Optimising metal powders for additive manufacturing

Powder rheometry can be used to ensure that metal powders for additive manufacturing deliver the performance and consistency required in demanding applications. Jamie Clayton, Operations Director of Freeman Technology Ltd and Rob Deffley, R&D Manager of LPW Technology Ltd, explain.

As additive manufacturing (AM) becomes increasingly established across a number of industrial sectors, efforts continue to exploit its wider potential for the efficient production of complex, precisely dimensioned components. Currently AM is widely used in prototyping, to produce components with 'form and fit'. Moving to the point of being able to engineer functionality into a component requires exacting control of the process, of the performance of the AM machine and of the powders used. The manufacture of high performance components for applications in the biomedical, aerospace and automotive industries, exemplifies the need for precise and consistent control across the production process.

This article describes how LPW Technology Ltd, a global supplier of metal powders to the AM industry, is using the FT4 Powder Rheometer®, a universal powder tester from Freeman Technology, to develop a new understanding of how metal powders perform in AM machines. Experimental data show how the measurement of multiple powder properties, most especially dynamic flow properties, is helpful in optimising the use and re-use of metal powders, helping to improve lifecycle management right through from virgin powder to final waste.

Metal powders for AM

AM offers a number of advantages over traditional approaches to manufacturing. It enables the fast, efficient construction of intricate, customised components to close tolerances, and allows the use of materials that may be hazardous or difficult to machine. Increasingly AM machines are being used to make components with built-in functionality. Such items include prosthetic implants with controlled porosity to encourage bone regrowth and efficient cooling systems for aerospace applications that require complex microfluidic channels.

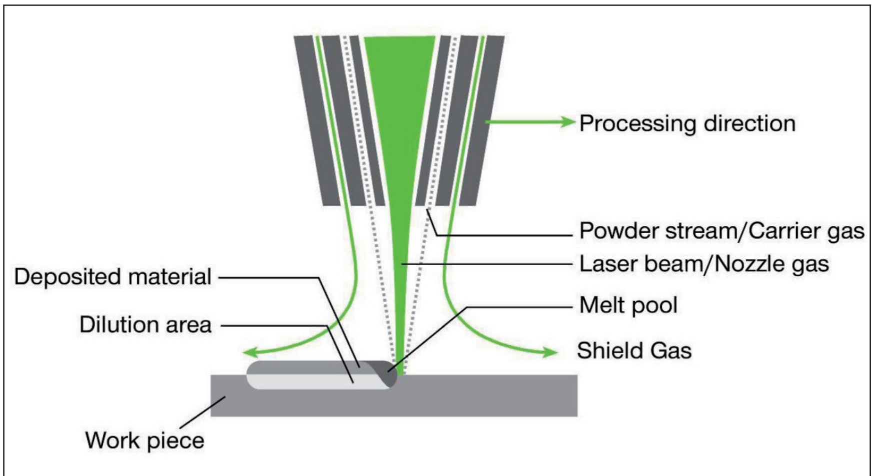

Figure 1: Laser Metal Deposition feeds a concentrated stream of powder into a selectively targeted 'melt pool' on the surface of the work piece.

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Manufacturing for such demanding applications requires detailed understanding and control of the characteristics of the metal powders being used. There is a need to closely match the properties of the powder to the application and the specific machine being employed, for example, and, for many applications, to safeguard a highly consistent, certified supply chain. Lifecycle management of the powder is also critical, raising the question of whether metal powder recovered from the process can be re-used without compromising the product quality.

“AM offers a number of advantages over traditional approaches”

For companies working with or supplying AM powders, bulk powder analysis is therefore a fundamental capability. Analytical techniques that characterise the powders in ways that directly correlate with their performance in AM machines are essential, for development work, day-to-day quality control and powder lifecycle management.

Choosing a new instrument for powder testing

LPW Technology employs a number of techniques to characterise metal powders comprehensively. These include methods for the determination of chemical composition and a range of sophisticated physical measurement techniques such as laser diffraction particle sizing and morphological analysis. Such methods provide valuable information about the particles in a metal powder, however there is a complementary need to characterise bulk powder behaviour, most especially flowability.

Historically the company has relied on relatively basic bulk powder measurement techniques such as tapped density, angle of repose and Hall flow rate to meet this requirement for flowability data. Angle of repose is one of the oldest and simplest methods for measuring powder flow and classifies flowability on the basis of the angle at which a pile of powder settles when poured from a vessel. Tapped density methods on the other hand provide a classification of powder flowability from measurements of the change in bulk density induced by uni-directional tapping. Hall flow rate tests determine flowability by measuring the rate at which a powder flows through a calibrated orifice.

Each of these three tests is carried out to ASTM standards and provides useful insight into powder characteristics and they all remain in use by LPW Technology. However in 2013 the company decided that it needed to invest in more sophisticated powder

Understanding how powders behave in AM machines

There are a number of techniques used within AM machines, each of which subjects metal powders to different flow and stress regimes. This makes it crucial to match powder characteristics for each specific application. During Laser Metal Deposition (LMD) for example, powder contained in a carrier gas stream flows continuously through the annulus of a nozzle onto the surface of the work piece (see Figure 1). A laser beam forms a melt pool on the working surface into which the powder is fed in a controlled stream. The powder melts to form a deposit that is fusion bonded to the substrate, giving the finished component the properties of the parent metal. Both the laser and the nozzle from which the powder is delivered are controlled using a Computer Numerical Control (CNC) robot or gantry system, creating a fully automated process that eliminates any requirement for experienced metal workers or welders.

Clearly, a consistent flow of powder to the work piece is essential for reliable, continuous LMD. The powder is flowing under gravity in a low-stress, highly-aerated state, so quantifying flowability characteristics under these conditions is necessary in order to provide information that is relevant. However, away from the working area the metal powder is stored in a feed hopper. Here it is subject to the consolidating load of its own weight, meaning that flow properties in this type of a moderate to high shear stress environment are also influential in terms of overall process performance. In addition, the ability of the powder to release the carrier gas as it is drawn into the melt pool will influence the precision with which powder can be deposited and, as a result, the quality of the finished component.

In contrast, the flow regime for metal powders in a Selective Laser Melting (SLM) machine is quite different (see Figure 2). Here, a thin layer of metal powder is dispensed across the surface of the component being built, which is constructed on a retractable platform. A roller or scraper wipes the deposited powder across the working area to create a very thin layer of uniformly distributed powder. Typically around 20-50 µm in depth, this is selectively melted by a laser, fusing it to the growing component, as in LMD. The platform is then fractionally lowered and another layer of powder is wiped across. This cyclical process is repeated many times until the component is fully built.

As with LMD, the performance of the powder under moderate stress is relevant since it is similarly stored in, and dispensed from, a feed hopper. However, for SLM applications there is a need to understand how the powder flows under the forcing conditions that apply as it is spread across the bed. The ease with which the powder releases air is also a factor since the powder must form a uniform, homogeneous layer with no air pockets, to ensure a finished product of consistent, defined quality. Both permeability data, which are indicative of how easily air can flow through a powder, and flowability measurements, are highly relevant.