IN THE KNOW

TUNGSTEN COMPONENTS - 3D PRINTING VERSUS TRADITIONAL MANUFACTURE
CHOOSING BETWEEN TUNGSTEN ALLOYS MANUFACTURED USING POWDER METALLURGY OR 3D PRINTED TUNGSTEN COMPONENTS.

TUNGSTEN ALLOYS

Tungsten is a popular engineering material because of its very high density and radiation shielding properties. However, it has an exceedingly high melting point (3422°C) which makes traditional methods of manufacturing, such as casting, impractical. As a consequence, powder metallurgy techniques have been developed to produce tungsten heavy alloy. This process combines tungsten powder with binders such as Ni-Cu and Ni-Fe, capable of liquid phase sintering. It removes the need for extremely high processing temperatures that would otherwise be required to melt the pure metal. In addition, it increases the ductility and machinability of the sintered product. At 90-97% tungsten content the alloys are still able to deliver the desired high density and radiation attenuation.

FORMED PARTS ARE SINTERED IN A FURNACE

STEMS IN THE MANUFACTURE OF WOLFMET TUNGSTEN HEAVY ALLOYS

- Powder mixing - Raw tungsten powder is mixed with other metal powders that have lower melting points such as nickel, copper or iron. The desired grade is determined by weight, application and industry standards.
- Pressing - The blended metal powder is pressed under high pressure to form a specific shape as close as possible to the geometry of the final part in order to minimise material, time and energy waste.
- Forming - Basic machining known as forming is carried out to cut the “green” unsintered pressing into semi-finished shapes. This reduces the amount of material to be machined off after sintering, minimising material usage, costs and machining time.
- Sintering - Formed parts are sintered in a furnace which converts the pressed powder into the solid composite metal alloy and increases the density of the material.
- Machining - The sintered alloy is machined into the final parts using standard CNC machining.
- Quality Control - Prior to dispatch parts are inspected for dimensional tolerance, traceability, density and any additional customer requirements.

TUNGSTEN ALLOYS - BENEFITS AND APPLICATIONS

Components manufactured from tungsten alloy have a high density and excellent radiation attenuation properties. They are also non-toxic and can be recycled at the end of life. The high density means they are used extensively in applications where mass is needed in a restricted space, for example in the nose and wings of aeroplanes. Similarly, tungsten alloy components are favoured in high performance motorsport where space, weight and balance are crucial considerations. It is worth noting that suppliers of tungsten alloy for the aerospace industry are expected to have AS9100 certification.

The high density of tungsten alloy allows it to deliver excellent radiation attenuation. This has made it a natural choice for shielding and collimation in nuclear applications such as containers for isotopes and molecular imaging scanners. It gives designers a significant advantage, allowing them to reduce the thickness of their shields and collimators, while maintaining the same attenuation levels as can be achieved with lead.

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ACHIEVING NEW GEOMETRIES

Today, major advances in nuclear industries including nuclear fusion and nuclear medicine are driving demands for the manufacture of more complex designs such as coded aperture masks.

The geometry of these designs is beyond the capabilities of conventional milling and turning. Consequently, experts have turned to additive manufacture, with the preferred method for metals currently being Selective Laser Melting (SLM).

SLM obviates the need for part-specific tooling or reproduction costs, and because it operates from computer aided design software it allows rapid iterations of design without associated materials costs.
SELECTIVE LASER MELTING TUNGSTEN

SLM uses a laser beam that melts and fuses pure tungsten powder together. A thin layer of powder is deposited over a substrate plate and the laser beam melts and fuses the particles selectively. This operation is repeated and successive layers are built up until the part is complete. A number of process parameters have to be carefully tuned in order to fabricate a defect-free part. The most important process parameters include laser power, laser scan speed, hatch distance, layer thickness and scan strategy.

The entire SLM process takes place inside a closed chamber which is filled with an inert gas such as nitrogen or argon. Once complete, post processing operations to ensure stress relaxation of materials are applied pre or post removal of the part from the substrate plate via wire cutting.

THE ADVANTAGES OF SLM TUNGSTEN VERSUS TRADITIONAL MANUFACTURE

As with traditional manufacturing, when tungsten is selective laser melted it retains its heat resistance, density and excellent radiation attenuation. However the process also offers additional advantages such as:

1. Production of complex shapes and geometries not possible using traditional manufacturing methods
2. Topology optimisation to save weight and material usage
3. Consolidation of multiple parts into a single component
4. Rapid prototyping
5. Efficient usage of materials through powder recycling
6. Elimination of tools and moulds

As per point 1 this process allows for the manufacture of exceptionally thin walls down to a measurement of 0.3mm. Smaller measurements are possible but consultation is required.

Taking point 2 as an example, traditionally, milling and turning operations have created finished tungsten components by removing unwanted material from a rough semi-finished part. This inevitably creates costly waste material which can only be recycled using a specialist process. It is also time consuming. SLM, has almost zero waste, as the final product is built up layer by layer, with minimal finishing required.

The possibilities opened up by the introduction of SLM have been embraced by many industries. In particular, the mix of excellent radiation attention and complex geometries has captured the imagination of the medical imaging community. SLM has proven to be ideal for the manufacture of high-precision components such as collimators and radiation shields in imaging modalities such as CT, SPECT, MR and X-ray. In particular, collimator designers have found a SLM tungsten collimator significantly reduces septal penetration in comparison with the same collimator made from lead – resulting in a reduction of artefacts and much improved image quality.

A study saw experts from the University of Liverpool – Department of Physics, and The Royal Marsden and Royal Liverpool University Hospitals work to develop a dosimetry system (known as DEPICT). Using a SLM manufactured collimator as the imaging component; the aim was to better quantify the absorbed radiation and help facilitate personalised cancer treatment planning.

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THE CHALLENGES FACING SLM

Many of the geometries achieved through SLM are extremely complex and either could not be produced using traditional manufacture or could only be done at great cost in time and money. In this respect SLM is a relatively cost effective process. However, 3D printing tungsten is an exciting innovation that only a handful of experts have mastered. In addition the machines are expensive and have specific laser build parameters. More work is needed to validate the mechanical and thermal properties of SLM output, develop standards for SLM-built materials and find suitable methods for non-destructive evaluation and inspection of final components and relevant post processing operations.

Tungsten presents particular technical challenges in SLM because of its high melting point, high thermal conductivity and affinity for oxygen at high temperatures. However a number of academic and commercial units, in the UK and abroad, are moving the science behind this technique forward rapidly and beginning to achieve consistent and complex builds.

Despite the challenges, the team at Wolfmet have been successfully manufacturing components with complex geometries for a range of applications via Wolfmet 3D, their unique SLM process.

SUMMARY

When comparing SLM of tungsten with traditional manufacture of tungsten heavy alloy, the main advantages of the additive manufacturing process are:

- The production of highly complex component designs with geometries not possible with traditional CNC machining
- Reduced time from design to production of finished item
- Reduced development costs with no tooling charges
- Minimal waste as the parts are not cut from larger tungsten bars
- No large storage requirement to stock inventory because parts can be printed on demand

Currently some of the challenges for SLM are achieving surface finish and consistent material and mechanical properties throughout a component build. The industry has yet to define universal quality standards. It is however a rapidly advancing new technology and it will not be long before these hurdles are overcome.

SLM of tungsten is not a substitute for the conventional manufacturing process of tungsten heavy alloy but it is a process that allows the production of parts that are outside the scope of subtractive manufacturing methods.

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