

ELECTRON BEAM MELTING

Electron Beam Melting is a unique prototyping and manufacturing process that can simultaneously reduce costs, weight, and time.

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Electron Beam Melting (EBM) is a rapid manufacturing process in which fully dense parts with properties equal to those of wrought materials are built on a layer-by-layer basis. After melting and solidifying one layer of titanium powder, the process is repeated for subsequent layers until the part is complete. For industries such as aerospace, this creates new opportunities for both prototyping and low-volume production of titanium parts. The time, cost, and challenges of machining or investment casting are eliminated, which makes titanium parts readily available for functional testing or installation on the aircraft. Additionally, the additive process opens the door to new design configurations and weight-reduction alternatives.

How it works

When the high-speed electrons strike the metal powder, the kinetic energy is instantly converted into thermal energy. Raising the temperature above the melting point, the electron beam rapidly liquefies the titanium powder (Fig. 1).

Within the electron beam gun, a tungsten filament incandesces and “boils off” a cloud of electrons (Fig. 2) These electrons stream through the gun at approximately half the speed of light. Two magnetic fields organize and direct the fast-moving electrons. The first acts as a magnetic lens, which focuses the beam to the correct diameter. The second magnetic field deflects the focused beam to the target point on the powder bed.

The electron beam gun is stationary, and no moving mechanical parts are needed to deflect the beam. This delivers very high scanning speeds, up to 1000 m/sec. (3280 ft/sec) and fast build rates, up to 60 cm³/hour (3.7 in³/hour). The process is three to five times faster than other additive technologies.

The EBM parts are built in a vacuum to prevent a loss of energy that would be caused by the fast moving electrons colliding with air or gas molecules. The vacuum has two advantages:

- The process is 95% energy-efficient, which is

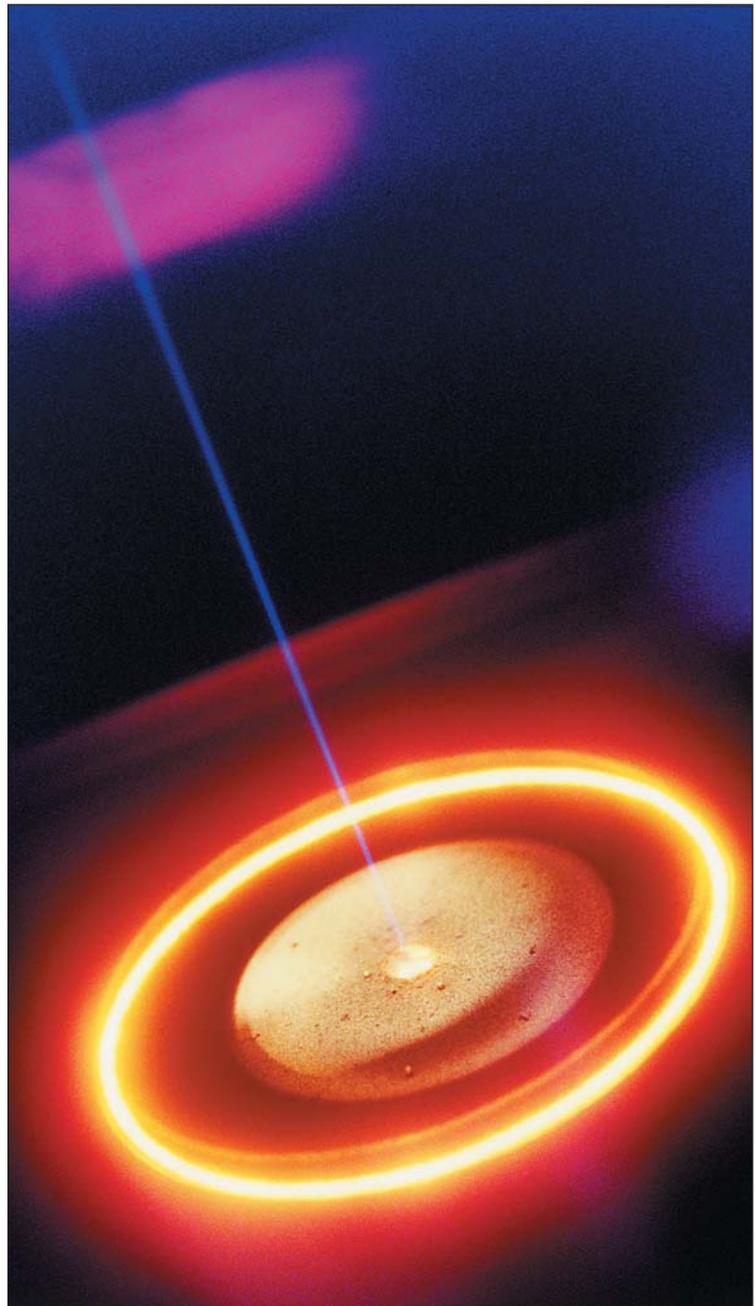


Fig. 1 — Impact of electrons traveling at half the speed of light creates temperatures that melt titanium powders.

five to ten times greater than laser technology.

- The vacuum supports processing of reactive metal alloys such as titanium.

