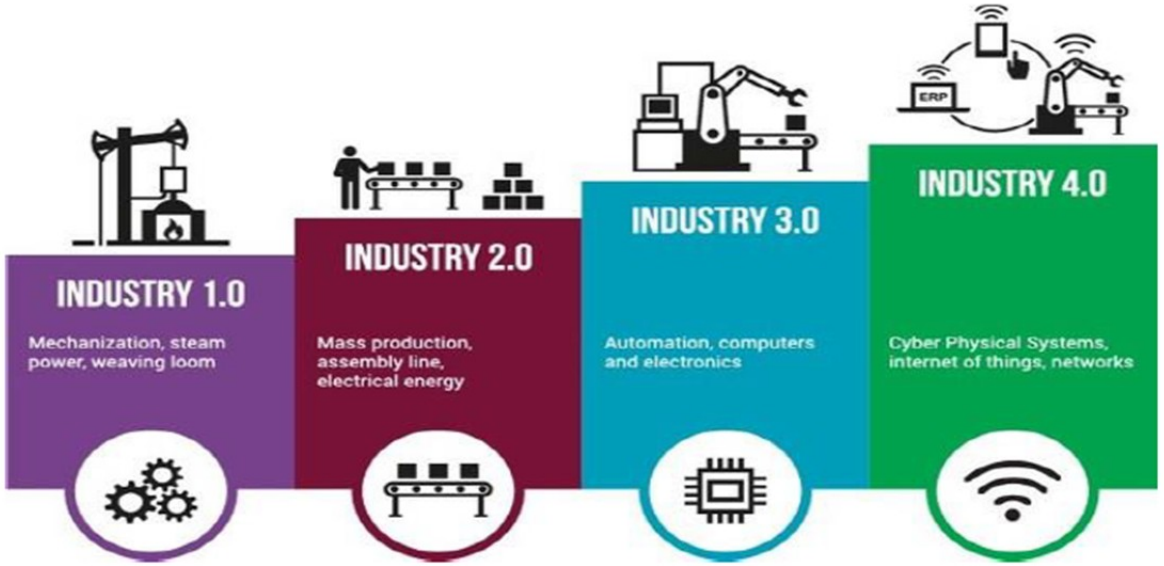
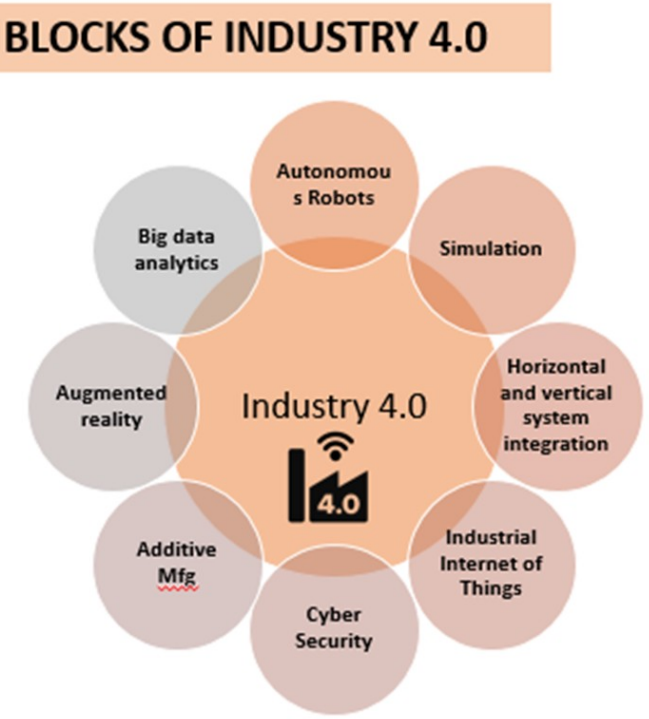
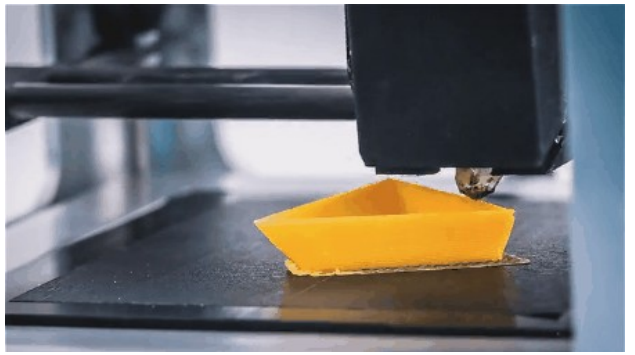
Industry 4.0 has been defined as "a name for the current trend of automation and data exchange in manufacturing technologies, including cyber-physical systems, the Internet of things, cloud computing and cognitive computing and creating the smart factory".





Additive manufacturing

- ***'Additive manufacturing fabricates parts by building them up layer-by-layer, as opposed to cutting material away or molding it'.***



- Additive manufacturing can also be viewed as a way to turn a digital model (of the object to be constructed) into a physical one since it starts as a (3D) software design.

