Steel standing

Gill Thornton and Dr Xinjiang Hao MIMMM at Liberty Powder Metals reflect on how digitally enabled additive manufacturing can transform the steel sector.

Liberty Powder Metals

Steel serves as the foundation for many industry sectors. Globally, demand for steel has increased enormously, reflected in crude steel output from 200Mt in 1950 to 800Mt in 2000, doubling to over 1.6Bt in 2015, according to World Steel.

Despite fast-growing market demand, the global steel industry has been facing severe challenges since the 2008 financial crisis, largely due to over-capacity in China and regulatory pressure, such as the Kyoto Protocol and Paris Agreement on climate change.

Challenges the UK steel industry faces include dumping from the Far East, high energy costs and a historic lack of investment in new technology and production facilities, all, of course, made more challenging with the COVID-19 pandemic.

Powder potential

Additive manufacturing (AM) is a clean manufacturing technology. It is hoped that AM could significantly reduce material waste and CO_2 emissions throughout the steel value chain. It has been identified by the UK Government as a strategic manufacturing technology in the *Additive Manufacturing UK National Strategy 2018-2025*.

It offers significant benefits over many conventional production methods – unrivalled design freedom, material freedom, print-on-demand production flexibility and low material waste.

In 2018, Liberty Steel established Liberty Powder Metals (LPM), in Middlesborough, UK, as an independent innovation incubator to produce high-value metal powders. It is supported by the Tees Valley Combined Authority (TVCA) and located in the Materials Processing Institute site, with access to expertise on every aspect of materials technology, from thermodynamic modelling and physical testing to life cycle analysis.

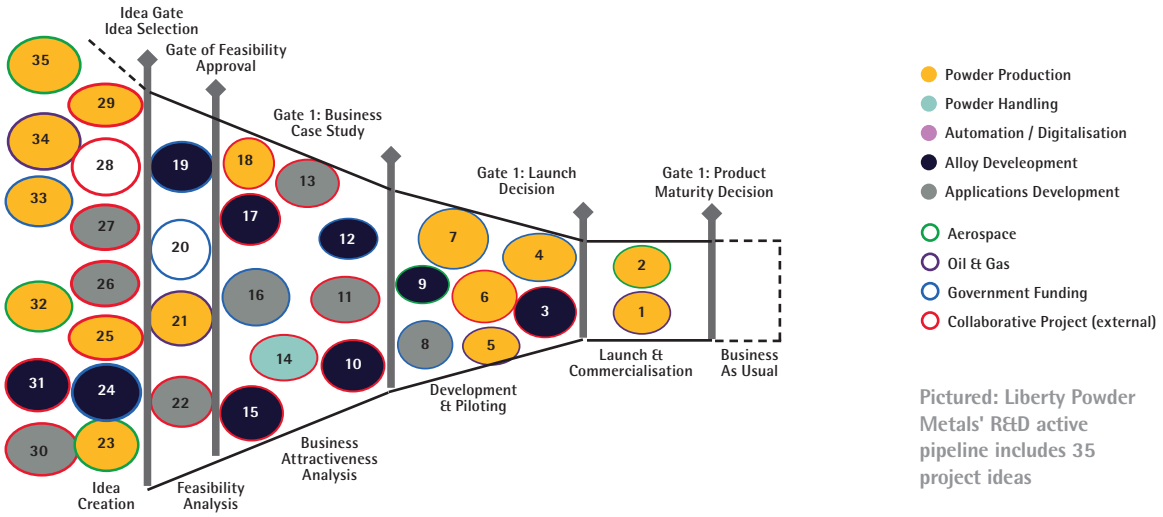
Here, LPM has produced advanced steel, cobalt and nickel alloy powders with one Atomising Systems Limited/Consarc 250kg batch size vacuum induction melting atomiser (VIM) with anti-satellite technology.

Above: Liberty Powder Metals' atomiser plant in Teesside, UK

Phase by phase

Liberty Powder Metals (LPM) uses the phase-gate approach to help convert innovative ideas into practical applications and new products. The approach enables a continuous flow of innovation and product creation to be maintained. It has many benefits, including:

- Visibility to the balance of process or product ideas, the market and whether it is a collaborative project with external parties or government-funded. For example, currently LPM is focused on improving the atomising process, including yield and particle size distribution for the specific alloy and application, so there are a lot of yellow circles (see figure below) in the phase gate at the moment, almost half of the current 35 ideas.
- It is easier to present or share progress with the wider business and externally, therefore enhancing discussion and collaboration between cross-functional teams and with partners and, consequently, encourages buy-in to the projects.
- Helps identify and eliminate potential risks or errors in the project life cycle.
- Contributes to better decision-making.
- Maximises value creation.
- Ensures innovation remains closely aligned to the organisation's strategic objectives.



Pictured: Liberty Powder Metals' R&D active pipeline includes 35 project ideas

Liberty Powder Metals

The advanced modern atomiser is designed to enable highly spherical, extremely free-flowing, steel and non-ferrous alloys, including powders specially designed in combination with customers to meet their specific AM needs.

