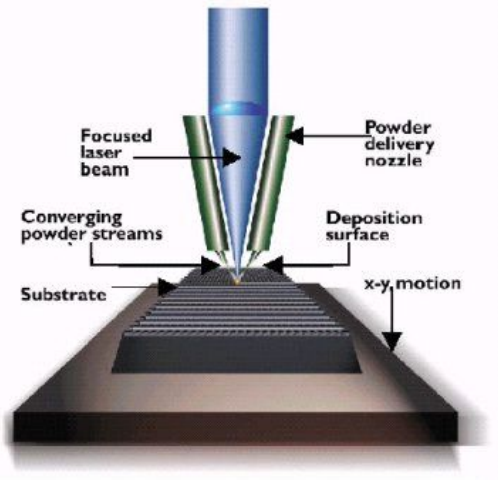
ADDITIVE MANUFACTURING OVERVIEW

An innovation with the production of highly complex and custom parts, Additive Manufacturing (AM) is the process of producing prototypes, tooling and full-scale production parts by successive melting and fusing of layers of material.

ASTM defines AM as the "process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining." It is sometimes referred to as rapid manufacturing, additive fabrication, layer manufacturing, freeform fabrication and 3D printing. The process, which may be used to produce both plastic and metal parts, may incorporate one of several technologies depending on the specific application, material and manufacturing conditions. Some of the most widely deployed AM processes include:

Laser Sintering

A high power laser is directed on a substrate to create a melt pool. Material, generally in powder form, is added to the melt pool, enlarging the pool and becoming incorporated into the part. With selective laser sintering (SLS), a high power laser (e.g. a carbon dioxide laser), driven by a CAD file, fuses particles of plastic, metal (direct metal laser sintering, or DMLS), ceramic or glass into a 3D shape. The laser fuses thin layer upon layer of material by rastering across the entire cross section of the part on the surface of a powder bed. After each cross section is scanned, the powder bed is lowered by one layer thickness and a new layer is fused on top of it. This process is repeated until the part is fabricated.

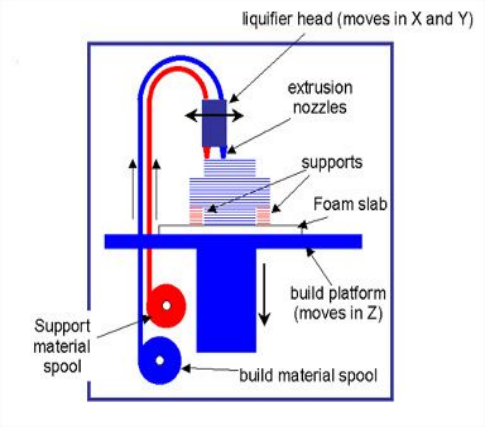


Laser Sintering Process

Fused Deposition Modeling

With fused deposition modeling (FDM), also called fused filament fabrication (FFF), liquefied thermoplastics are deposited by an extrusion head driven by a CAD file. The successive layers, which can be as thin as 0.005 inch, are deposited one layer at a time to create a part.

A range of materials are amenable to FDM, including, for example, ABS, polycarbonates, polyamide, polycaprolactone, polyphenylsulfones, polyethylene, polypropylene and investment casting wax.



Fused Deposition Modeling Process

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Electron Beam Melting

Electron Beam Melting (EBM) is applicable to metal parts. In the EBM process, an electron beam melts metal powder in a layer-by-layer process. Each layer is deposited on top of the previous layer, in an ultra high vacuum, to build a complete part. It is a particularly applicable process for building parts with reactive materials such as titanium alloys.

Aerosol Jetting Deposition

In aerosol jetting deposition, an atomized, high-velocity stream of particles is focused on a substrate. Typically, a secondary, thermal process is employed to sinter the particles after the aerosol deposition. Aerosol jetting deposition is particularly useful for creating very intricate patterns onto almost any substrate.

While AM is not currently suitable for high volume manufacturing, it has several significant advantages over both formative (e.g. molding) and subtractive (e.g. machining) processes in those cases where the manufacture of low volume, customized or highly complex parts is needed.

These advantages include:

- CAD-driven technology, ensuring precision and repeatability
- Significant time savings (as much as 75% over some machining processes)
- Labor savings
- Highly efficient material usage / significant waste reduction
- The ability to produce highly complex products that would otherwise require post processing and fabrication
- The ability to produce highly customized products
- Quality improvement and the elimination of failure points as a result of whole-part manufacturing / improved fit-and-finish
- Energy savings

The process may also be applied in conjunction with conventional techniques, such as casting and molding, to produce composite parts.

AM Equipment Used for Full-Scale Production

The AM process is routinely used to produce highly complex parts that otherwise could not be produced in one piece but would require significant fabrication and assembly.

Some examples of complex parts manufactured by AM include:

Automobile Prototype

In-theater Military Equipment Repairs

Axle Assemblies

Automotive Parts