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Taking control of metal powder properties: Exploring the benefits of real-time particle sizing

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The growing use of powder metallurgy (PM) processes is directly attributable to the opportunities they offer to reduce costs and/or enable the manufacture of components with properties that cannot be accessed via conventional subtractive techniques.

PM processes typically use up to 97% of the starting material in the finished component, achieve precise tolerances and are relatively energy efficient compared with processes such as machining. However, successful manufacture is directly dependent on the quality of the metal powders used, with particle size and shape critical to performance. Learning how to produce high-quality powders as cost-efficiently as possible, and manage them during processing, is crucial to further improve the economics of PM processes and extend their application.

In this article, we consider the value of real-time particle sizing technology within this context, focusing on established process analytical technology with proven potential to enhance production economics – both for metal powder manufacturers and PM processors.

Defining particle size and shape requirements

The optimal particle size for metal powders for PM varies considerably depending on the technology being deployed (see Fig. 1). Particle size influences both the properties of the finished component and process performance by directly impacting:

- Packing behavior
- Flowability
- Response to heat.

Generally speaking, larger particles pack less efficiently than smaller particles of equivalent shape, with smaller particles also melting more easily/rapidly. However, with a polydisperse material – one with a broad particle size distribution – progressively smaller particles will fill the voids left by adjacent larger particles, densifying packing and potentially improving heat transfer. Larger particles are advantageous for flowability because the forces of attraction between particles increase with decreasing particle size.

Contrasting the requirements of powders for MIM and AM illustrates the relative importance of these different properties and how this influences the specification of metal powders for alternative processes. Fig. 2 shows a typical MIM process which includes: mixing/blending of the metal powder with a binder, followed by subsequent granulation; injection molding to produce a green part; de-binding; and a final sintering step.

In this process, the higher packing densities associated with finer particles enable high particle loading in the feedstock, thereby minimizing binder usage and, as a direct result, part shrinkage during sintering. Good flowability is essential for timely and complete filling of the mold. The melting characteristics of the powder are less critical, since sintering involves heating to just below the melting point of the metal, often with the simultaneous application of pressure. Powders for MIM are some of the finest for all PM processes, typically lying in the sub-38 micron range (see Fig. 1).

Fig. 3 shows a Powder Bed Fusion AM process, an example of a widely used AM technology. Powder is spread by a roller across a build platform in a layer just tens of microns thick. Selective laser fusion joins successive layers to progressively form the component as the build platform is gradually retracted. Here, flowability of the as supplied powder is crucial, since achieving a smooth even layer with no air voids, rapidly, is essential for cost-effective processing. Set against this is the need for relatively fine particles to achieve the necessary layer thickness, and rapid melting at an acceptable power input. High density packing is required to produce components of consistent quality with few flaws. Balancing all these demands leads to a closely defined

