Rapid Manufacturing

Prof. Janakarajan Ramkumar
Professor
Department of Mechanical
IIT Kanpur, India.

Index

- Introduction of Rapid Manufacturing (RM)
- Steps involved in RM
- Classification of RM processes
- Rapid Tooling (RT)
- Geometrical freedom for RM
- Applications of RM
- Disadvantages of RM

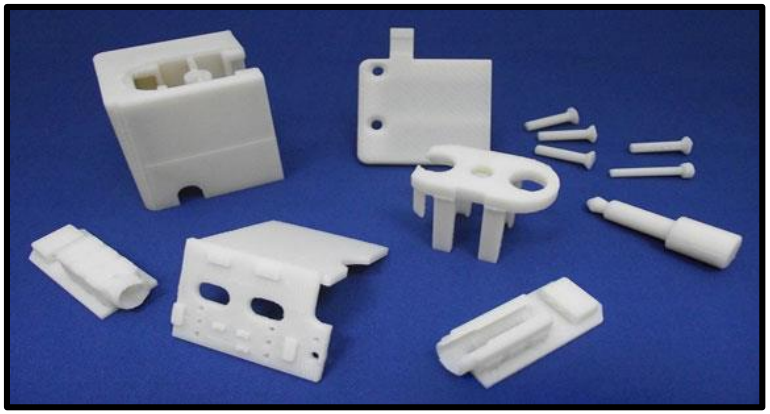
Introduction

Rapid Manufacturing is defined as "the use of a computer aided design (CAD)-based automated additive manufacturing process to construct parts that are used directly as finished products or components."

- Rapid Manufacturing is a new area of manufacturing developed from a family of technologies known as Rapid Prototyping.

"improving products and reducing their development time"

- Rapid Manufacturing has developed as the next stage, in which the need for tooling is eliminated.



Why Rapid Manufacturing?

"It is a technique for manufacturing solid objects by the sequential delivery of energy and/or material to specified points in space to produce parts"

1. Mass customization is possible.
2. More customer satisfaction, with highest integrity
3. High speed for manufacturing complex parts
4. Eliminates tooling cost
5. Simple and automated operations
6. Personalized products become conceivable
7. Design Freedom
8. To minimize sustaining engineering changes
9. On demand manufacturing
10. Use of Reverse Engineering for making component

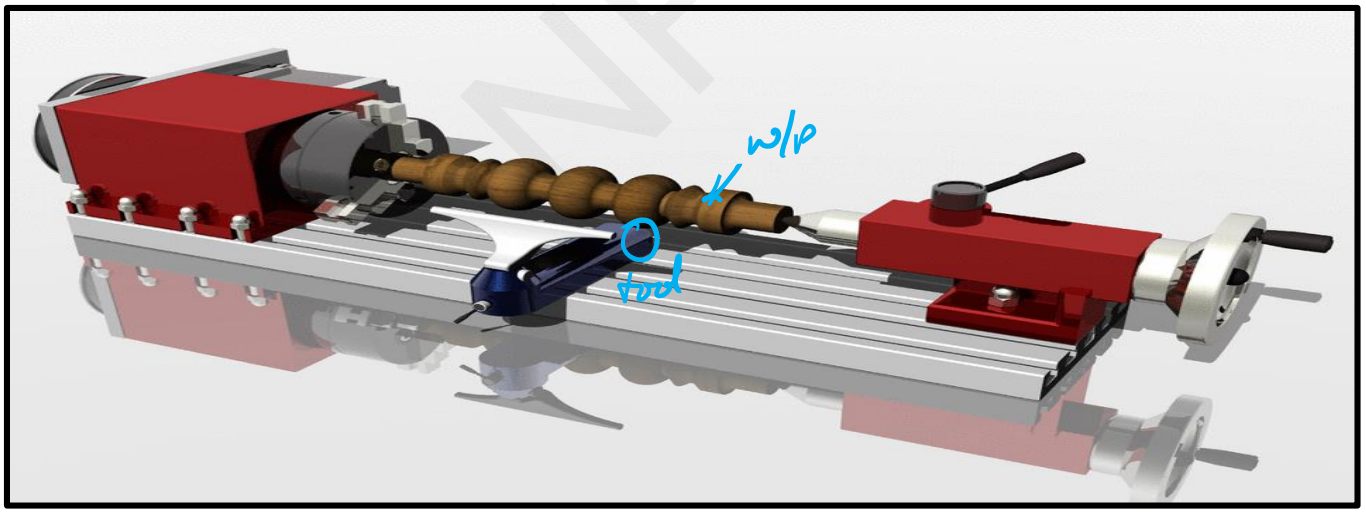
Types of Manufacturing Process

- **Manufacturing process,** are the steps through which raw materials are transformed into a final product. The manufacturing process begins with the product design, and materials specification from which the product is made.

- These materials are then modified through manufacturing processes to become the required part.

Subtractive Manufacturing

- It is a process in which product is created by removing material from larger pieces of material
- It is a traditional manufacturing method that involves milling, turning, drilling, lathe and other CNC operations.
- This process is considered as wasteful as compared to other methods.
- Limited to large volume production with simple part design

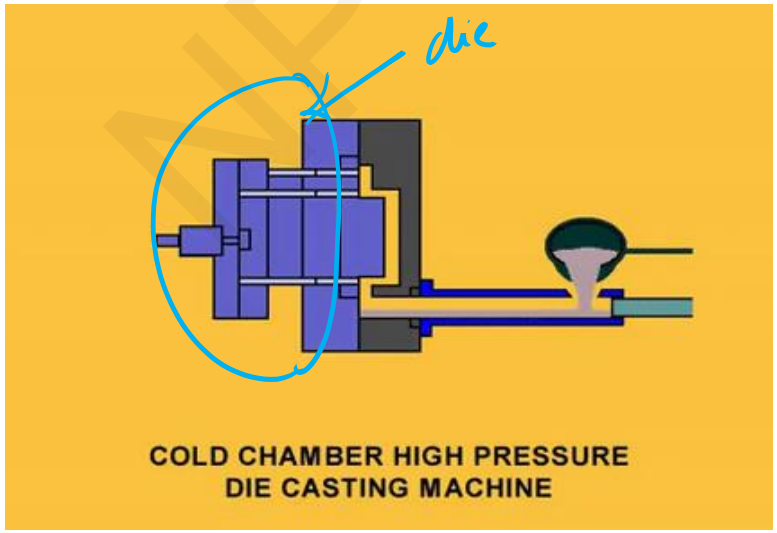


https://b2b.partcommunity.com/community/knowledge/en/detail/767/Lathe

Formative manufacturing

This includes the process like die-casting, injection molding, pressing, stamping etc., to form material into the desired shapes.

- Used for wide variety material including metals and plastics.
- It has the ability to make a single component with different materials
- High quality parts can be made with comparatively low cost/product
- Post processing in the form of tooling is required which increases the cost



https://gfycat.com/confusedgrimycowrie

Additive Manufacturing

- It is a process that involves assembly of a product layer by layer.