- Additive manufacturing doesn't replace other manufacturing methods (at least not for many years to come) but leads to a wealth of new opportunities. Moreover, some objects would be almost impossible to make without additive manufacturing.

- ***Additive manufacturing and 3D printing are used in multiple domains (healthcare, the construction industry, defense, retail, pharma, automotive industry, aerospace, making parts in close to any area you can imagine, including human tissue and food, smart manufacturing). They are also the subject of intensive research and development (methods, materials, new techniques, application areas, etc.).***

Different 3D Printing Processes

- A total of seven different types of additive manufacturing processes have been established and identified. These seven 3D printing processes brought forth ten different types of 3D printing technology that 3D printers use today.

- 3DPrinting Process: Material Extrusion
  - Fused Deposition Modeling (FDM)
- 3D Printing Process: Vat Polymerization
  - Stereolithography (SLA)
  - Digital Light Processing (DLP)
- 3D Printing Process: Powder Bed Fusion
  - 3D Printing Process: Powder Bed Fusion (Polymers)
    - Selective Laser Sintering (SLS)
  - 3D Printing Process: Powder Bed Fusion (Metals)
    - Direct Metal Laser Sintering (DMLS)/Selective Laser Melting (SLM)
  - Electron Beam Melting (EBM)
- 3D Printing Process: Material Jetting
  - Material Jetting (MJ)
  - Drop on Demand (DOD)
- 3D Printing Process: Binder Jetting
  - Sand Binder Jetting
  - Metal Binder Jetting
- Sheet Lamination
- Directed Energy Deposition

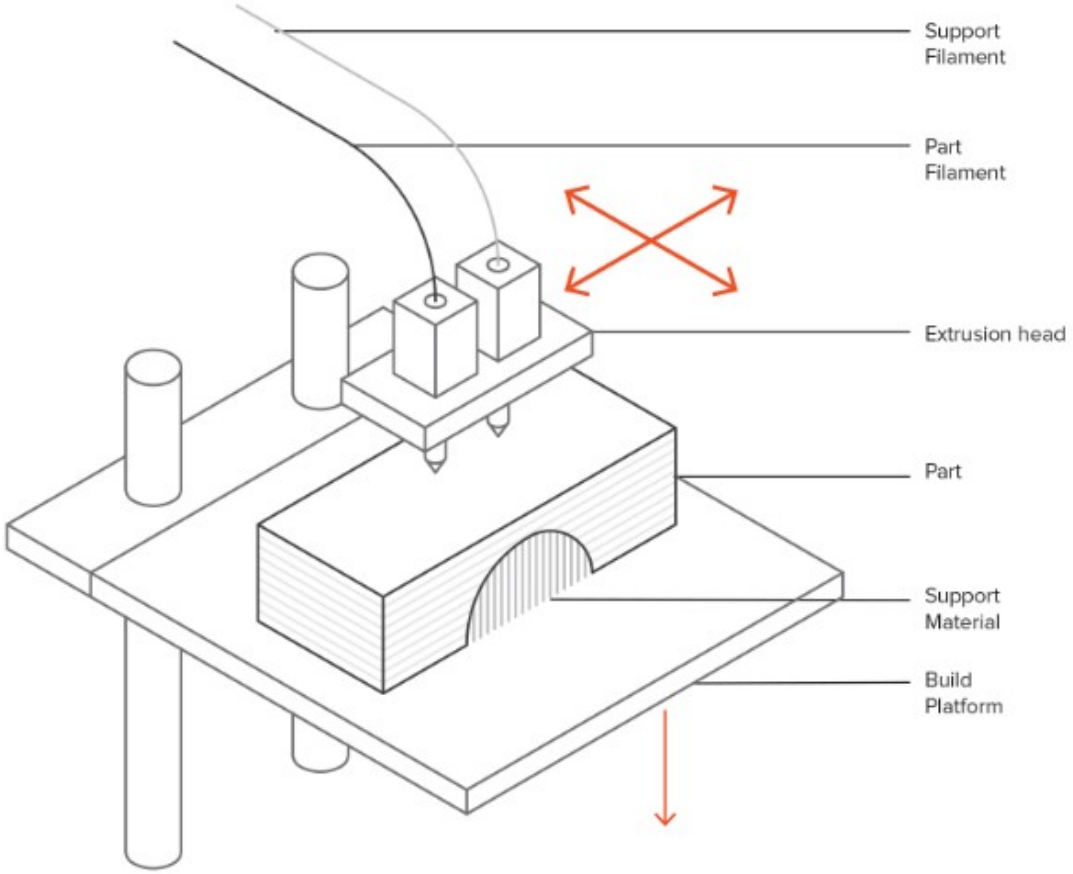
Material Extrusion – Fused Deposition Modelling

- Material extrusion is a 3D printing process where a filament of solid thermoplastic material is pushed through a heated nozzle, melting it in the process.