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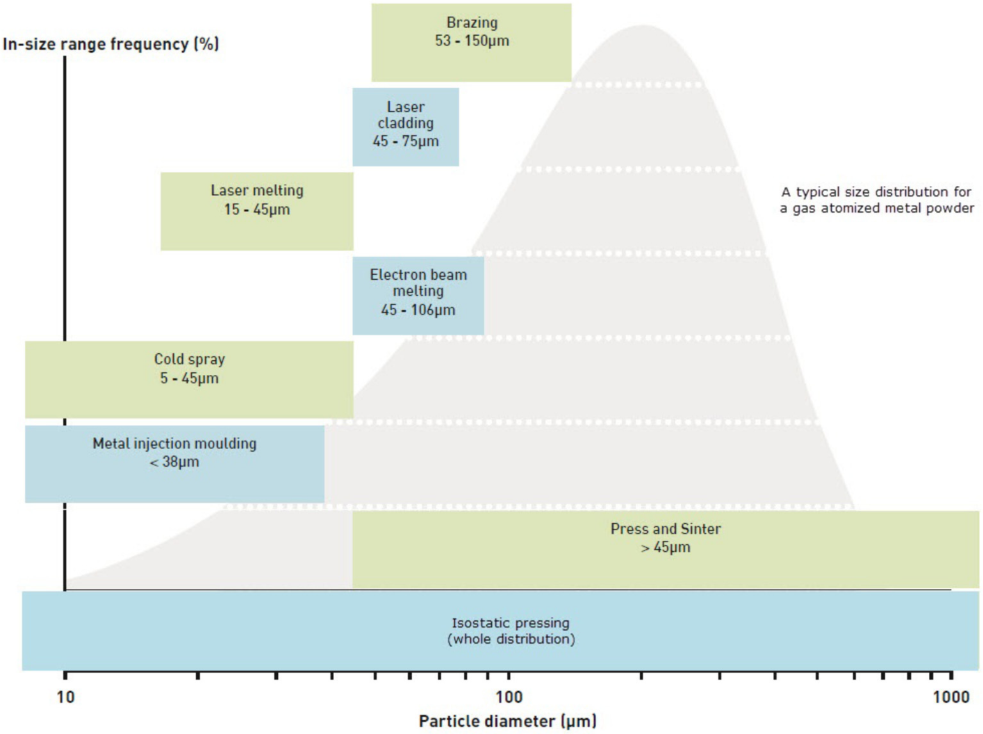

FIGURE 1

Typical particle size ranges for a variety of advanced PM manufacturing technologies.

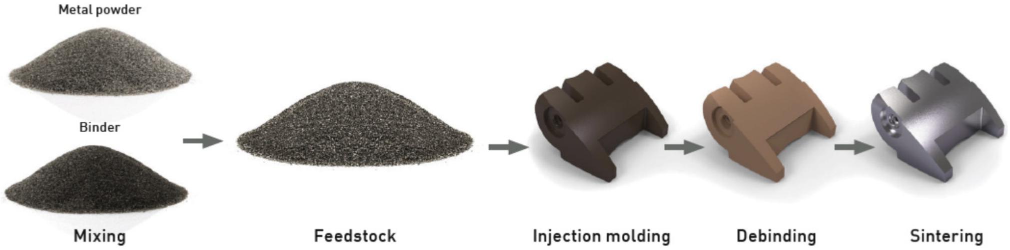

FIGURE 2

A schematic showing key stages of a MIM process.

particle size specification in the region of 15–45 microns for selective laser melting processes (see Fig. 1).

Making metal powders

The production of metal powders predates many PM processes, which have increased demand and intensified pressure on specifications. To meet the evolving needs of the PM industry, metal powder manufacturers are working to much tighter particle size tolerances than previously, driving a need for rigorous process optimization. The primary processes used to manufacture metal powders are attrition milling and gas atomization, which is well-suited to the production of powders for AM and MIM applications (see Fig. 1). Key optimization goals are to:

- Maximize yield – where yield is defined as the output rate of in-specification product
- Minimize production costs – all size reduction processes are energy intensive; cutting energy consumption and waste are the key goals.

In gas atomization, molten metal is ejected through a nozzle of defined dimensions into a high pressure gas stream (typically argon or nitrogen) to create a fine spray of metal droplets that is cooled rapidly to form particles. The size of these particles is influenced by the properties of the molten metal and nozzle geometry, but for routine process control, it is usually feed rate and/or pressure driving the metal through the nozzle that are manipulated. Post-atomization processes such as scalping – the removal of oversized particles – sieving and/or air classification enable tailoring of the as-atomized product to meet the defined particle size specification.

Post-atomization processes are effectively 'yield killers' that slow down overall production rates by adding in steps, processing time and cost. To maximize yield – the first optimization goal – there is a need to reduce such processes to an absolute minimum by controlling the process to make a product with a particle size distribution that is as close as possible to the required specification. Efficiently meeting the specification is essential to reduce waste and energy consumption and achieve the second

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