- The term AM encompasses many technologies including subsets like Rapid manufacturing, Rapid Prototyping (RP), Direct Digital Manufacturing (DDM),layered manufacturing and additive fabrication

Steps involved in Rapid Manufacturing

❖ **Create a CAD model of the design**

1. Object to be build is modelled using CAD software
2. Solid modelers like Solid Works, CATIA, PROE,AUTOCAD etc. can be used
3. Modelling must be done in the form of surface/solid models

❖ **Convert the CAD model to STL (Standard Tessellation Language) file format**

1. STL format is the standard for Rapid Manufacturing/Prototyping industry
2. This format represent 3D surface as an assembly of planar triangles and describes only surface geometry.

Steps involved in Rapid Manufacturing

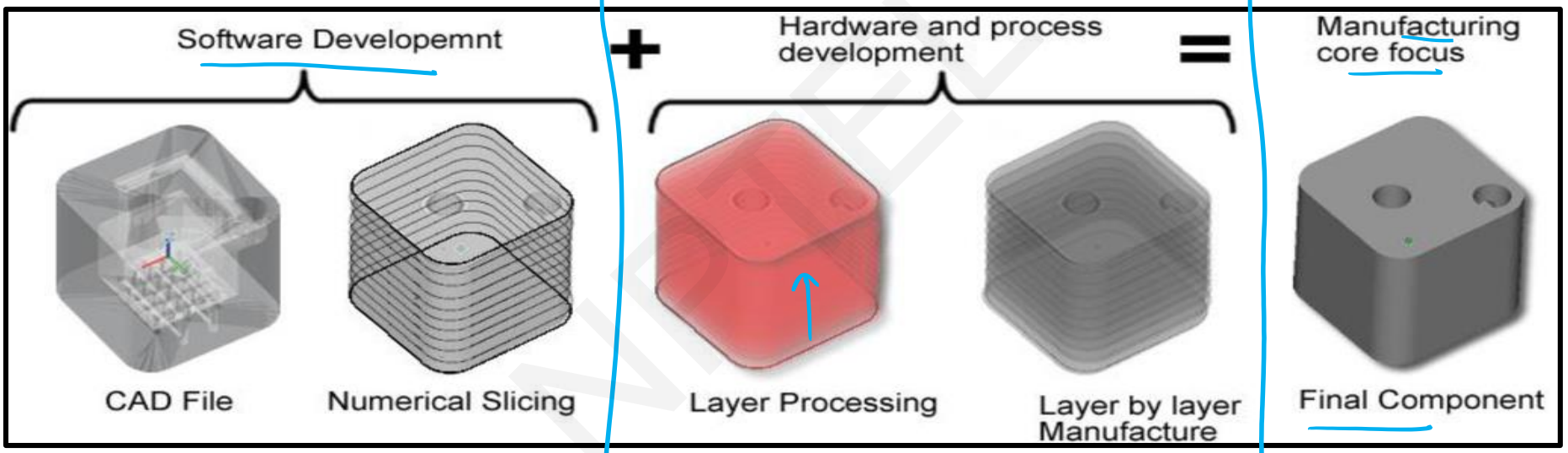
❖ **Construct the model one layer atop another**

1. Rapid manufacturing machine build one layer at a time either from powdered metals, polymers or paper.
2. The whole system is automatic and no human intervention is needed.

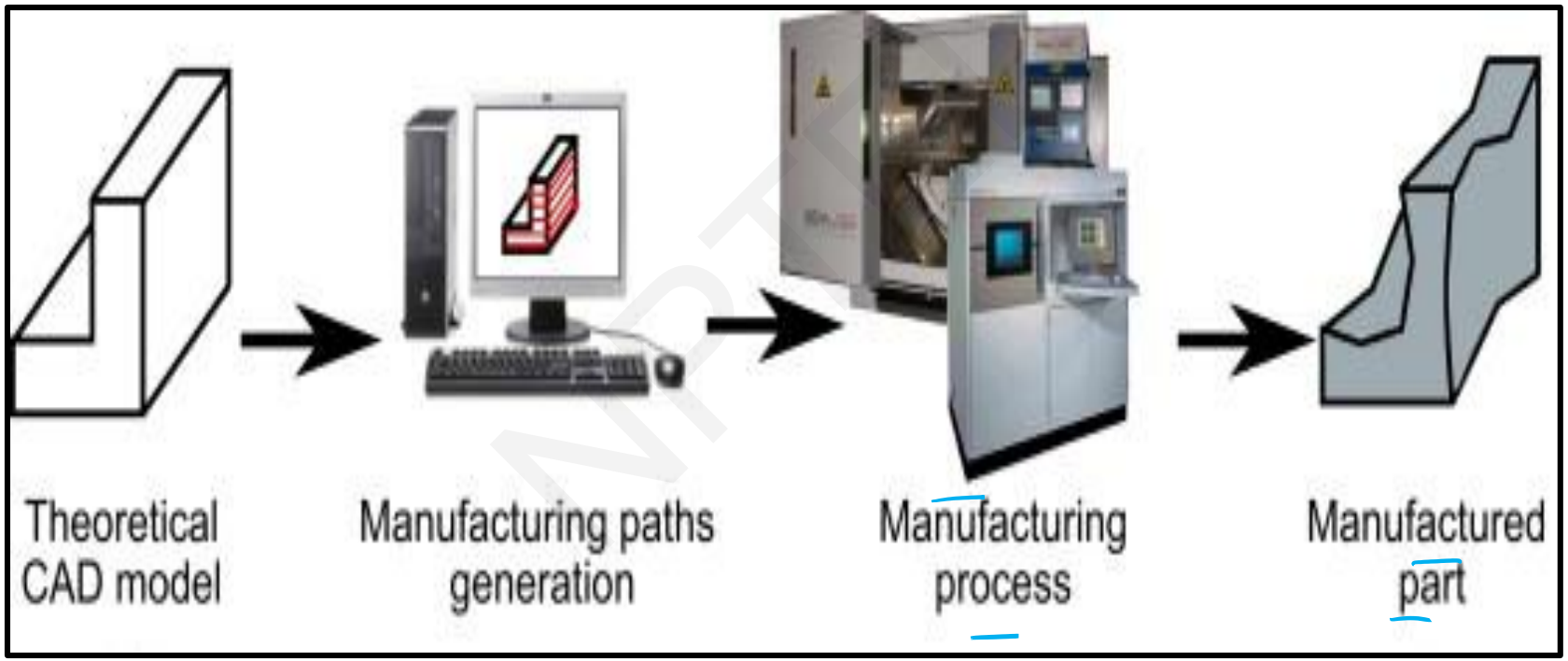
❖ **Clean and Finish the model**

1. Post processing step
2. Product may require minor cleaning and surface treatment.

Steps involved in Rapid Manufacturing



Steps involved in Rapid Manufacturing



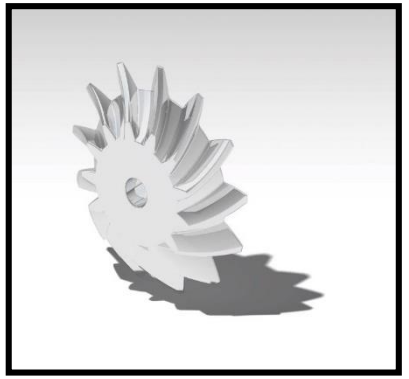
http://cafe.foundation/blog/additive-manufacturing-for-electric-motors/

