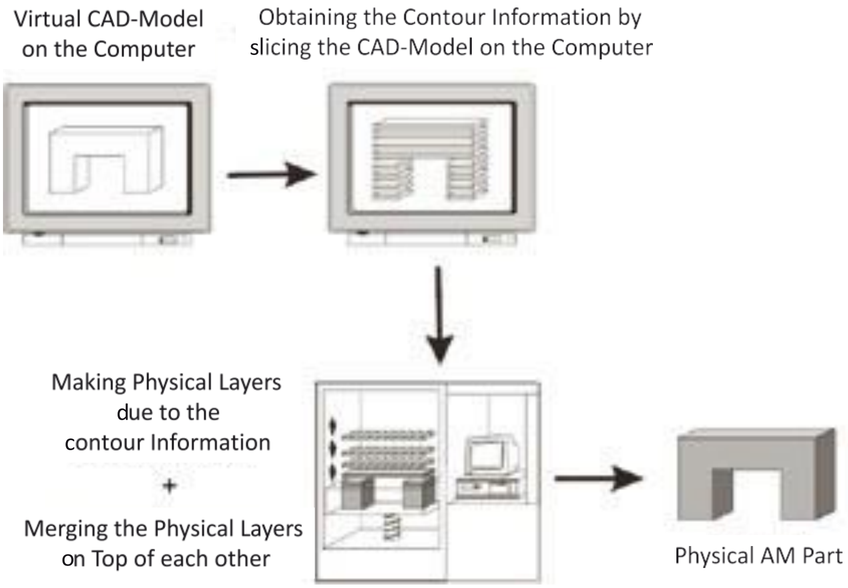
Definition:

"Additive Manufacturing" (AM) is a layer-based automated fabrication process for making scaled 3-dimensional physical objects directly from 3D-CAD data without using part-depending tools.

Additive manufacturing (AM) is an automated and revolving process developed from the principle of layer-based technology. It is characterized by a process chain. It starts with a (virtual) 3-dimensional CAD data set (solid) that represents the part to be produced. In engineering, the data set is typically obtained by 3D CAD design or by scanning or other imaging technologies such as computerized tomography scanning (CT-Scanning).



Applications of AM:

- Automotive Industries and suppliers
- Car components: Interior and exterior
- Aerospace industry
- Consumer goods
- Toy Industry
- Art and history of art
- Foundry and casting technology
- Medical

- Architecture and landscaping
- Aerodynamics and free form elements

Direct and indirect application level:

AM technology is divided into three main application levels which are prototyping, tooling and manufacturing.

Direct AM Processes

Direct Prototyping

Prototyping encompasses AM applications based on fabricating any proto- type, concept model, specimen or mock-up. It has two sub-levels which are:

1. Solid imaging and conceptual models that are applied for verifying concept and can be compared to meagre three-dimensional print- outs of the design; they are also known as show-and-tell models. To verify intricate drawings, scaled concept models (also called data control models) are used. Colored models utilized to evaluate designs also fall under this category.
2. Functional prototypes are used to check and verify functions of a limited number of parts of final product during production decisions.

Direct Tooling

Tooling encompasses AM applications based on fabricating cores, cavities, inserts for tools, dies and molds, etc. “Rapid tooling” and can be further categorized into two types, i.e. direct or proto- type tooling. It is confined to the tooling applications only and is generally based upon metal additive manufacturing (MAM). A key point to be made clear is that the complete tool is not obtained but only its important parts are created. The tool is obtained via conventional manufacturing route here, also by utilizing its parts like cavities, cores, etc. AM tooling facilitates the easy fabrication of inner cavities for features such as cooling channels beneath an outer surface.

Direct Manufacturing

Manufacturing encompasses applications based on obtaining a final part or end product that can either be used directly or suitably assembled.

Most AM processes come under genre of direct AM since 3D CAD models are used to directly obtain physical parts.

Indirect AM Processes

Indirect Prototyping

Indirect prototyping is utilized to improve AM part characteristics to suit specific customer demand. For example, if a specific colored part is required that is not compatible with the available AM facility, then we can make a rigid master model of any color and use it for further casting of the required component.

Indirect prototyping techniques rarely find utility in solid imaging or concept modelling owing to cost considerations. This technique is mostly employed for functional prototyping.

Indirect Tooling

Indirect tooling offers considerable saving in time and cost over conventional methods of tool fabrication. Unlike indirect prototyping, this tool is used for final components and can be utilized for a large number of components. Milling inserts can be utilized for improving a sharp edge.