The powder shape and flow properties are controlled through use of the anti-satellite technology. Flexible powder sieving is set up to provide particle sizes from 15µm-150µm, suitable for a variety of high-value powder applications, with all handling, sieving, blending, sampling and packaging carried out under inert atmospheres to minimise oxygen pick-up. A state-of-the-art powder characterisation laboratory has been installed to give a suite of standard powder analysis techniques to provide particle size distribution, Hall/Carney flow, density, and powder chemistry.

The output means we are now looking to establish AM powder metal and AM applications as a core centre of excellence. Furthermore, having been awarded the EN9100:2016 manufacturing quality management system approval, we are now able to supply into the aerospace sector.

This new initiative is an attempt to change the industry's value chain position from a lower margin material supplier to a high margin engineered solutions provider by tapping into metallurgical and testing knowledge and skills, alongside product design experience. The goal is to create a full vertically integrated AM supply chain, including design, powder production, part fabrication through directed-energy deposition and laser powder bed fusion, post-processing through hot isostatic pressing and machining, and inspection.

To reach the goal, LPM has allocated 25% of its first VIM atomiser capacity, equivalent to 100t or 400 melts per annum, to research and development. Over the past year, the firm has engaged with over 20 external UK companies, universities and real-time operating systems, and had funding support for several projects from Innovate UK, the Department for Business, Energy and Industrial Strategy, TVCA and The Royal Academy.

Some of the R&D project work is presented on the following page.

Innovate UK-funded projects

Innovate UK has funded several LPM R&D projects over periods of three months to two years, both in collaboration with other companies and real-time operating systems, and independently.

One of these projects linked the recycling of high-value alloys to net-shape technologies through powder metal to enhance resource efficiency and reduce environmental impact of metal component manufacture. Through the recently completed SATURN (Superalloy Atomisation Trials Using Revert and TurNings) project, LPM was able to show that waste metal turnings can be cleaned, briquetted and melted in the VIM atomiser. The resulting high-purity nickel alloy or stainless steel powders could be used in high-end applications including AM. Gramme for gramme, the recycled metal is worth ten times more at the end of the atomisation process than it was at the beginning.

Another project used computational and experimental modelling of the atomiser to improve the powder yield during production, giving economic and environmental benefits. A further initiative is focused on developing specific grades for use in AM where traditional alloy compositions are not suitable.

Tees Valley Combined Authority (TVCA) Funding

The TVCA has helped LPM establish itself in Teesside while critically awarding a grant to enable R&D work to begin prior to the business making powder sales and becoming commercially viable. The grant was mainly used to develop the process know-how and focused on raw materials, atomiser modelling, powder handling and characterisation of LPM's and competitors' powders.

Royal Academy Chair sponsorship

LPM is sponsoring a Royal Academy of Engineering Chair at Lancaster University, UK – Professor Pedro Rivera. The Chair's focus is alloy and microstructure design for additive layer manufacturing, and aims to develop advanced metallic alloy formulations especially tailored to AM technologies.

This is possible by relating the unique AM microstructures with enhanced properties, as compared to wrought counterparts. An example is the ability to tailor strength and plasticity in stainless steel by controlling the microstructure, a result of carefully tailoring process parameters (e.g. scan speed and layer thickness), and then relating them to alloy composition.

Correlating processing, microstructure and properties in AM products will lead to enhanced build/component performance. The Chair currently works in developing alloys to enhance the performance of stainless steels (austenitic and precipitation hardened systems), as well as nickel alloys which fits with LPM's manufacturing strategy.

UK Government-funded Future Leader Fellowship

Dr Xinjiang Hao, Principal Scientist at Liberty Powder Metals, will lead the UK government-funded Future Leader Fellowship on 'Additive manufacturing: driving the steel industry into the digital age (AM-Steel).' Having worked both in industry and academia, Hao intends to apply his experience of the steel sector and supply chain and research knowledge of powder metallurgy and AM to a range of materials (steel, titanium and nickel alloys) and industrial sectors, and the aim is to drive the steel industry to embrace disruptive digital manufacturing technologies, of which AM plays a key role.

Hao will help shape the future investment plans at LPM and develop the knowledge and skills required to implement a complete, successful AM supply chain, including part design, powder alloy design and production, AM part production, post-processing and inspection.

University/Catapult collaborations

Hao is also leading a powder alloy development programme in collaboration with Warwick Manufacturing Group (WMG) at the University of Warwick, UK. It involves extensive thermodynamic modelling. Progress has been made to understand the metallurgical change during powder production and the net-shape and AM processes, resulting in six joint publications with researchers in industry and academia, and two oral presentations at World PM2018 and Euro PM2019.

A key aspect is that alloys with fine grains generally have better mechanical properties – strength, ductility, toughness, fatigue etc. AM is a net-shape process, so no further grain refining process (such as rolling, forging) is involved. It is important to control grain size during solidification through alloy design. Recently, Hao has developed a world-first fine-grained stainless-steel product (shown opposite), developed through alloy design to control the grain size utilising the unique characteristics of the AM process.