CAD for Rapid Manufacturing

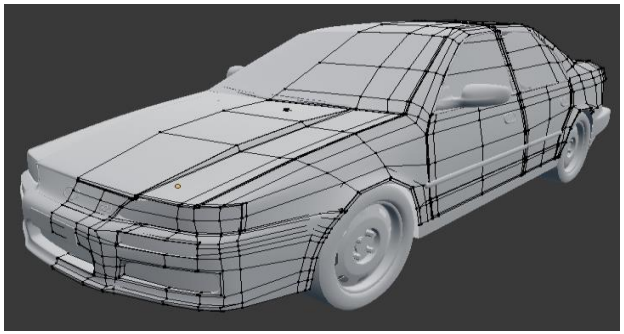
- **Computer-aided design** (**CAD**) is the use of computers to aid in the creation, modification, analysis, or optimization of a design.

- CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.

- Geometric Modelling Kernel is a software component that provides solid modeling and surface modeling features to CAD applications.

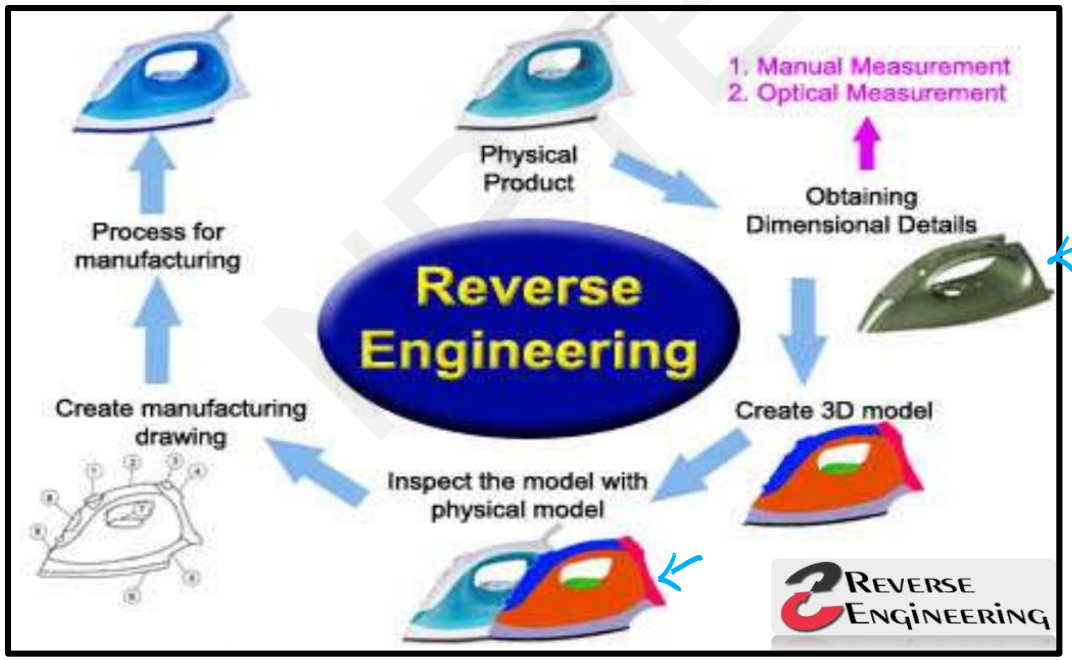


Solid Modelling Vs Surface Modelling



Reverse Engineering utility for Rapid Manufacturing

- Reverse Engineering is a process of redesigning an existing product to improve and broaden its functions, add quality and to increase the useful life.
- Its main aim is to reduce the manufacturing cost of the new product, making it competitive in market.



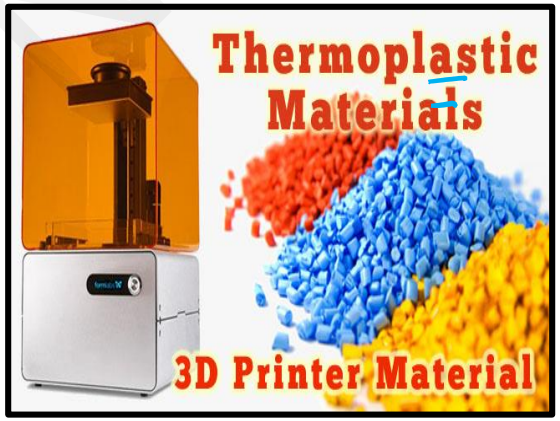
Point cloud & data S/W

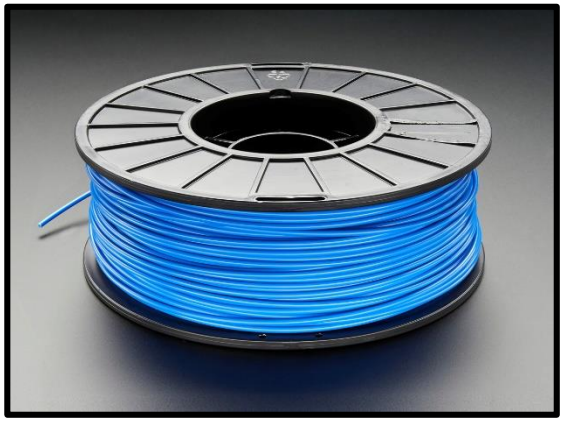
The results obtained can be used for Rapid Manufacturing of the product.

https://www.indiamart.com/proddetail/reverse-engineering-4480021012.html

Classification of Rapid Manufacturing processes

- There are various ways to classify the RP techniques that have been developed
- The RP classification used here is based on the form of the starting raw material:
  1. Liquid-based
  2. Powder-based
  3. Solid-based





Liquid-based Processes

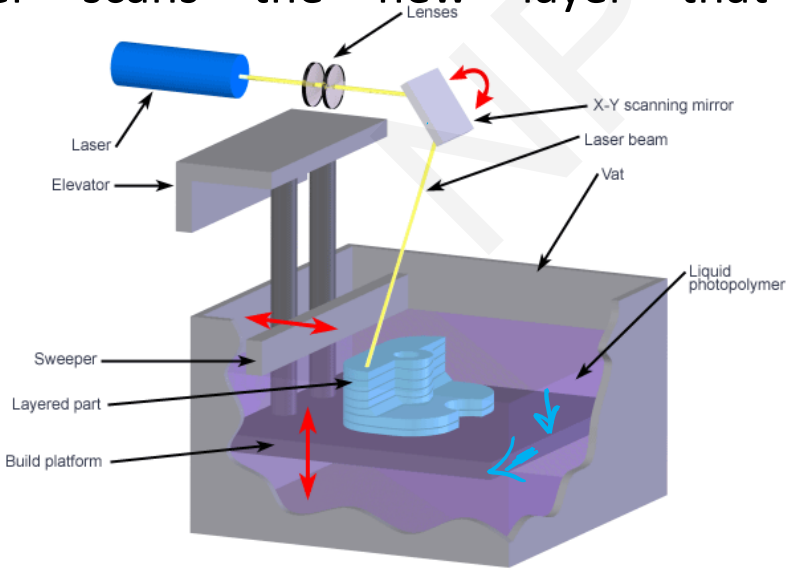
- The starting material is in the form of Liquid.
- It involves the formation of a solid by selectively curing regions of photosensitive polymers.
- It has a superior accuracy as compared to other processes for RM

