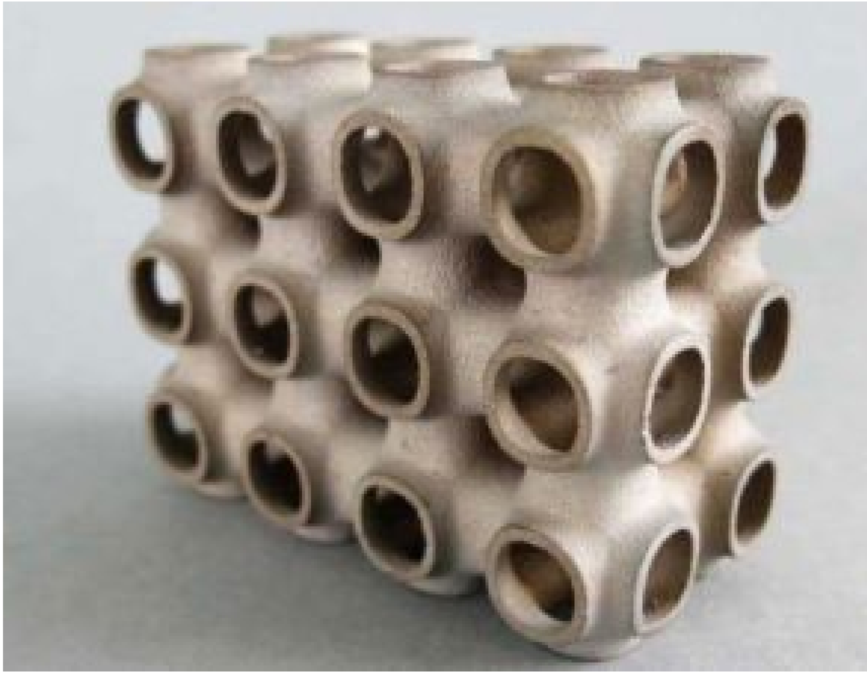
3D Printing with Metal Powders

Metal additive manufacturing (AM) has been steadily gaining traction in the manufacturing industry. At present, there is a big focus on advanced aerospace, medical and military products. There is a drive to reduce the cost of metal powders in order to open up the technology to a larger portion of the manufacturing industry. There are numerous metal printing technologies available, and the vast majority make use of metal powder. Some of the more common 3D printing machines are listed in the following section.



Different types of 3D metal printers

- **SLS & SLM** – Selective laser sintering (SLS) is one of the most common 3D metal printers, it works by depositing a layer of metal powder and then tracing out the cross-sectional shape of the part with a laser. This action sinters the powder to the previous layer. The process repeats with the next layer, and so on. Selective laser melting (SLM) is a similar process, but instead of sintering the particles, they are melted together, creating a stronger, more dense part.
- **EBM** – Electron beam melting (EBM) is a highly advanced process that is similar to SLM systems. The difference is that the build volume is held in a vacuum, and instead of a laser a focused electron beam is used to fuse the particles together. The vacuum build volume makes it possible to print reactive metals like titanium.
- **DED** – Directed energy deposition (DED) is a method whereby the metal powder is delivered to the bed plate via nozzles, and is melted with a laser at the required location. This process is ideally suited for intricate repair work on existing components and it is limited in its material availability.

How is metal powder made?

Metal powders are the most superior metal 3D printing material, as they allow highly irregular designs to be manufactured with ease and allow the simplification of previously complex assemblies.

Metal powder is made in 3 main processes as listed below. All of these processes are a form of gas atomisation.

- **Gas Atomisation** – The base material is melted and is then fed into the atomization chamber. Gas is introduced into the top of the melt chamber and thus forces the melt through a ring nozzle where it comes into contact with gas that then disperses and atomises the melt. The spherical particles are collected at the bottom of the chamber.
- **Plasma Atomisation** – Plasma atomization is a relatively new technique for making metal powder and works by feeding wire from a spool into contact with plasma torches which then melt the material. Gas is simultaneously blasted into the melt to disperse and atomise it. The spherical particles produced are then collected at the bottom of the chamber.
- **Electrode induction melting gas atomisation** – This process is best suited for reactive materials like titanium. The material is fed into the atomisation chamber in the form of bar stock, this material is rotated while it moves through an induction coil which melts the material. The melt then falls down where it is atomised by a gas stream. The spherical particles are collected at the bottom of the chamber.

Characteristics of metal powders

Metal powders are characterised by their particle size distribution as this will determine the minimum layer height that is achievable. The particle size, purity and shape are very important factors in determining the quality of a powder. The more spherical and contaminant free the particles, the higher the quality of the powder.

It must be noted that the mechanical properties of parts made with powdered metals in a laser sintering or laser/electron beam melting processes are not as good as the base material.

The final strength achieved will depend on the process being used. However, the strength of many 3D printed metal parts can be compared to that of cast parts. It should also be noted that many high stress components are made using the metal powder process and thus the mechanical properties achieved are often 'good enough' for the application they are being designed for. In all cases, accurate mechanical properties must be determined by doing tests.

Grade of metal powders

Almost any metal can be atomised for use in metal additive manufacturing machines. A comprehensive list of suitable materials can be found here. Some key metal groups and their metal powders are listed below:

Titanium

- **Ti-6Al-4V** – This titanium alloy is the most widely used titanium alloy and is characterised by excellent corrosion resistance. Due to its versatility it is used in anything from sporting equipment to aerospace components. The ELI-A version is designed for use in laser powder bed processes whereas the ELI-B version is designed for use in electron beam melting processes.

Cobalt

- **CoCr F75 –** This alloy consists of cobalt and chromium. This material is used extensively in the medical industry for implants as well as for turbine components. It is characterised by high wear resistance and stiffness.

Steel

- **316L –** This is a widely available grade of steel and is used where higher corrosion resistance is required. It is also characterised by high creep strength at elevated temperatures. It is used extensively in maritime applications where a high corrosion resistance is essential. This material can be used in laser power bed electron beam melting and directed energy deposition machines.
- **H11** – This is a hot work tool steel optimised for laser bed fusion applications. It has excellent impact toughness and thermal fatigue cracking resistance. This powder is designed for use on laser powder bed machines.

Nickel

- **Ni 625 –** This alloy is a nickel chromium alloy more commonly known as Inconel and is an advanced aerospace alloy used for turbine blades and jet engine components. Inconel is characterised by its high strength and corrosion resistance.
- **Ni 230 –** This Nickel alloy consists of chromium, tungsten and molybdenum and is ideally suited to high temperature applications. It can withstand high temperature environments for long periods of time.

In conclusion

The range of machines making use of metal powder for 3D printing is continuously increasing, thus opening up a multitude of new applications. With improved and optimised manufacturing processes, the price of the powders used in these machines will continue to fall. Furthermore, with improvements in the manufacturing processes, the mechanical properties of these powders will approach that of forged materials.