AP&C
a GE Additive company

Aluminum Powders for additive manufacturing

ABSTRACT

Aluminum alloys are essential powders in the world of additive manufacturing (AM). Their attractive combination of fine microstructures, high heat conductivity and low weight, make their mechanical properties higher or at least comparable to cast material. Therefore, aluminum alloys are in high demand, and well-suited, for additive manufacturing processing in the automotive and aerospace industries. Even so, there are still some challenges with these alloys if you have a low quality powder, which includes:

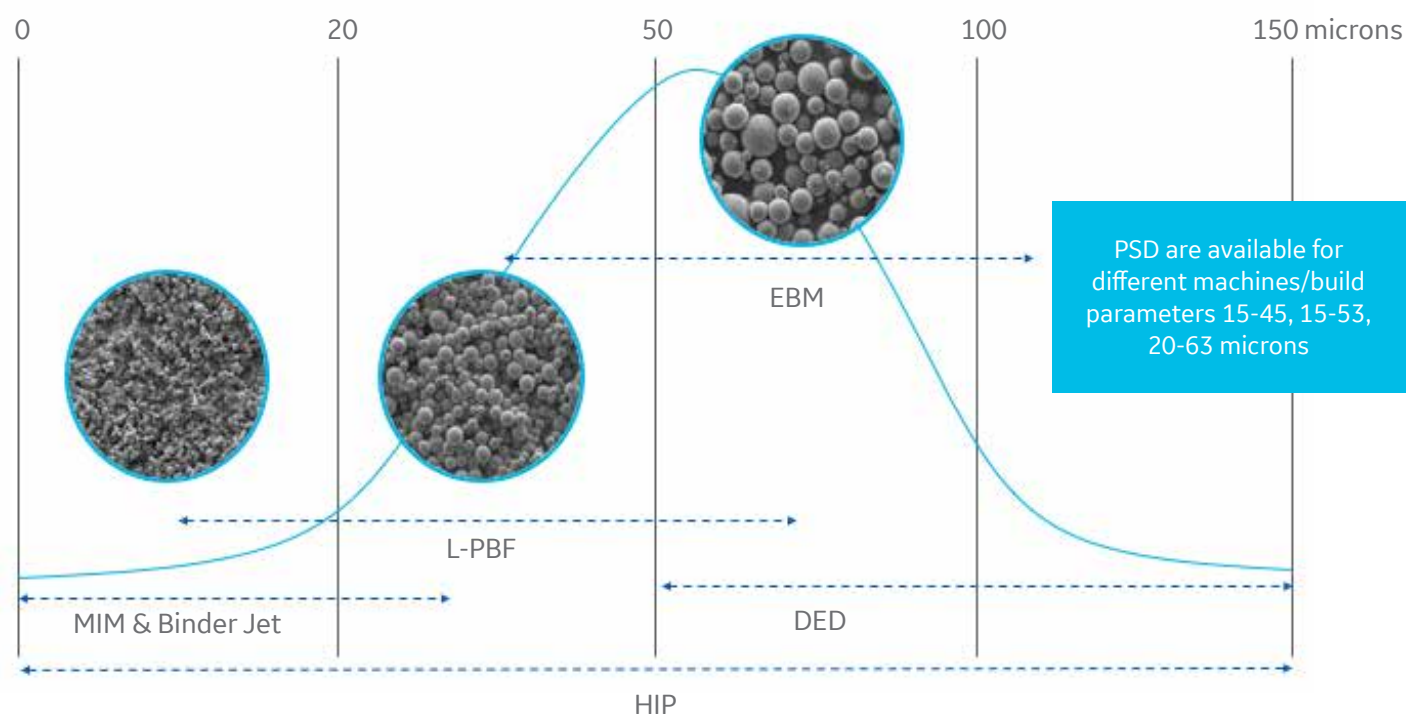
- Processability and,
- Production of repeatable and reliable parts

Historically, with AM aluminum alloys powders, processability can become a challenge because the powders tend to stick to different mobile components during the printing process like the raster. This behavior leads to spreadability issues on the powder bed like voids or lack of fusion zones.