Major Types are:-

1. Stereolithography
2. Jetting process
3. Direct light processing technologies ← very popular
4. High-viscosity jetting
5. The MAPLE process

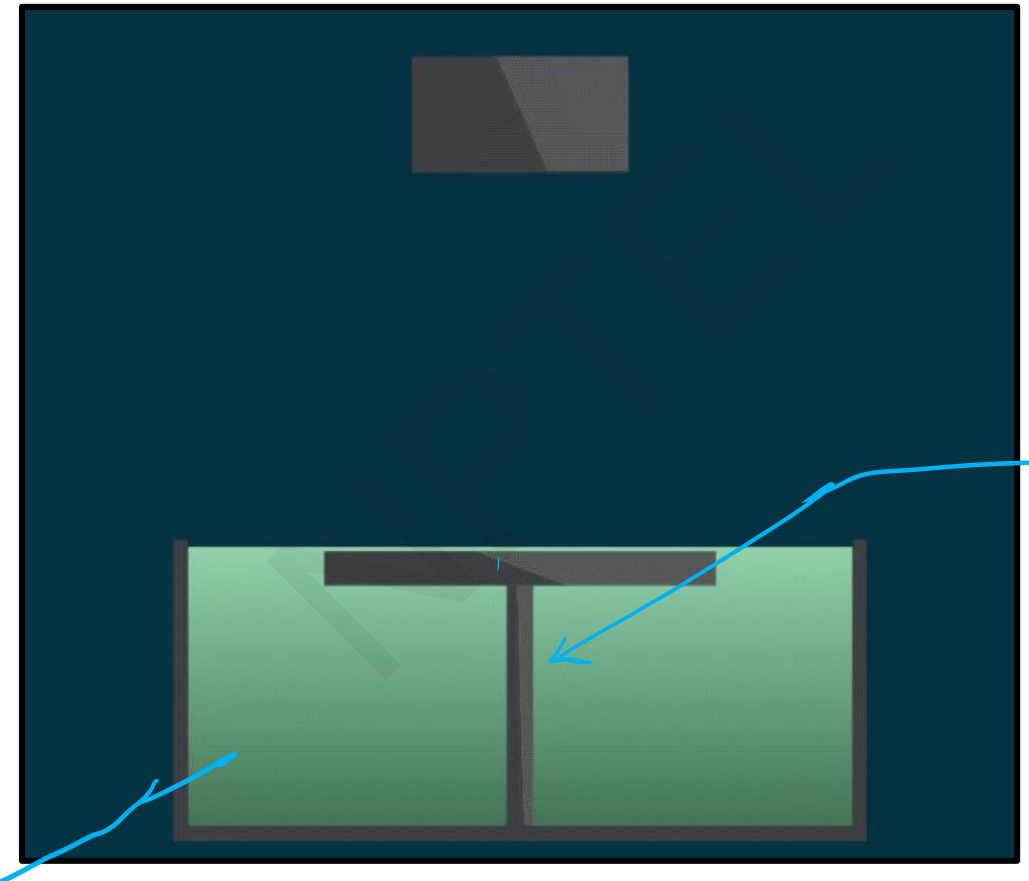
Stereolithography

- RP process for fabricating a solid plastic part out of a photosensitive liquid polymer using a directed ultraviolet laser beam to solidify the polymer
- A selected portion of the surface of a vat of resin is cured and solidified on to a platform.
- The platform is then lowered, typically by 100 mm, and a fresh layer of liquid resin is deposited over the previous layer.
- Laser scans the new layer that binds the previous layer.



https://www.custompartnet.com/wu/stereolithography

Stereolithography

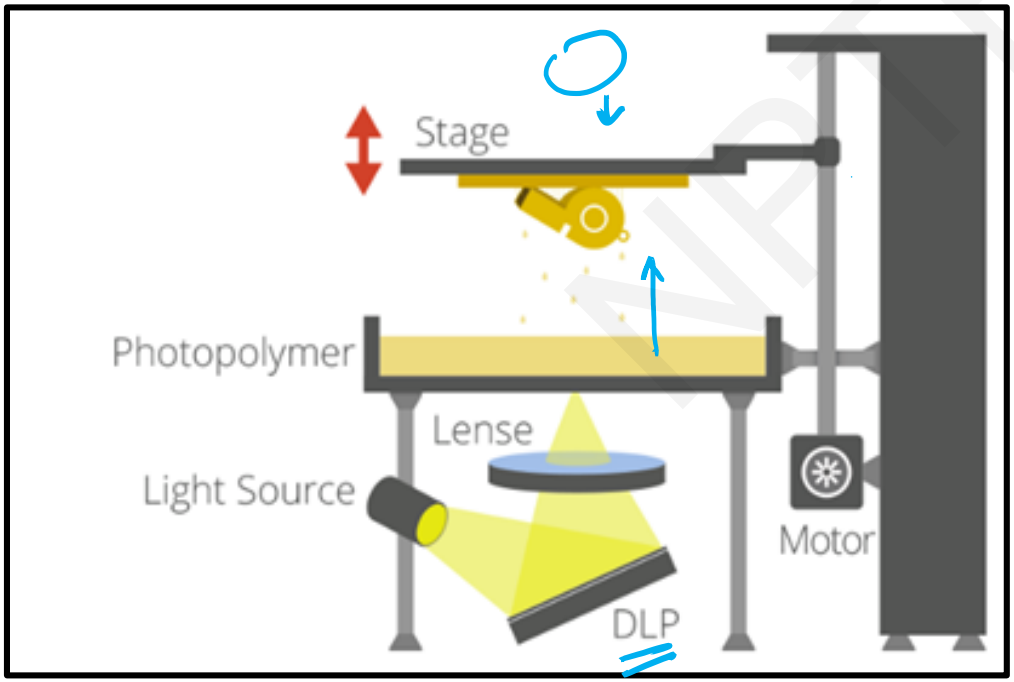


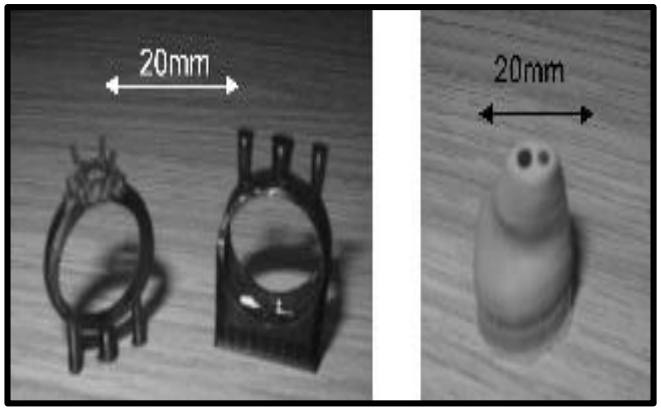
Stereolithography Illustration

https://www.nazdar.com/en-us/News-events/ArtMID/4165/ArticleID/399

Direct Light Processing Technologies

- This uses parts from acrylate based photo curable resin
- This is based on Top to Bottom growth, the ramp move up to make the product
- With a build speed of 10-15 seconds per layer the process is well suited to build parts quickly





http://www.3dprinting.lighting/3d-printing-technologies/stereolithography/

Powder-based Processes

- The starting material is in the form of a powder.
- It provides a wider variety of material possibilities with
    1. Polymers
    2. Metals &
    3. Ceramics
- Powder based materials provides the possibility of functionally Graded Materials(FGM),which increased potential of RM components.