Indirect Manufacturing

Indirect manufacturing also finds its basis in the creation of AM master parts. The objective is to create final parts with properties equivalent to traditionally manufactured products.

Nomenclature of AM machines

In general, a machine used for layer oriented AM is called a "fabricator", especially if it can make (fabricate) final parts. If it is only capable of making prototypes, some call it a "prototyper". The trend is to call all types of layer oriented additive manufacturing machines "printers" or "3D printers".

All AM machines in the market are assigned to three categories or classes: fabbers, office machines, and shop floor machines.

Fabber is used in particular to address a small and simple machine. If a fabber is used by a private person or a group of private individuals and operated from home or a co-working space, it is increasingly called “personal fabber” (PF).

An “office machine” can be operated in an office environment. That means it emits less noise, smell, and particles. The build material can be refilled by office staff and is typically delivered in cartridges. Operation is easy and part handling is simple, including post processing. The waste is disposable as normal office- or household waste.

A “shop floor” machine requires an industrial environment, including trained personnel and logistics. It is designed for high output and productivity, which means it can handle large amounts of material. Here, economic production is more important.

Advantages of AM:

- Noise free
- Can be operated from the comfort of home or office
- Offers an excellent and impressive spectrum of applications
- Can form process chains when suitably combined with other conventional/unconventional manufacturing processes
- Lesser time for products to reach markets for customer end use
- Reduced material wastage owing to non-occurrence of mistakes
- Lesser costs owing to appreciable manufacturing savings
- Improved qualities
- Parts with complex and intricate geometries can be obtained
- Tools, molds or punches not required.

Types of AM Process:

Various types of AM processes have been defined on different bases:

1. Direct and indirect application AM processes based upon application levels.

2. Metallic and non-metallic AM processes based upon type of modeller/raw material used.
3. Solid, liquid, powder or gaseous AM processes based upon the physical state of raw material utilized.
4. One-dimensional, array of one-dimensional and multi-dimensional arrays based upon data transfer mechanism from stereo lithography (STL) data format to the modeller.
5. Resin photo polymerization, material extrusion, directed energy based, building printing, sheet lamination and powder bed binding/ fusion based upon the working principle or underlying technique.
6. AM based on binder, laser, heat of friction, plasma, beam of electrons, etc. on the basis of energy source used during the process.
7. Plastic, ceramic, powder, resin, etc. AM on basis of raw material used.
8. Powder bed and powder feed AM machines on basis of material delivery system utilized.

Stereolithography process (SLA):

Stereolithography is a 3D Printing process which uses a computer-controlled moving laser beam, pre-programmed using CAM/CAD software. Stereolithography (SL) is an industrial 3D printing process used to create concept models, cosmetic - rapid prototypes, and complex parts with intricate geometries

Laser based SLA 3D printing uses a laser to trace out the cross-sections of the model. Here each layer is deposited in a continuous stream of filament, the laser essentially "draws" the layer to be cured. The laser is focused using a set of lenses and then reflected off two motorized scanning mirrors .The scanning mirror directs the precise laser beam at the reservoir of UV sensitive resin to cure the layer. Alternatively, some laser based SLA 3D printers move the laser directly using a XY stepper motor arrangement similar to those used in filament based printer.

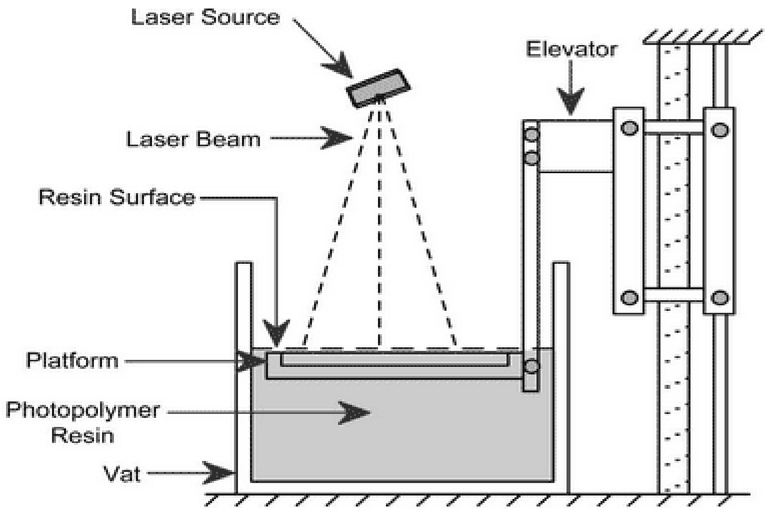


Diagram of SLA printing process

Fused Deposition Modelling (FDM)

