Renishaw fact sheet: additive manufacturing

What is 'additive manufacturing'?

- Additive manufacturing (AM) is a term used to describe the technologies that build 3D objects from a digital model by adding layer-upon-layer of material in different 2D shapes.
- The principle of additive manufacturing can also be known by other names, including ALM (Additive Layer Manufacturing), 3D printing, rapid prototyping and laser melting or sintering.

How does the technology work?

- A 3D object is designed using CAD design software. This file is then converted into the required type used by the 3D printing / additive manufacturing machine, using a file preparation software interface.
- The geometry is divided into individual slices of constant thickness creating a 2D representation of the object.
- The additive manufacturing system is filled with the desired material, which may be plastics, metal powders, wood, or even chocolate! These consumables are used by the 3D printer to 'print' the final object, layer by layer.
- Various materials require different systems for fusing the layers together. On metal systems the materials are atomised metal powders that are fully melted to join the layers together.
- Renishaw's additive manufacturing machines distribute a layer of metallic powder evenly across a build plate within the machine's build chamber. The powder is then fully melted to the layer below using a high powered ytterbium fibre laser. This builds up the shape in a 2D cross section by guiding the laser across the powder bed to fuse the metal powder.
- The process is repeated, building up complex geometries, layer by layer, until the part has been completed.

How does additive manufacturing compare to traditional manufacturing techniques?

Traditional (subtractive) manufacturing techniques rely on the removal of material through cutting, milling and drilling. This results in:

- High levels of wasted material.
- Long product lead times.
- The requirement for tooling and fixtures.
- Complex, multi stage processes.
- Component complexity is limited by process tooling paths.

What are the advantages of additive manufacturing?

- Minimal wasted material.
- Consoliated assemblies of parts.
- The ability to create previously unachievable complex shapes and geometries such as internal pathways, voids and structures.
- Designers can easily create completely bespoke / customised models and objects.
- Topological optimisation: reduce weight by optimising part geometry based on design loads.
- Complex parts that previously would have been manufactured separately and joined together due to geometric restrictions, can now be made as a single piece.

What industries currently use additive manufacturing?

- Automotive: passenger, commercial, motorsport.
- Aeronautical: civil aerospace, space.
- Consumer: fashion, jewellery, lighting, furniture, entertainment, art.
- Medical: customisation of implants, bone, teeth, hearing aids, surgical guides.
- Power and communications: sonar body, housing, fuel cells.
- Production and manufacture.

What are the current limitations of additive manufacturing?

Whilst additive manufacturing has great potential it is still a relatively new technology and there are key areas for improvement and consideration when adopting the technology. These include:

- Surface finish and accuracy:
  Component anisotropy can become an issue dependent on layer thickness and orientation of a surface, which can result in 'stair stepping' (i.e. ridges appearing in the final component as a result of the layer building process).
  Whilst part finish is improving it is still not comparable to that of subtractive systems.

- Process speed:
  Building layer by layer can be a time consuming process, particularly for larger component manufacture.
- Size of components that can be produced are limited to machine chamber size.
- Skills shortage:
  A completely new design process must be considered when (re)designing a component for additive manufacture. Aspects such as structural integrity, material properties, part orientation and component weight must be fully understood to ensure the process is effective. The technology and its advantages and limitations must be widely understood for additive manufacturing machines to be used for industrial applications on a widespread basis.
- Software:
  The software used by additive manufacturing machines can seem complex, and it will need further development as the manufacturing process advances. A lot of existing CAD software is designed for more traditional manufacturing techniques, and interfaces can be unintuitive and hard to use, particularly for non-experts.
- Expense:
  As with other new technologies, additive manufacturing machines can represent a sizable capital investment, which may be prohibitive.
- Standardisation:
  There is a requirement for international standards and practices for additive manufacturing which will enable performance measurement, monitoring and assurances. Standard practices will also facilitate partnerships between users and system manufacturers and help the technology and usage to continue to develop.

Designing for the process

Through the utilisation of additive manufacturing it is possible to optimise the design of components and objects, so as to optimise design and weight: one way of achieving this is topological optimisation.

Topological optimisation

Topological optimisation software is the term given to programs that are used to determine the 'logical place' for material. Material is removed from areas of low stress until a design optimised for load bearing has evolved. The resulting model represents a component that is is both light and strong, but can look unconventional.

Examples of design optimisation

Renishaw have used design optimisation techniques in their work with the BLOODHOUND Supersonic Car project creating a prototype nose tip for the car which will attempt to beat the 1000 mph speed barrier in 2015. For more information please see **www.renishaw.com/bloodhound**.

Renishaw have also collaborated with a leading British bicycle design and manufacturing company, Empire Cycles, to create the world's first 3D printed metal bike frame. Through the use of topological optimisation the new titanium frame is 33% lighter than the original. Read the case study at **www.renishaw.com/empirecycles**.

Current research and future developments

The properties of different materials used in additive manufacturing bring advantages and new compromises to the final component. Research is currently being conducted into the use of new alloys for additive manufacturing that are designed to bring additional performance advantages.

As a partner in the AMAZE project, Renishaw, along with the European Space Agency, Airbus, and others have worked to develop alloys and processes, including tungsten alloy components capable of withstanding temperatures of over 3000 °C.

Research and development is also going into other aspects of additive manufacturing, including process speed, improvements in strength, and fatigue resistance within the final component.

This mountain bike was developed by Renishaw and Empire Cycles using additive manufacturing