Powder-based Processes

Major types are:-

1. Selective Laser Sintering(polymers , ceramics & metals)
2. Direct Metal laser sintering
3. Three dimensional printing
4. Fused metal deposition system
5. Electron beam melting
6. Selective laser melting
7. Selective masking sintering
8. Electro photographic Layered Manufacturing
9. High Speed Sintering

Selective Laser Sintering (SLS)

- Moving laser beam sinters heat-fusible powders in areas corresponding to the CAD geometry model one layer at a time to build the solid part .

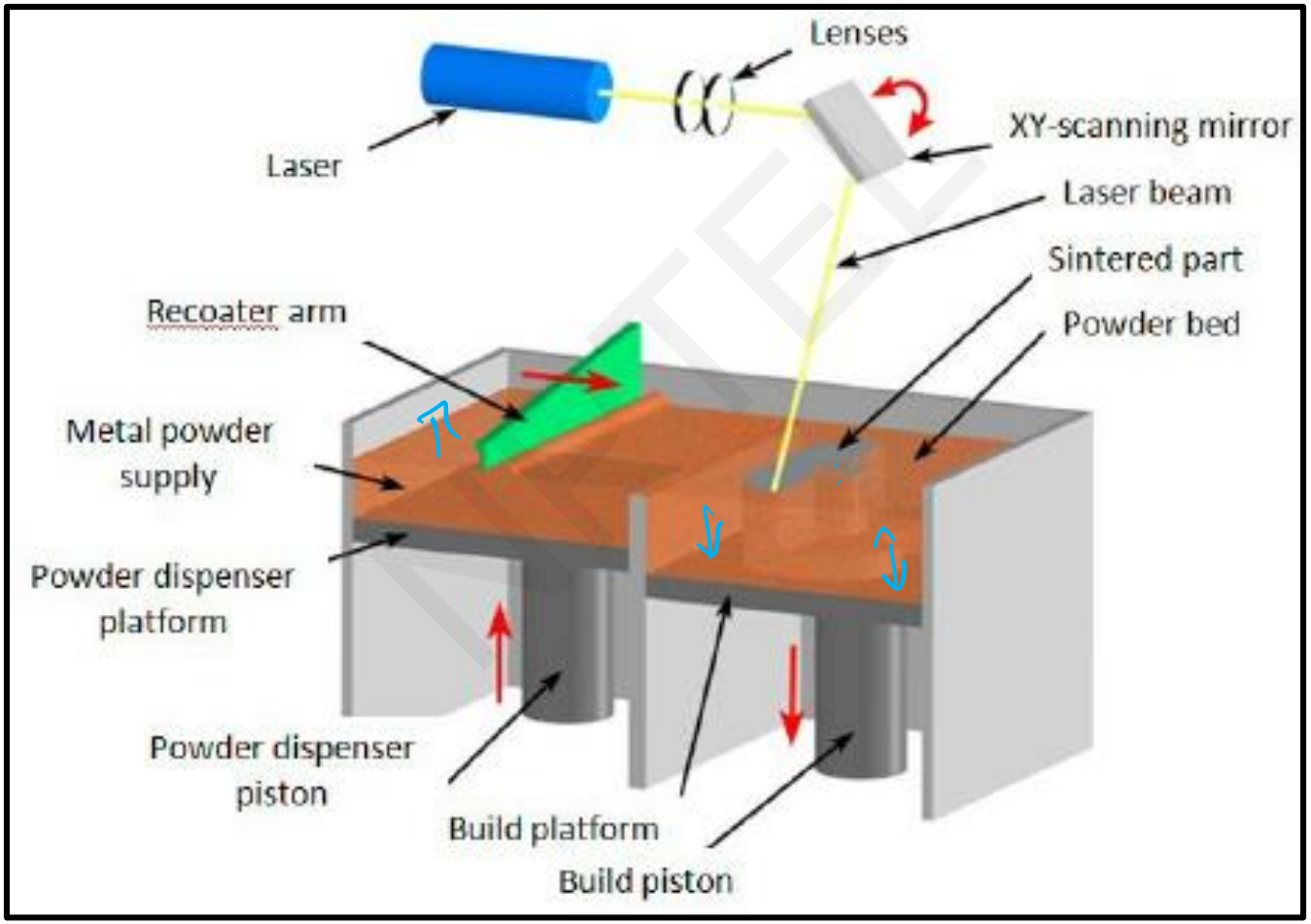
- After each layer is completed, a new layer of loose powders is spread across the surface.

- Layer by layer, the powders are gradually bonded by the laser beam into a solid mass that forms the 3-D part geometry .

- In areas not sintered, the powders are loose and can be poured out of completed part .

