Chapter 1 -3D Printing (Additive Manufacturing)

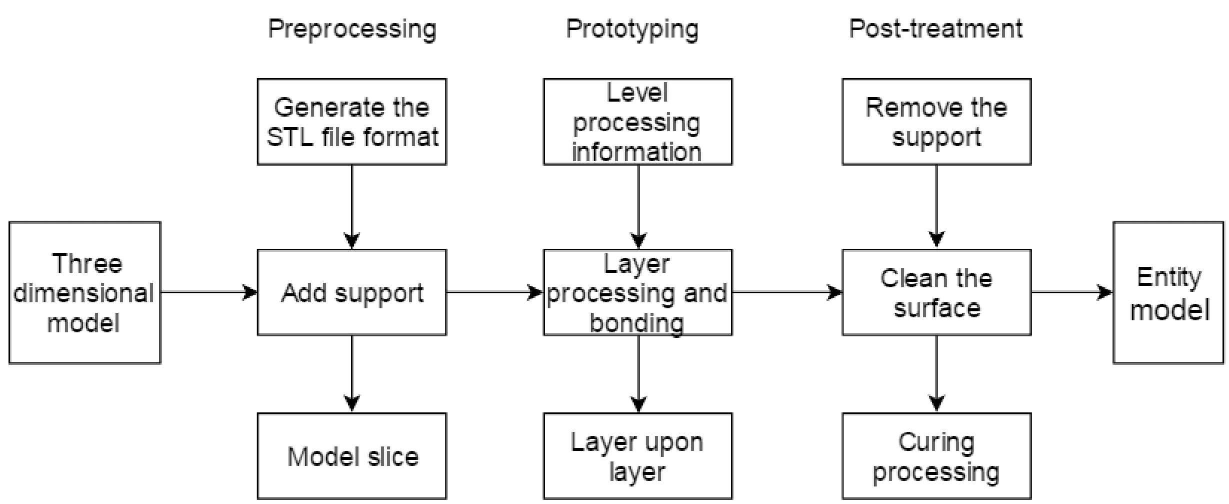
Define Additive Manufacturing (3D printing) -

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.

Different terms used for 3D printing.

- "Additive" Additive Manufacturing (AM)
  Additive Layer Manufacturing (ALM)
  Additive Digital Manufacturing (DM)
- "Layer" Layer Based Manufacturing
  Layer Oriented Manufacturing
  Layer Manufacturing
- "Rapid" Rapid Technology
  Rapid Prototyping, Rapid Tooling, Rapid Manufacturing
- "digital" Digital Fabrication
  Digital Mock-Up
- "Direct" Direct Manufacturing, Direct Tooling
- "3D" 3D Printing, 3D Modeling

Block Diagram for 3D Printing Process



The Generic Additive Manufacturing Process

- AM involves a number of steps that move from the virtual CAD description to the physical resultant part.
- Different products will involve AM in different ways and to different degrees.
- Small, relatively simple products may only make use of AM for visualization models, while larger, more complex products with greater engineering content may be involved.
- AM during numerous stages and iterations throughout the development process.

AM process involve, to some degree at least, the following eight steps

Step 1: CAD

All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the output must be a 3D solid or surface representation. Reverse engineering equipment (e.g., laser scanning) can also be used to create this representation.

Step 2: Conversion to STL

Nearly every AM machine accepts the STL file format, which has become a standard, and nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices

Step 3: Transfer to AM Machine and STL File Manipulation

The STL file describing the part must be transferred to the AM machine. Here, there may be some general manipulation of the file so that it is the correct size, position, and orientation for building.

Step 4: Machine Setup

The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

Step 5: Build

Building the part is mainly an automated process and the machine can largely carry on without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches, etc.