Due to the nature of this AM powder alloy, the particles morphology, particle surface composition, and particle size distribution are key factors that impact the production of repeatable and reliable consolidated parts. Traditional aluminum alloy powders typically fail to ensure part to part reliability due to the fact their physical properties that influence apparent density and flowability are not optimal. Furthermore, these properties may significantly impact the number of times you can reuse the powder due to normal powder degradation which often occurs after multiple uses. Even for AM platforms that don't require high flowability powders, it's been proven that these properties are key in producing reliable parts that meet the most stringent industrial quality requirements.

The aluminum alloys process window is smaller than other AM alloys; therefore, the selection of the correct powder from the beginning of the production cycle is key to ensuring dependable properties.

THE DIFFERENCE IN PARTICLE SIZE DISTRIBUTION (PSD)



This paper is solely focused on the particle size distribution (PSD) cuts typically used in Laser-Powder Bed Fusion (L-PBF). The behavior of such fine metal powder is a complex interaction of powder particles (solid), moisture on surface and between particles (liquid) and the atmosphere between powder particles (gas).

The L-PBF process may be optimized by using different PSD, and the final selection will influence process capabilities such as fine features, surface roughness, productivity, and raw material cost. The selection of the appropriate PSD should be based on final part application and requirements.

The PSD has a significant impact on several factors:

- Price, of the powder due to the production yield
- Flow properties, often linked to process control and reliability
- Reactivity and oxygen content, due to the surface area
- Process parameter sets, PSD has a strong impact on energy density and build rate calculations
- Part design, PSD influences layer thickness, surface finish and feature resolution

Powder characteristics are defined by the manufacturing process. Although, powders from different atomization routes may have remarkably similar chemical composition, their powder parameters may be vastly different than their behavior during consolidation in the AM process. The powder production process will directly influence aspects like impurities, particle shape, PSD, satellites presence, apparent density, internal porosity, and agglomerates.

FIGURE 1: Spinal cage designs manufactured via DMLM and EBM.

ATOMIZATION METHODS

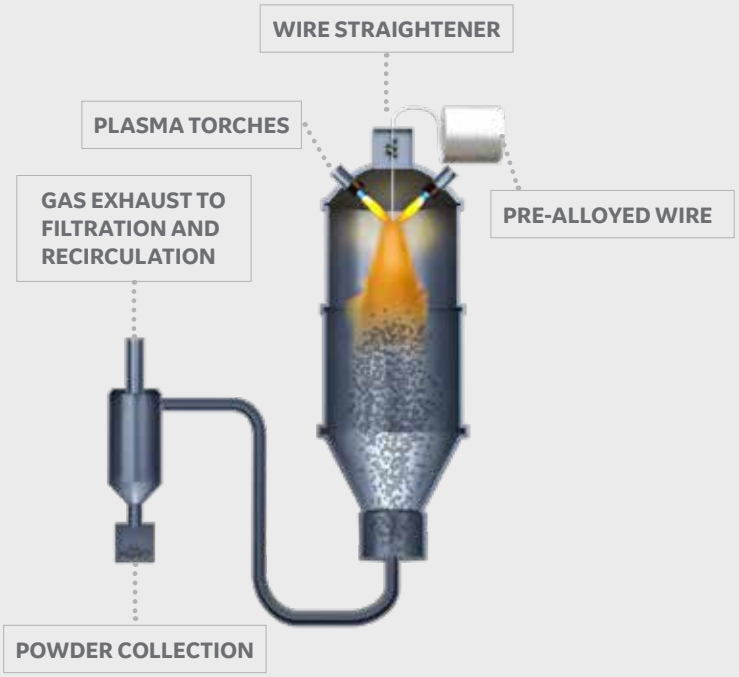
Different manufacturing routes will impact the powder properties of aluminum alloys:

- Gas atomization – wide range of morphology that frequently exhibit irregular shape particles, with few of them being close to spherical shaped particles, and a moderate to low amount of impurities (depending on atomization gas) with risk of iron and silicon contamination. Some amount of agglomerates, satellites, and entrapped porosity.
- Plasma atomization – highly spherical shaped particles, extra clean process with minimal amount of impurities. Furthermore, the powder exhibits low amount of agglomerates, satellites, and entrapped porosity.