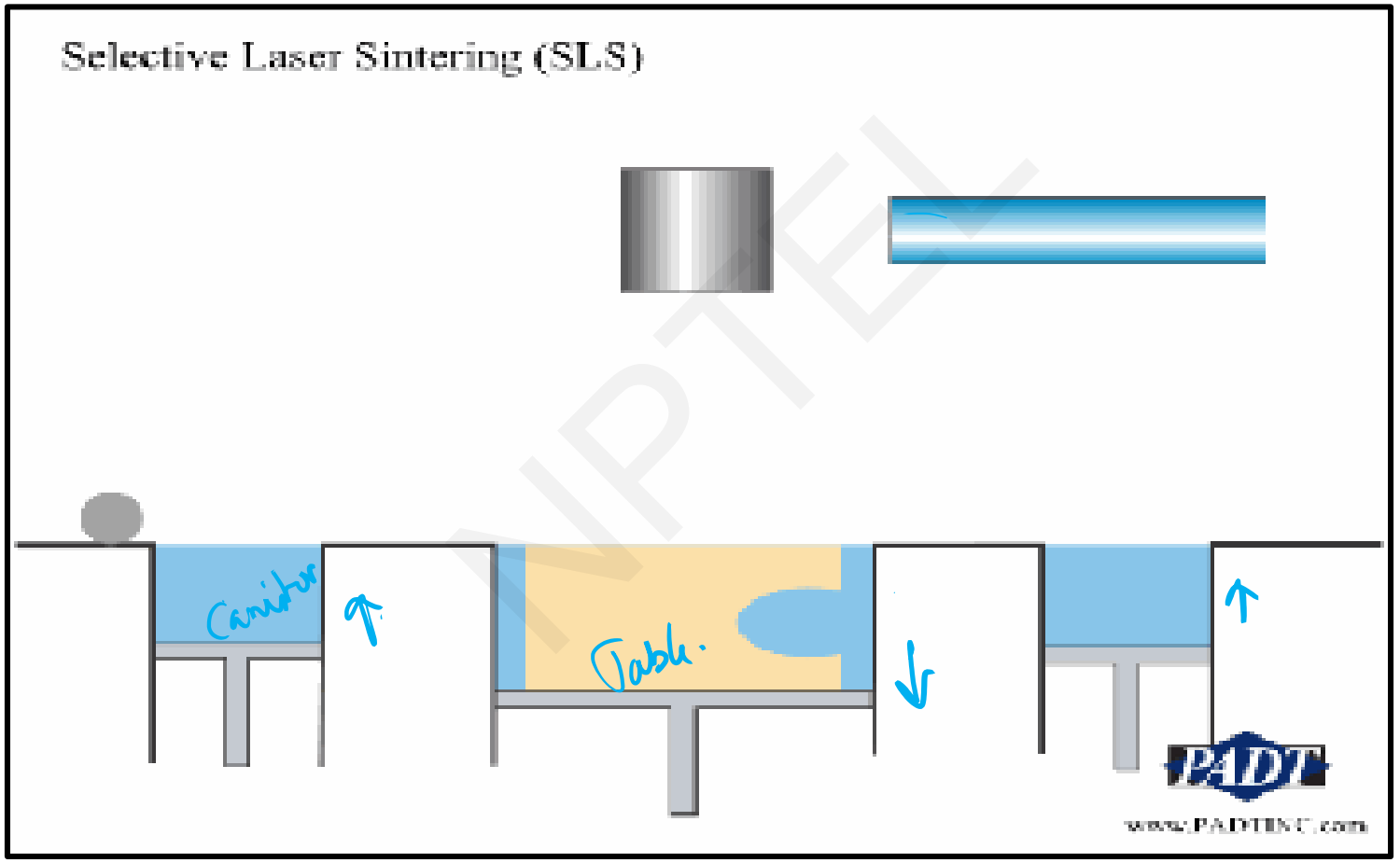
- Prior heating is required to bring the temperature of the powder below sintering temperature

Selective Laser Sintering



https://www.custompartnet.com/wu/selective-laser-sintering

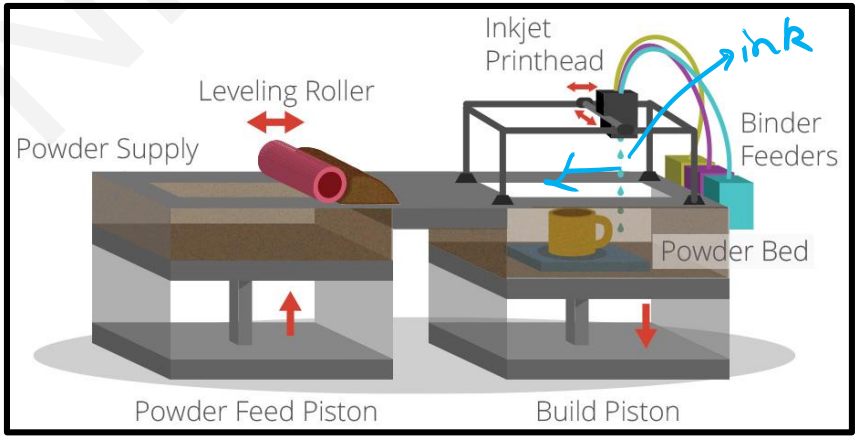
Selective Laser Sintering



https://giphy.com/explore/laser-sintering

Three dimensional printing

- Part is built layer-by-layer using an ink-jet printer to eject adhesive bonding material onto successive layers of powders.
- Binder is deposited in areas corresponding to the cross sections of part, as determined by slicing the CAD geometric model into layers .
- The binder holds the powders together to form the solid part, while the unbounded powders remain loose to be removed later.
- To further strengthen the part, a sintering step can be applied to bond the individual powders.



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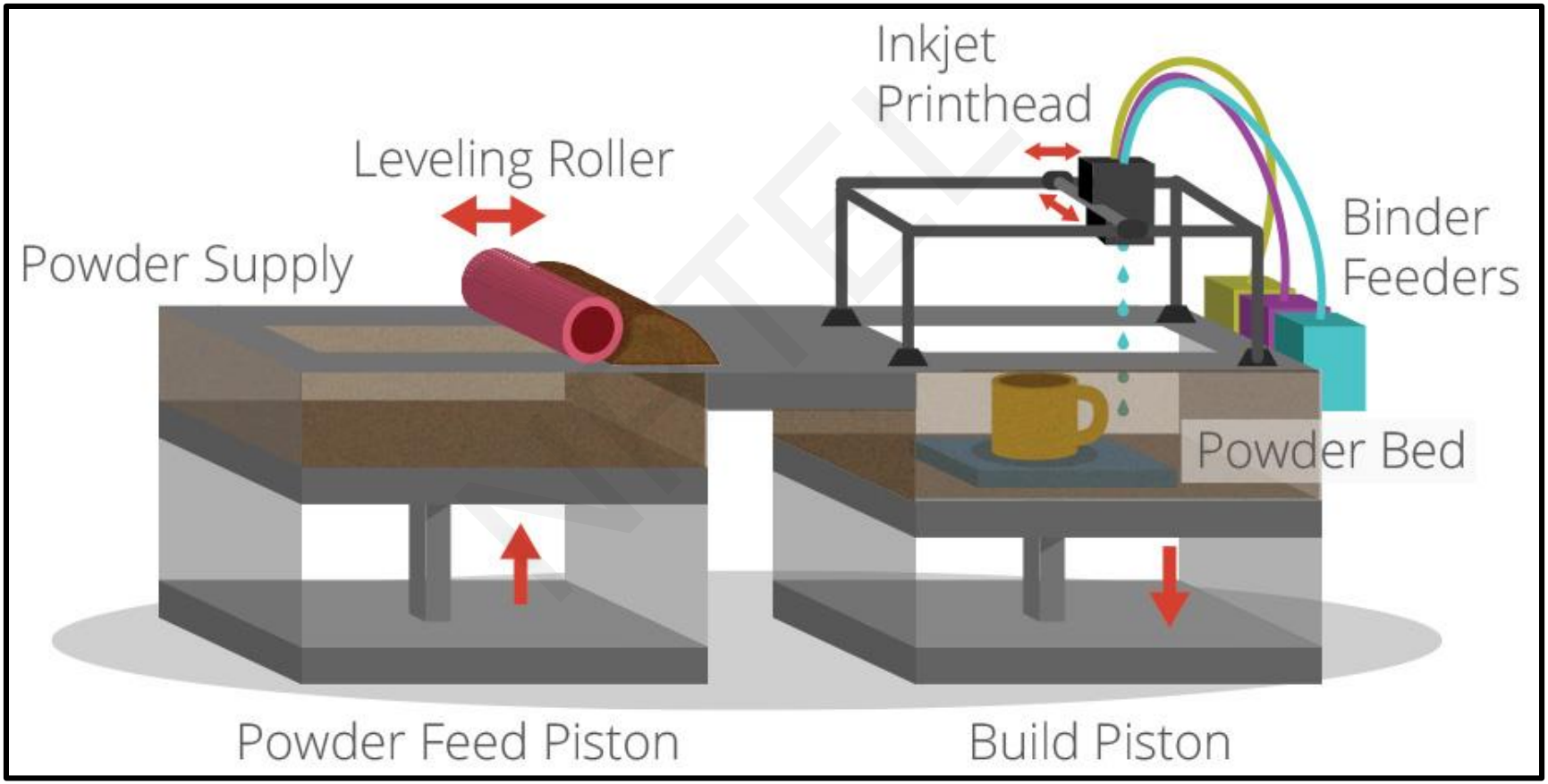
Three dimensional printing