Step 6: Removal

Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

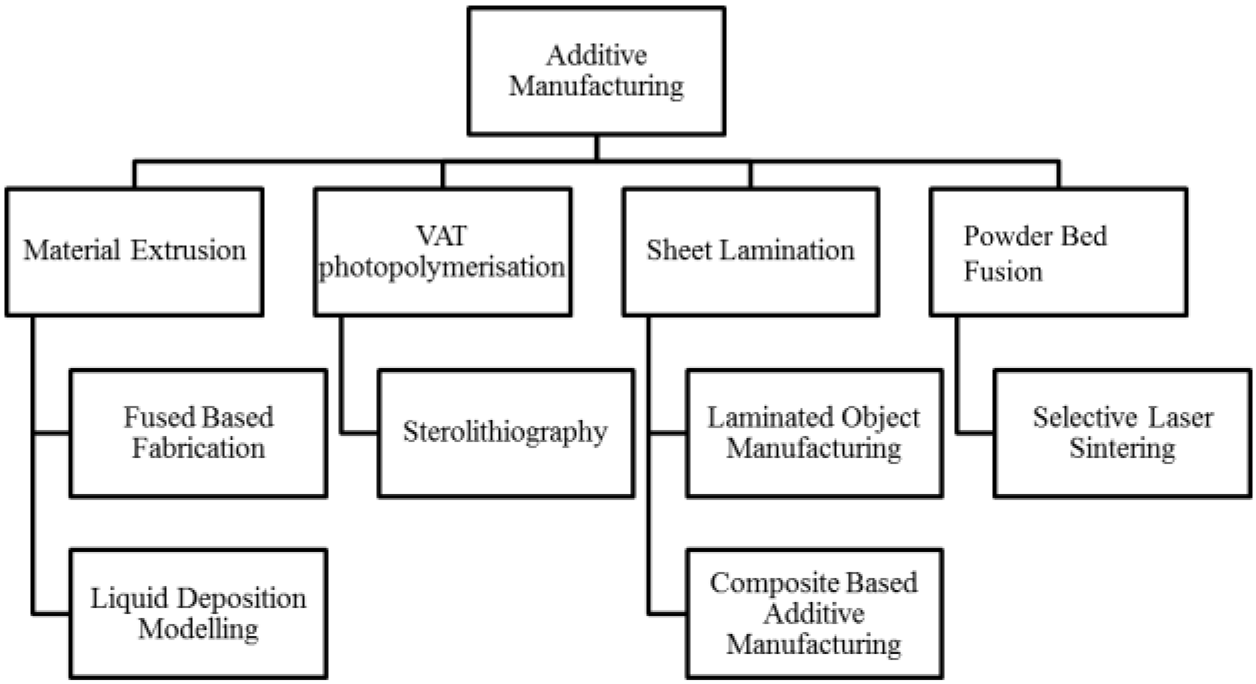
Step 7: Post Processing

Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation.

Step 8: Application

Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use. For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding.

Classification of 3D printing



Material Extrusion:

- Fused deposition modelling (FDM) is a common material extrusion process.
- Material is drawn through a nozzle, where it is heated and is then deposited layer by layer.
- The nozzle can move horizontally and a platform moves up and down vertically after each new layer is deposited. It is a commonly used technique used on many inexpensive, domestic and hobby 3D printers.
- The process has many factors that influence the final model quality but has great potential and viability when these factors are controlled successfully.
- Whilst FDM is similar to all other 3D printing processes, as it builds layer by layer, it varies in the fact that material is added through a nozzle under constant pressure and in a continuous stream.

VAT photopolymerisation:

- Vat polymerisation uses a vat of liquid photopolymer resin, out of which the model is constructed layer by layer.

- An ultraviolet (UV) light is used to cure or harden the resin where required, whilst a platform moves the object being made downwards after each new layer is cured.
- As the process uses liquid to form objects, there is no structural support from the material during the build phase., unlike powder based methods, where support is given from the unbound material.
- Resins are cured using a process of photo polymerisation or UV light, where the light is directed across the surface of the resin with the use of motor controlled mirrors.

Sheet Lamination:

- Sheet lamination processes include ultrasonic additive manufacturing (UAM) and laminated object manufacturing (LOM).
- The Ultrasonic Additive Manufacturing process uses sheets or ribbons of metal, which are bound together using ultrasonic welding.
- The process does require additional cnc machining and removal of the unbound metal, often during the welding process.
- Laminated object manufacturing (LOM) uses a similar layer by layer approach but uses paper as material and adhesive instead of welding.
- The LOM process uses a cross hatching method during the printing process to allow for easy removal post build.
- Laminated objects are often used for aesthetic and visual models and are not suitable for structural use.
- UAM uses metals and includes aluminium, copper, stainless steel and titanium. The process is low temperature and allows for internal geometries to be created. The process can bond different materials and requires relatively little energy, as the metal is not melted.

Powder Bed Fusion:

- The Powder Bed Fusion process includes the following commonly used printing techniques: Direct metal laser sintering (DMLS), Electron beam melting (EBM), Selective heat sintering (SHS), Selective laser melting (SLM) and Selective laser sintering (SLS).
- Powder bed fusion (PBF) methods use either a laser or electron beam to melt and fuse material powder together.