ADVANCED PLASMA ATOMIZATION - APA™

BENEFITS:

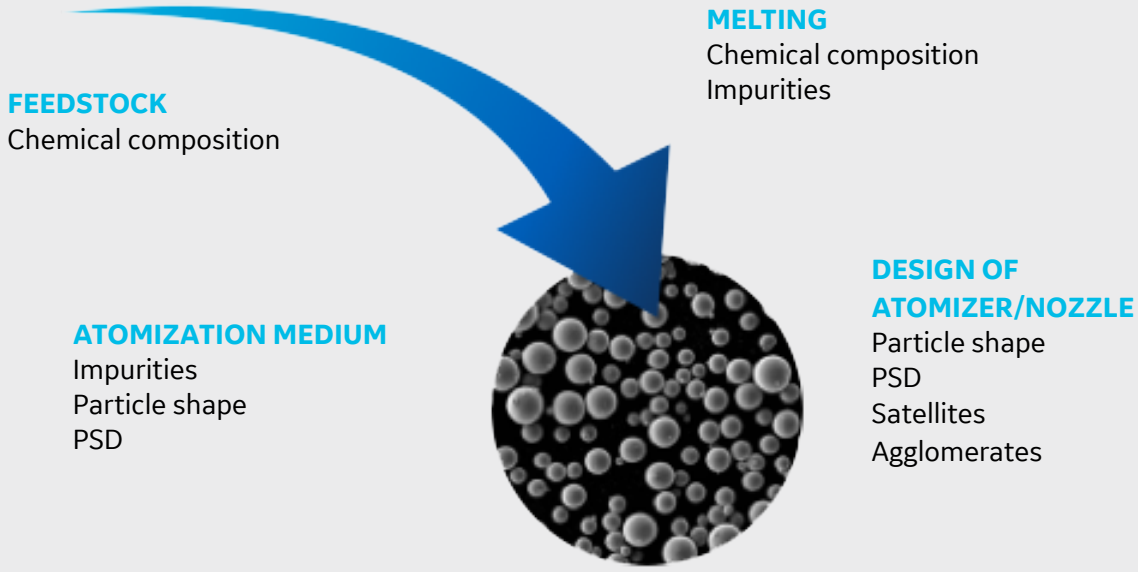
- Better feeding control
- Pre-alloyed wire
- In-line atomization equals safer and better control
- Ceramic free melting
- High purity spherical powder, with high flowability and low porosity
- Higher yield of fine particles



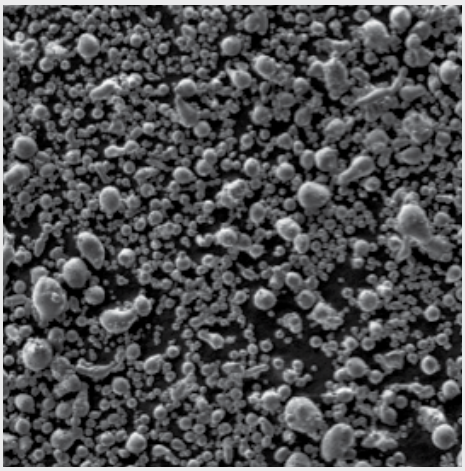
The plasma atomization process produces high quality powder with improved physical properties compared to the powder produced by gas atomization and other traditional powder production routes. AP&C uses its proprietary Advanced Plasma Atomization (APA™) process which uses plasma torches to melt and atomize metal wire feedstock sourced from 100% virgin melted material.