https://www.researchgate.net/publication/330855815_3D-printing_and_advanced_manufacturing_for_electronics/figures?lo=1

Solid-based Processes

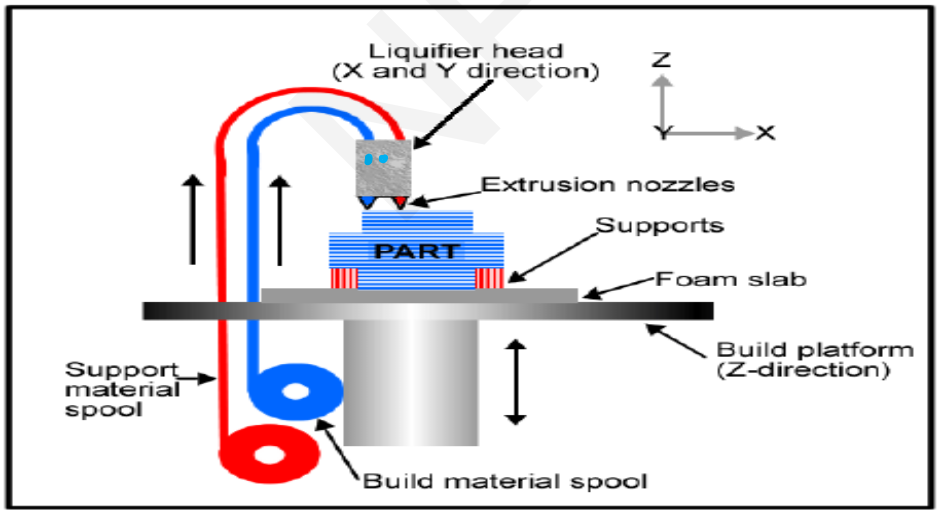
- The starting material is in the form of solid.
- Generally It includes materials such as Acrylonitrate Butadine Styrene (ABS), Polycarbonate, polyphenyl sulfone etc.
- Material is in the form of Wire spool or sheets.

Major Types:-

1. Fused Deposition Modelling
2. Sheet Stacking Technologies
   a) Laminate Object Manufacturing

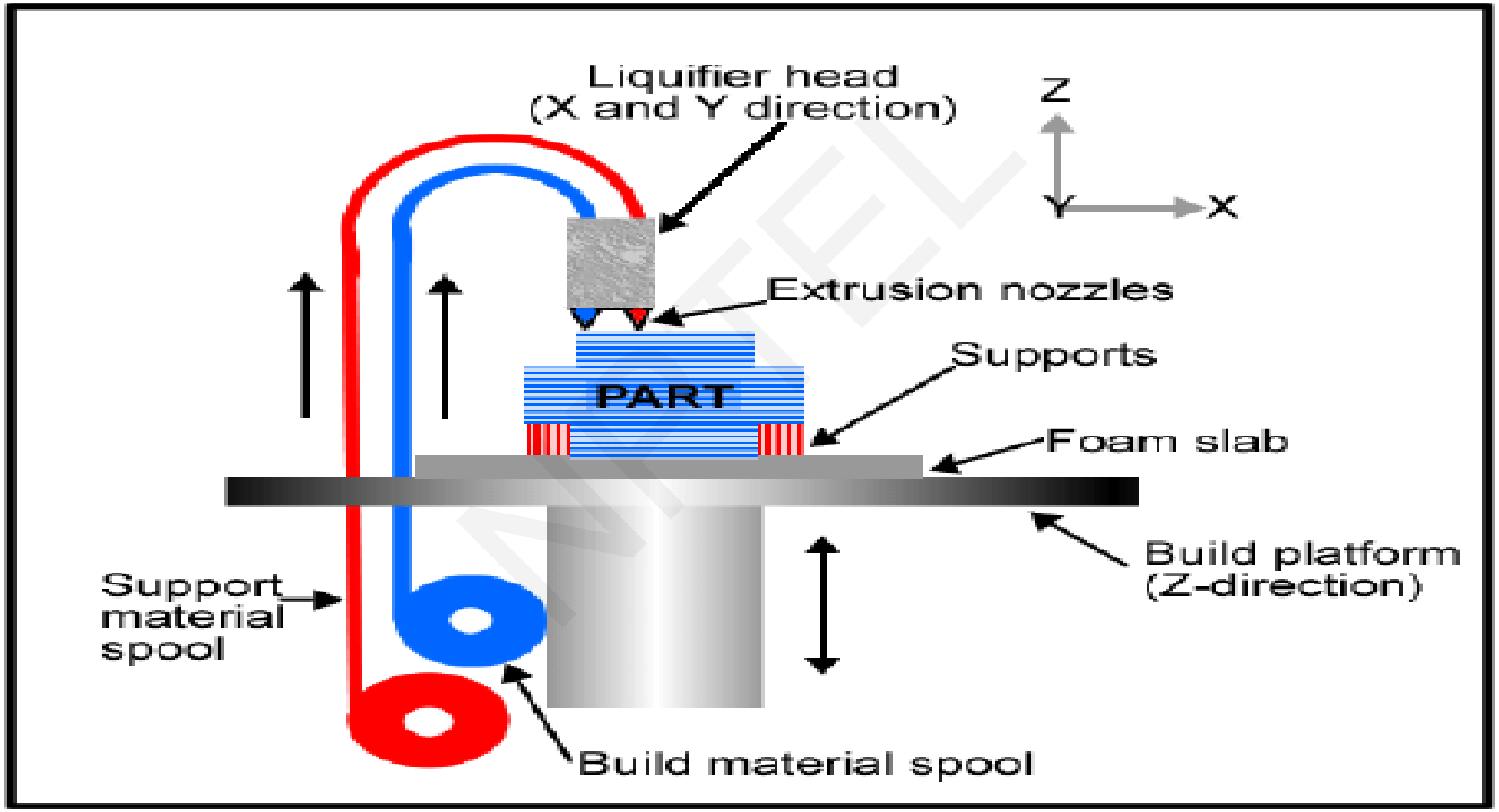
Fused Deposition Modelling

- This uses the principle of extrusion of material from the nozzle that traverse in X and Y direction to create a two dimensional layer.
- Both part and support material were used in different nozzles.
- Each layer, separate nozzles were used to create the part with its support material.
- The diameter of the nozzle limits resolution and accuracy.
- This machine is very easy to setup and it is cost effective.