Fully dense titanium

The EBM machine produces components from Ti6Al4V and Ti6Al4V ELI, two alloys common in

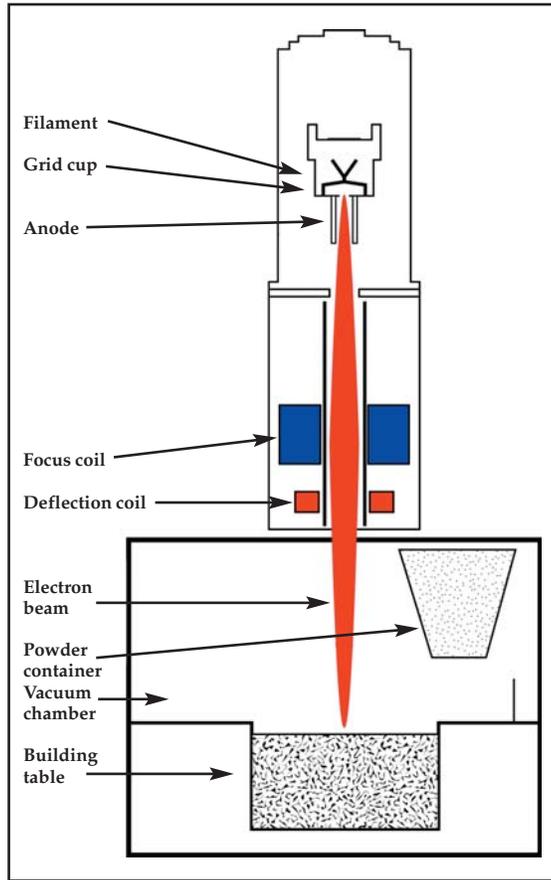


Fig. 2 — This schematic shows the components of the Arcam S400 rapid manufacturing system.

the aerospace industry. The Ti64 parts exhibit properties that match those of wrought materials and exceed those of investment castings. Directly from the EBM machine, the parts are 100% dense, eliminating the need for a secondary infiltration processes. However, the Ti-64 parts can be hot isostatically pressed.

Parts produced via EBM are near-net shape, like those made via casting processes. Since the electron beam fully melts the titanium, the liquefied metal conforms to the surrounding metal powder, which yields a surface finish similar to a precision sand casting. As a result, some light secondary machining or grinding of the surface may be required.

With material properties that match or exceed those of conventional processes, EBM allows aerospace companies to produce titanium prototypes and production parts without the inherent cost and

EBM S400 at a glance

Max. build size	200 x 200 x 180 mm (7.9 x 7.9 x 6.3 in.)
Build rate	up to 60 cm ³ /hour (3.7 in ³ /hour)
Layer thickness	0.050 – 0.200 mm (0.002 – 0.008 in.)
Electron beam positional accuracy	±0.05 mm (0.002 in.)
Accuracy	±0.40 mm (0.015 in.)
Output (electron beam)	4 kW max
Size	1.8 x 0.9 x 2.2 m (6 x 3 x 7 ft.)
Weight	1350 kg (2976 lb)

challenges of machining, casting, and welding.

The ease and speed of producing titanium parts with the EBM machine makes functional prototypes readily accessible to the design and manufacturing team. This means that functional evaluations can be completed earlier and more frequently in the design cycle.

Complex designs

Inherent to additive fabrication processes is the ability to produce complex designs that are difficult or impossible to make when machining or casting. This freedom of design can be exploited to achieve exceptional strength-to-weight ratios, reduce manufacturing costs, and minimize assembly time. Because EBM produces true titanium parts, these advantages can be applied to components for commercial and military aircraft. EBM creates an opportunity to rapidly manufacture flight-ready titanium structures.

Although titanium is often the best material for certain aircraft components, its high cost and manufacturing challenges often prevent its application. In these instances, machined or investment cast aluminum is chosen for weight reduction. When aluminum is not satisfactory, steel may be selected in spite of its weight. With EBM, manufacturers have an effective alternative that combines the advantages of aluminum and steel, while overcoming the obstacles of making titanium parts. Other advantages:

- **Multi-piece assemblies:** The additive process can make a multi-piece assembly as one component. In those cases where the limits of machining and casting force a designer to create an assembly, EBM can reduce production costs. By combining two or more individual components into a single piece, assembly is eliminated, and the cost of manufacturing may be reduced.

- **Buy-to-fly ratios:** EBM creates an opportunity to design and manufacture aircraft components with unprecedented strength-to-weight and buy-to-fly ratios.

- **Hollow parts:** The EBM process can also produce hollow parts with an internal strengthening scaffold. Impossible with any other method, EBM can deliver the required mechanical strength with much less mass. This reduces the cost of raw materials and the weight of the component.

Aerospace companies such as Boeing Phantom Works have recognized the benefits of EBM for prototyping and manufacturing. Directly from CAD, it is producing metal parts for functional testing, and creating new designs that capitalize on the design freedom that the additive process offers. ●

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EBM is a technology of Arcam AB, Mölndal, Sweden. Stratasys Inc., Minneapolis, Minn., is the exclusive supplier of Arcam products in North America.