge products that increase process productivity, improve product quality and deliver cost-effective automation solutions.

A worldwide network of subsidiary companies and distributors provides exceptional service and support for its customers.

Products include:

- Additive manufacturing and vacuum casting technologies for design, prototyping, and production applications
- Dental CAD/CAM scanning systems and supply of dental structures
- Encoder systems for high-accuracy linear, angle and rotary position feedback
- Fixturing for CMMs (co-ordinate measuring machines) and gauging systems
- Gauging systems for comparative measurement of machined parts
- High-speed laser measurement and surveying systems for use in extreme environments
- Laser and ballbar systems for performance measurement and calibration of machines
- Medical devices for neurosurgical applications
- Probe systems and software for job set-up, tool setting and inspection on CNC machine tools
- Raman spectroscopy systems for non-destructive material analysis
- Sensor systems and software for measurement on CMMs
- Styli for CMM and machine tool probe applications

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