FDM is an extremely popular and robust AM technique since complicated parts can be obtained in reasonable time. Likeother AM techniques, it requires no tooling and minimal human interference. This can be used to obtain models, prototypes as well as end parts and is based on the layered AM principle. Its working involves uncoiling of plastic filament from its spool which then goes into an extrusion nozzle. The choice of nozzle and filament depends upon specific need. Melting of material occurs due to the heating element in the nozzle. Horizontal and vertical direction movement occurs with the help of an automated computerized mechanism, which is under the direct control of a CAM software package. Layer formation takes place by extruding specific thermoplastic material directly either on substrate or on the previous layer.

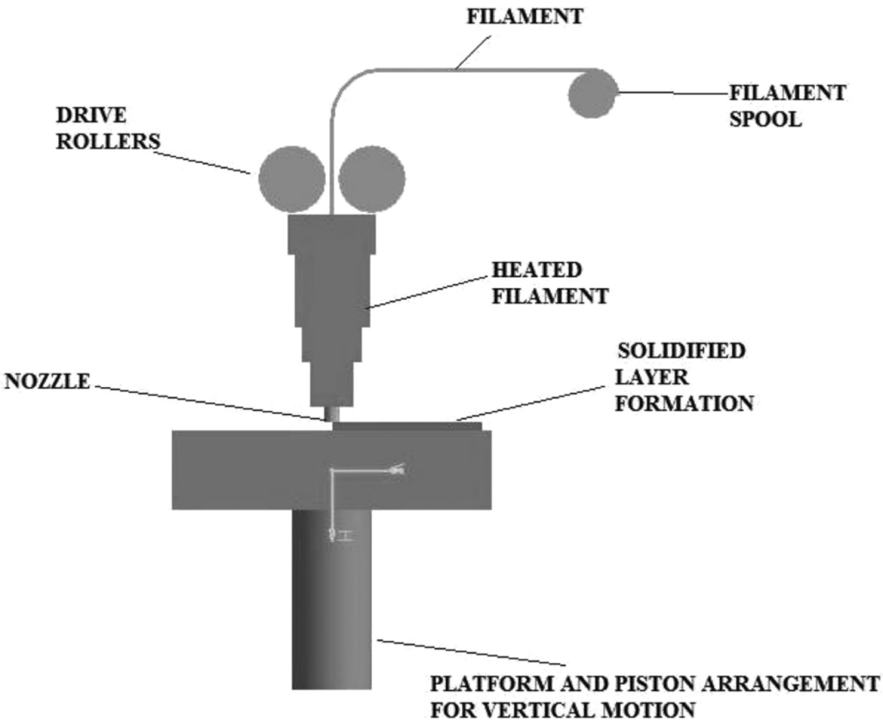
FDM Materials

The most common FDM raw material is ABS (acrylonitrile butadiene styrene) plastic which is a carbon chain copolymer. Polycarbonates, polyphenyl, sulphones, polycaprolactone, waxes, etc. are also used. Water soluble support materials are utilized with FDM which quickly dissolves by means of metal agitators with sodium hydroxide solvent.

Working Principles of FDM

FDM is based on the following working steps:

1) Exporting 3D solid model into FDM Insight^{TM} in. stl format
2) Generation of process plan for controlling FDM modeller
3) Feeding ABS filament into heating element to bring it into semi-molten form
4) Feeding filament via nozzle and its deposition upon previous layer/substrate
5) Repeating process to obtain final part



Since extrusion is in a semi-molten state, fusion of newer material into previous layers takes place. Movement of head around the x–y plane is followed by corresponding material deposition as per part geometry which in turn is followed by lowering of platform to enable deposition of new layer. This process continues till the complete part as per CAD data is obtained.

SLS Process:

Selective laser sintering (SLS) is an additive manufacturing process that is used to build three-dimensional solid prototypes and components, usually of a small scale. It is a rapid prototyping technique that use laser to sinter powder-based materials into solid products and models.

SLS use high-powered laser beam such as a carbon dioxide laser to join together raw materials and create the desired product/model. The material can be plastic, metal, glass or ceramic in a powdered form. The whole process of SLS is additive in nature. The laser beam takes cross section geometrical coordinates detail from a CAD drawing and adds the powder surface accordingly. When the layer is finished, the surface is powdered again and the process is repeated until the model is complete.