Electron Beam Melting: From Powder to Part

Rutuja Samant, Applications Engineer
Frank Medina, Senior Technology Advisor

Additive manufacturing (AM) is a novel, layer-by-layer, part-fabrication technique that has opened up a new paradigm in the manufacturing world. Its full adoption by the medical and aerospace communities demonstrates how the technology has moved beyond a rapid prototyping tool to an accepted manufacturing method. Over the past decade, a few specialty materials have been developed for this technology, but the complete potential of AM techniques is not yet being exploited. A wide variety of material classes are yet unexplored. This article focuses on what it takes to develop a new metal material to build parts using AM technology.

Electron Beam Melting

Electron beam melting is a powder-bed, fusion-based AM technology developed by Arcam. Here, an electron-beam gun with a tungsten filament (shown in Figure 1) is used as a heat source that emits electrons accelerated at a high voltage of 60kV. First, a defocused electron beam preheats the powder bed. This is followed by a focused electron beam that, with the use of electromagnetic lenses, melts the powder particles at desired locations so that they re-solidify to fabricate the part one layer at a time. This system is capable of electron-beam scan speeds of up to 8000 m/s, electron-beam positioning accuracy of +/- 0.025 mm, and layer thicknesses in the range of 0.05-0.2 mm. The system operates under controlled vacuum thus preventing any contamination of material during the build.

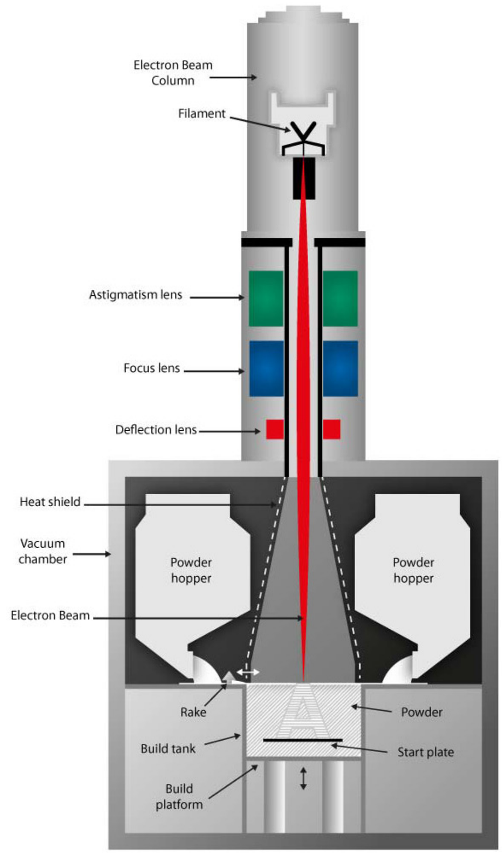

Figure 1. Schematic of Arcam's EBM System

Material Requirements for EBM

Today, metal powder is produced by various processes such as gas atomization (Figure 2), induction plasma atomization, Armstrong process, Hydride-Dehydride process, etc. But for any powder-bed based additive manufacturing technology, it is crucial that the powder has a spherical morphology, high flowability, high packing density, no internal porosity (Figure 3) and a tight particle size distribution with minimum number of fines (< 0.010 mm). Prior to parameter development using the EBM system, the powder must be

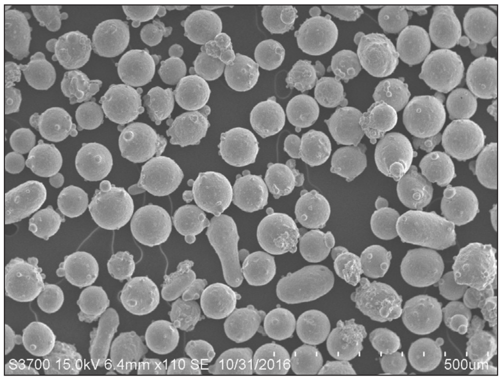

Figure 2. Gas Atomized Powder

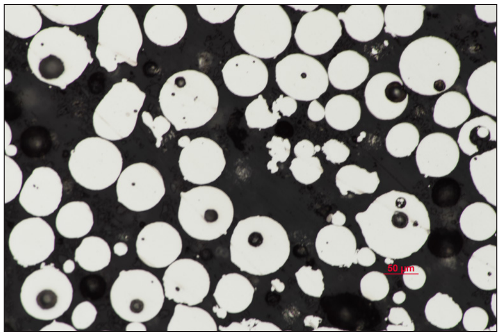

Figure 3. Internal Powder Porosity

characterized to determine if it is a good candidate for the technology. Another factor in determining a powder's usability for AM is safety during powder handling and use in the EBM system. It is important to perform minimum ignition energy testing in order to measure the ease of ignition of a powder dust cloud by electrical and electrostatic discharge. For the EBM systems, it is recommended to use powders with 45-105 μm particle distribution that have minimum ignition energy of > = 0.5 J.

Process Parameter Development for EBM

Once a powder has been selected for the EBM process based on its physical characteristics, the next step is to test the powder's behavior in the system and identify a parameter window that can then be optimized based on application. First a "smoke test" is performed in the build chamber with cold powder. When the charge distribution density exceeds the critical limit of the powder, the powder particles repel each other and an electrical discharge occurs, causing a powder explosion inside the chamber as shown in Figure 4. It is important to identify parameter sets within a "smoke-free" zone to maintain a stable build process. The smoke test is followed by a sintering test in which the build plate is pre-heated and held at predefined temperatures for 30 minutes to determine if the powder under the build plate is semi-sintered. If the powder is not semi-sintered, the test is repeated at a higher temperature. The powder must be sintered for platform stability when raking as well as for thermal conductivity. The sintering test determines the energy and time required to reach good starting conditions for the process.