To prevent contamination and ensure a high purity product the melting wire never meets a solid surface. The high control brought be feeding a wire brings controls over PSD and batch to batch consistency. The powder is atomized in a high purity argon atmosphere to ensure the lowest oxygen content. The produced powder size distribution ranges from 0 to 150 µm with the vast majority between 0 to 106 µm or 0 to 75 µm depending on configuration and offers excellent flowability and other enhanced physical properties.

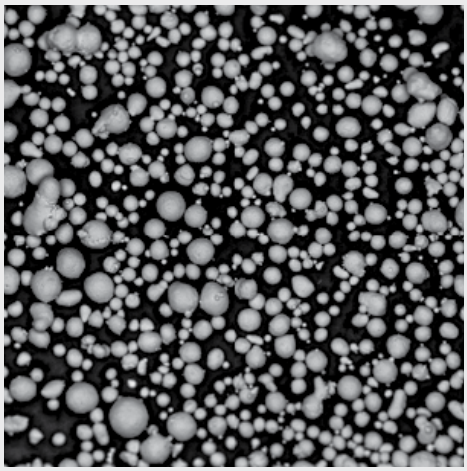
RELATIONSHIPS POWDER PRODUCTION- POWDER PROPERTIES



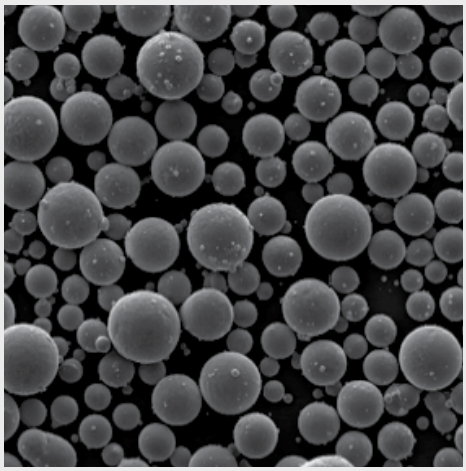
COMPARISON OF POWDER PRODUCED BY DIFFERENT ATOMIZATION METHODS:



Gas atomization process (1)
Powder with extremely high fine particle presence, high agglomerates presence and non-spherical particles



Gas atomization process (2)
Powder with some amount of particle presence, moderate presence of agglomerates and semi-spherical particles



Representative morphology of APA™ aluminum alloy powder:
Very low presence of fine particles, almost no presence of agglomerates or deformed particles, spherical shape

ASPECTS OF POWDER BEHAVIOR

We know that powder behavior can be defined by the physical characteristics developed during the atomization process. The significant characteristics include morphology, PSD, chemical composition, and the level of impurities. However, some powder behavior may also be influenced by external variables:

Flow and spreadability

These two physical properties are linked, it's well known that a powder with low flowability may affect the powder spread behavior during the consolidation process. A standard part is made from more than a thousand layers and if one single layer fails it can compromise the quality of the whole consolidated part.

Fine particles

A correct sieving process will ensure reliability on upper and lower powder cuts; it may help to limit the presence of fine particles that are known to affect the powder behavior due to the fact they are more susceptible electrostatic interaction with coarse particles sticking at their surface and affecting the powder behavior. The presence of these particles is also related to process fail due to powder sticking on parts of the re-coater. A powder that is made with spherical particles shape is ideal for correct sieving and fine removal. In addition, fine particles are more reactive than larger particles, a powder with low fine particles are safer for the process and the operator. Powder with many fine particles may be considered a "dangerous good" and special handling in a special facility may be required.

> The optimal aluminum powder for the AM process typically includes particles with an exceptionally sparse number of fines, a spherical shape, an optimized composition, and a high apparent density and flowability.

Moisture Content

Fine particles are also more susceptible to moisture pick-up than larger particles. Moisture between particles may also affect powder physical properties as apparent density, flowability and spreadability. Improved particle surface composition may reduce electrostatic interaction between particles and become less susceptible to moisture influence.