- Electron beam melting (EBM) methods require a vacuum but can be used with metals and alloys in the creation of functional parts.
- All PBF processes involve the spreading of the powder material over previous layers.
- There are different mechanisms to enable this, including a roller or a blade.
- A hopper or a reservoir below of aside the bed provides fresh material supply. Direct metal laser sintering (DMLS) is the same as SLS, but with the use of metals and not plastics.
- The process sinters the powder, layer by layer. Selective Heat Sintering differs from other processes by way of using a heated thermal print head to fuse powder material together. As before, layers are added with a roller in between fusion of layers. A platform lowers the model accordingly.

Advantages of AM

- Greater design ability. The technology allows assemblies to be printed in one process and organic shapes to be easily produced. Traditional constraints of manufacture are reduced or eliminated.
- Unlike many widely used manufacturing techniques such as injection moulding, no tooling is required, which can be a barrier to production due to the high cost.
- Anywhere manufactured. Parts can be sent digitally and printed in homes or locations near to consumers, reducing the requirement and dependence on transport
- Compared to conventional techniques with more geometric limitations, additive manufacturing can produce models quickly, in hours, not weeks.
- Fewer resources for machines and little skilled labour when compared to conventional model making craftsmanship.
- Customisation - Particularly within the medical sector, where parts can be fully customised to the patient and their individual requirements.
- Efficient material use due to the exact production of parts and no overproduction based on estimated demand.
- Commercial advantage and increased competitiveness, in the form of reduced costs and risk, as the development time from concept to manufacture is minimised.

- Material efficiency. Material required matches material used. Support material and powder can often be recycled at source, back into the system.
- Environmental benefits. The emissions from trans- port are reduced because of the ability to manufacture anywhere.
- With increasing numbers of machines, 3D printing is becoming more affordable, whereas injection moulding machines remain relatively expensive and inaccessible.

Comparison between Additive manufacturing and Traditional Manufacturing

Parameters	**Additive Manufacturing**	**Traditional Manufacturing**
Working Principle	It is the process of creating an object by building it one layer at a time.	It is a process of creating an object by cutting away at a solid block of material until the final product is complete.
Cost	Production of elements at the cost of materials	Fast production time - usually up to several dozen hours additional costs include preparation of moulds, dyes, finishing.
Time	Fast production time - usually up to several hours	Long time depends on the complexity of form, inventory and supply chain.
Consumption of resources	Optimum material quantity needed	High consumption
Product	Possibility to produce products with a complex geometry	Limited production, need to combine several elements into one
Post - Processing	Not always necessary	In most cases, the final processing required

Quality of material	Properties similar to steel	Load- bearing parts
Material losses/ Wastage	Low/ None	High losses
Airspace use	Possible with high temperature filaments, low weight and high mechanical resistance	Difficult
Manpower	High	Low

Define Material Extrusion

Material extrusion is an additive manufacturing (AM) methodology where a spool of material (usually thermoplastic polymer) is pushed through a heated nozzle in a continuous stream and selectively deposited layer by layer to build a 3D object.

Define Extrusion

Extrusion is a process used to create objects of a fixed cross-sectional profile by pushing material through a die of the desired cross-section. Its two main advantages over other manufacturing processes are its ability to create very complex cross-sections; and to work materials that are brittle, because the material encounters only compressive and shear stresses. It also creates excellent surface finish and gives considerable freedom of form in the design process

Post Processing Techniques

- Support Removal
- Sanding
- Vapor smoothing
- Priming and painting
- Polishing
- Electroplating
- Gluing and welding

- Hydrographics

Applications of 3D printing.

- Education
- Prototyping And Manufacturing\
- Medicine
- Construction
- Art and Jewelry
- Aerospace & Defence
- Prosthetics and Human Organs
- Biomedical Implants
- Pharmaceuticals
- Emergency Response Structures

Questions.

- *Define 3D printing/ Additive manufacturing.*
- *Explain the basic principles of Additive Manufacturing Process.*
- *Compare Additive manufacturing and Traditional Manufacturing.*
- *List the limitations of traditional manufacturing processes.*
- *Define Material Extrusion.*
- *State the use of additive manufacturing.*
- *Write any four applications of 3D printing.*
- *Classification of Additive Manufacturing.*
- *Draw the block Diagram for 3D Printing Process*
- *Explain the Generic Additive Manufacturing Process*