- The printer deposits the material on a build platform along a predetermined path, where the filament cools and solidifies to form a solid object.

  - **Types of 3D printing technology**: Fused deposition modeling (FDM), sometimes called fused filament fabrication (FFF)
  - **Materials**: Thermoplastic filament (PLA, ABS, PET, TPU)
  - **Dimensional accuracy**: ±0.5% (lower limit ±0.5 mm)
  - **Common applications**: Electrical housings; Form and fit testings; Jigs and fixtures; Investment casting patterns
  - **Strengths**: Best surface finish; Full color and multi-material available
  - **Weaknesses**: Brittle, not sustainable for mechanical parts; Higher cost than SLA/DLP for visual purposes

Material Extrusion – Fused Deposition Modelling



Material Extrusion – Fused Deposition Modelling

1) Part preparation

- The initial stage is to import the design file and choose options for the build, such as layer height, orientation and infill percentage.

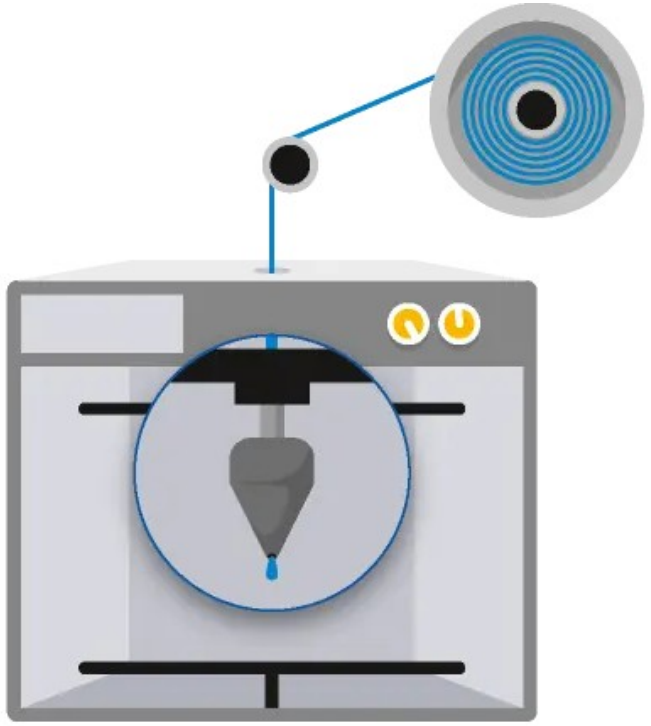
- The software then computes sections and slices the part into several layers. The program then creates extruder paths and building instructions based on the sectioning data to drive the extrusion heads.

Material Extrusion – Fused Deposition Modelling

2) FDM Machine setup

- The printer is loaded with a thermoplastic filament spool for both model and support extruders. Generally, the build platform is heated and maintained at a higher temperature to control the cooling of the extruded material.

- Extruders are heated, and when the nozzle reaches the required temperature, the head will start pushing and melting the filament into a small ribbon roughly the size of a human hair.

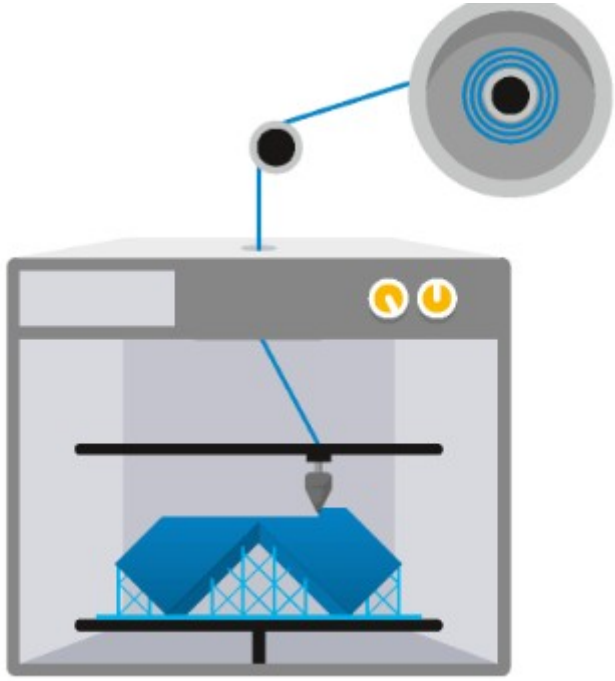


Material Extrusion – Fused Deposition Modelling

3) FDM printing

- The extrusion head gantry and the build platform are on a three-axis system, which allows the nozzle tip to move in three directions in space.

- The extruder will start depositing the material layer by layer in predefined areas to cool and solidify. Sometimes the material cooling is assisted using cooling fans mounted to the extrusion head.



Material Extrusion – Fused Deposition Modelling

4) FDM part removal

- Like any other 3D printing process, the next stage involves removing parts from the build platform and cleaning them by removing all supports.