Easy, scalable technology

The proprietary design of APA™ Plasma Atomization reactors allows for rapid scalability compared to traditional atomization methods. **The installation time for a new reaction is 4 months and with over 95% less capital cost compared to traditional gas-atomization.**

AM PROCESS IMPACT

Powder behavior is significantly impacted during the AM process. Therefore, minimizing the powder properties variations is essential to produce repeatable and reliable parts. The selection of optimal aluminum powder will help to avoid common process failures due to powder stock on the re-coater or dust being present on the build chamber. Voids or lack of fusion on printed parts have a strong impact on mechanical properties and affect the production of reliable parts. To prevent these defects during the L-PBF process, it is necessary to ensure the correct amount of powder is spread on the powder bed during the entire printing process. This will reduce the variation on the mechanical properties of the final printed parts and improve the reliability of the printed parts and help with certification.

Finally, due to applications like heat exchangers, there is a need to print fine features with AM aluminum alloys. An aluminum powder that behaves optimally on L-PBF process will allow you to print fine features. Depending on powder deposition parameters optimization, it will be possible to print fine features down to 200 µm.

Printed fine features and gaps down to 200 µm

AP&C ALSI10MG AND ALSI7MG (F357) POWDERS

AP&C has developed robust knowledge of powder behavior in the AM process that allows you to design and optimize a powders behavior for any powder based additive manufacturing machine available on the market—we are machine agnostic. And we have over a decade of experience working with major biomedical and aerospace OEMs.

Our powder exhibits exceptional spherical morphology, reduced satellite presence, excellent flowability and batch to batch consistency. AP&C Aluminum powder alloys are able to flow on Hall funnel with a low Hausner ratio, furthermore, it shows excellent spreadability behavior during AM process. The quality control and powder characterization provide customers with a consistent premium quality product, for even the most stringent industries.

- AP&C aluminum alloy powders show exceptional performance during processing and the printed parts have been shown to meet and exceed the mechanical properties of international standards as ASTM F3318 and AMS 4289.
- AP&C focuses on reliability and quality and we have a robust supply chain, able to adapt and grow with market demand.

AP&C facilities are equipped with the space to increase the reactor numbers to meet market demand, and recently increased the capacity of AP&C aluminum alloys due to high demand.

AP&C aluminum powder alloys can flow by the use of the Hall funnel with a low Hausner ratio; furthermore, it shows excellent spreadability behavior during the AM process.

OUR QUALITY SYSTEM

We acquire and inspect the raw material from a secured supply chain. This allows us to produce high quality, extremely clean powder with consistency between production batches.

In addition, every powder production batch is inspected under the highest quality criteria to ensure customers receive a product that meets and/or exceeds their expectations.

Our process environment

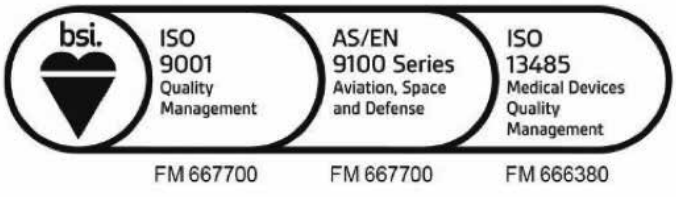
As part of quality system, all AP&C powders are produced in an extremely clean environment with:

- Dedicated equipment
- Optimized process flow
- Intelligent process monitoring (Industry 4.0)
- Powder handling equipment operating under inert atmosphere
- Powder handled in a dedicated closed room setup up with state-of-the-art safety systems

Our certified laboratory

Full characterization is achieved in our certified AS 9100 and ISO13485 laboratory which includes:

- Particle size distribution as per ASTM B214 and/or ASTM B822
- Powder flow as per ASTM B213 and/or ASTM B964
- Chemical analysis as per applicable standards
- Apparent density as per ASTM B212 and/or ASTM B417
- Tap density as per ASTM B527




AP&C
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What perfection is made of

AP&C's proprietary Advanced Plasma Atomization (APA™) powders are adapted for all additive manufacturing technologies – from R&D to large-scale production, offering exceptional flowability, purity and density with an exceptionally low level of porosity. The high quality of our powder allows for precise printing and batch-to-batch consistency.

For additional information visit us at advancedpowders.com

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