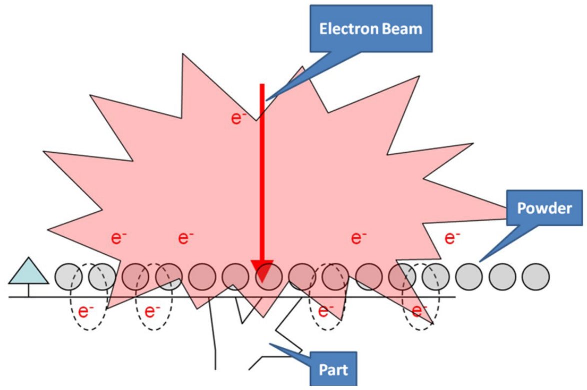

Figure 4. Powder Smoke in an EBM System

Once the correct starting conditions are set, the next step is to determine the build process parameters. In an EBM system, the two main parameter sets are the preheat and melt themes that control the build process. The pre-heat theme controls the process temperature and stabilizes the powder bed before the melting process begins. The melt theme controls the melt and re-solidification of the powder layer by layer to build the final part. This initial evaluation is usually performed on simple geometries like blocks or cubes with no negative surfaces or supports as shown in Figure 5. The development of these parameters sets is a visual process today, wherein an engineer modifies the build parameters based on the quality of the top surface as seen from the machine's observer window. A clean, flat and shiny top surface usually yields the best results. Once these parameters are developed, a tall verification build is performed and tested to evaluate the material properties of the parts as shown in Figure 6.

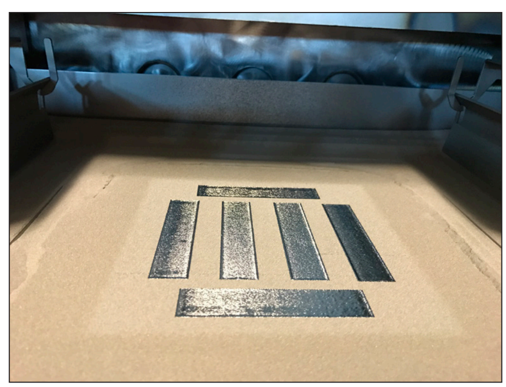

Figure 5. Simple Geometry Builds

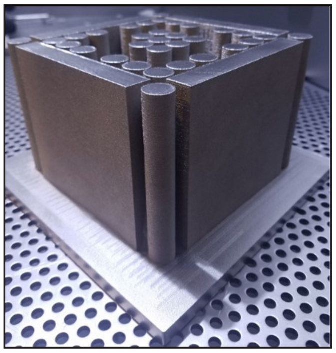

Figure 6. Arcam's Verification Build

Final Part Production

Once the base parameters have been successfully developed it can be said that the material is feasible for EBM technology. To build complex geometries as shown in Figure 7, however, further optimization is required based on applications. In cases where surface quality is important, design of experiment (DOE) is performed to identify the best parameters for both top and curved surfaces. For complete production-ready parameters, further development is required to optimize build speeds, part support structures, shrinkage factors, and post-process heat treatment and HIP cycles to achieve desired part properties.

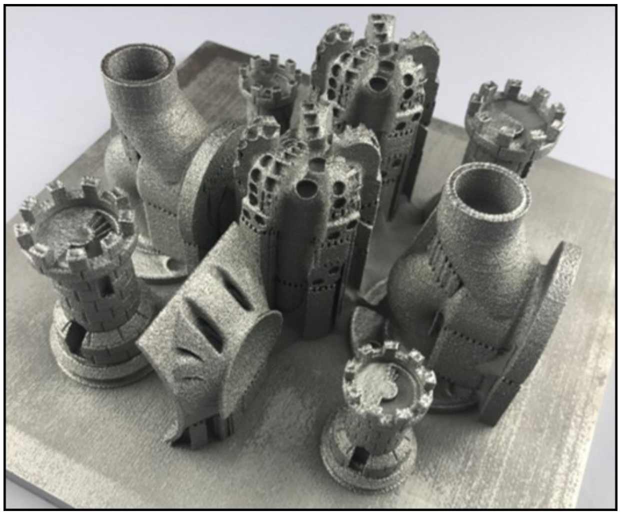

Figure 7. Complex Geometries

EWI has been helping the manufacturing industry develop and commercialize new materials for a variety of metal AM technologies including laser and electron-beam powder bed fusion, powder and wire direct energy deposition, and binder jetting. For more information regarding your material needs please contact Rutuja Samant at rsamant@ewi.org or Frank Medina at fmedina@ewi.org.

***Rutuja Samant**, Applications Engineer for Additive Manufacturing (AM), is based at EWI's Buffalo Manufacturing Works facility in Western New York. She specializes in metal powder-based additive manufacturing processes and design for AM.*

***Frank Medina**, Senior Technology Advisor for AM at Buffalo Manufacturing Works, has been with EWI since 2016. He has nearly two decades of AM experience in the academic, industrial, and research arenas, and holds multiple patents. He is world renown for his AM work in electron beam melting (EBM), and continues to teach and lecture in the field.*