https://www.researchgate.net/publication/282553729_Component_Replication_Using_3D_Printing_Technology

Fused Deposition Modelling



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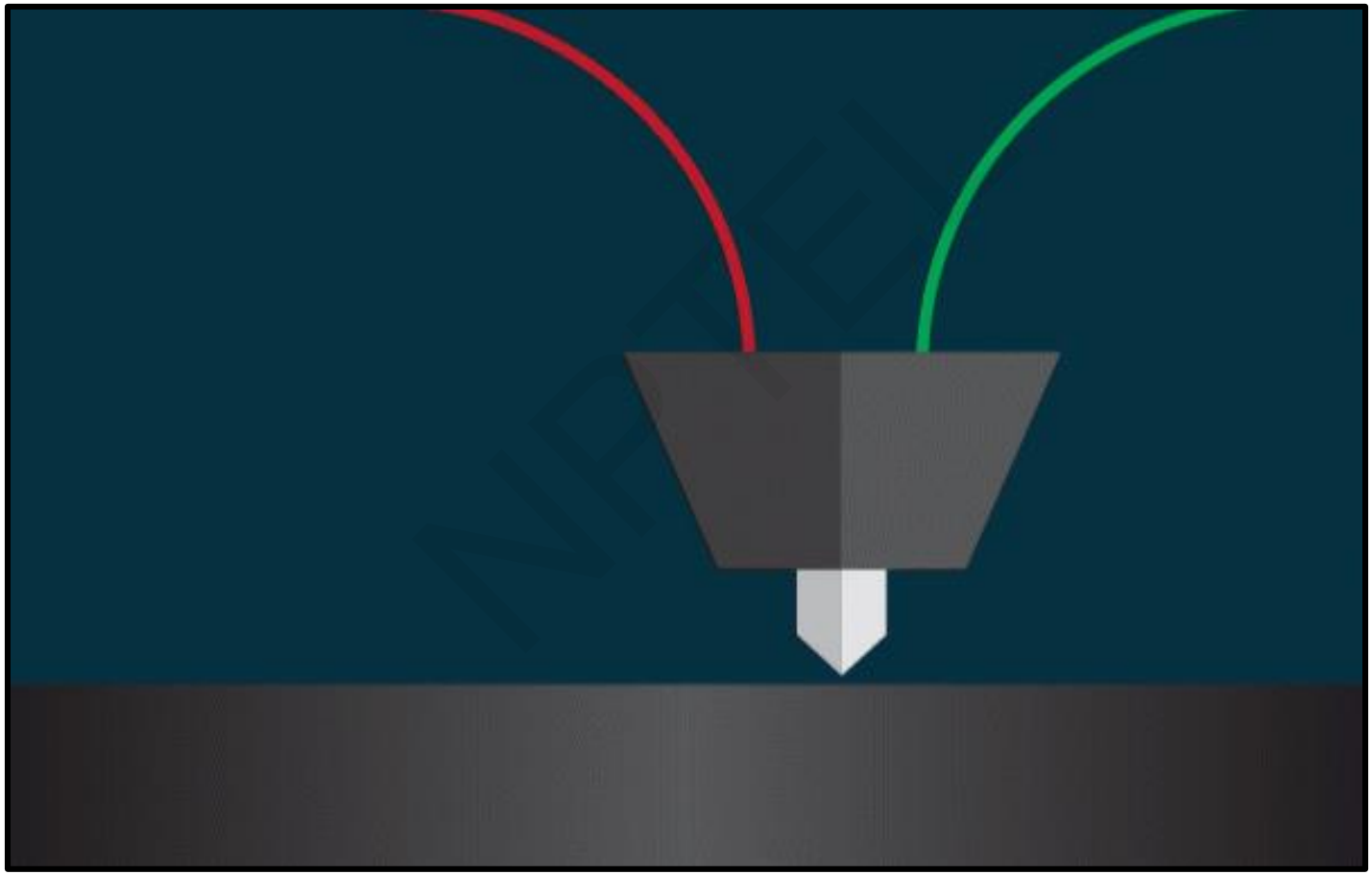
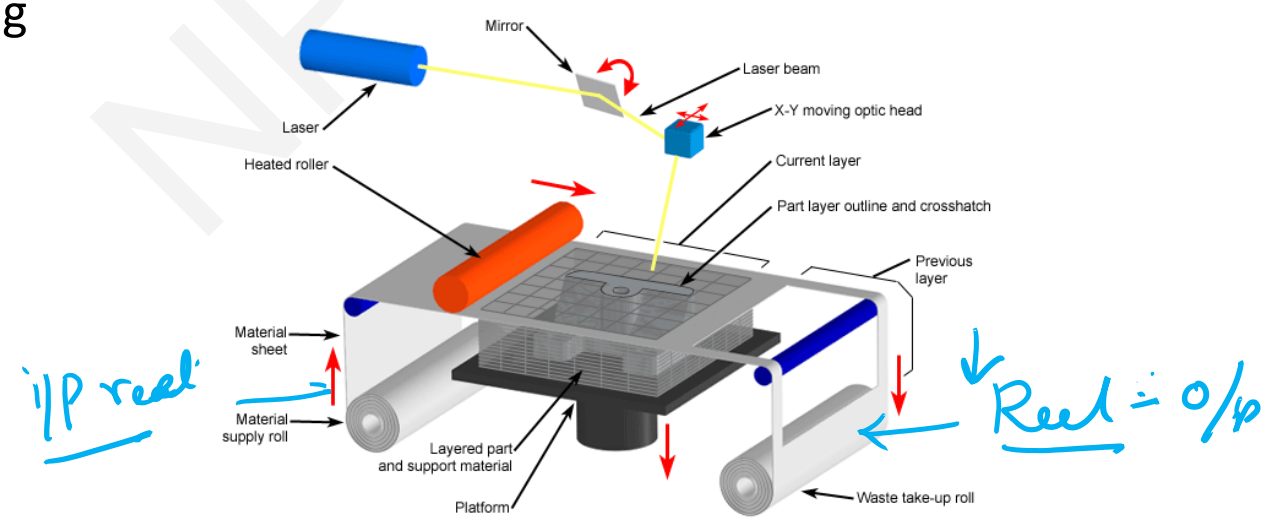
Fused Deposition Modelling



https://www.nazdar.com/en-us/News-events/ArtMID/4165/ArticleID/399

Sheet Stacking Technologies

- Solid physical model made by stacking layers of sheet stock, each an outline of the cross-sectional shape of a CAD model that is sliced into layers
- Starting sheet stock includes paper, plastic, cellulose, metals, or fiber-reinforced materials
- The sheet is usually supplied with adhesive backing as rolls that are spooled between two reels
- After cutting, excess material in the layer remains in place to support the part during building



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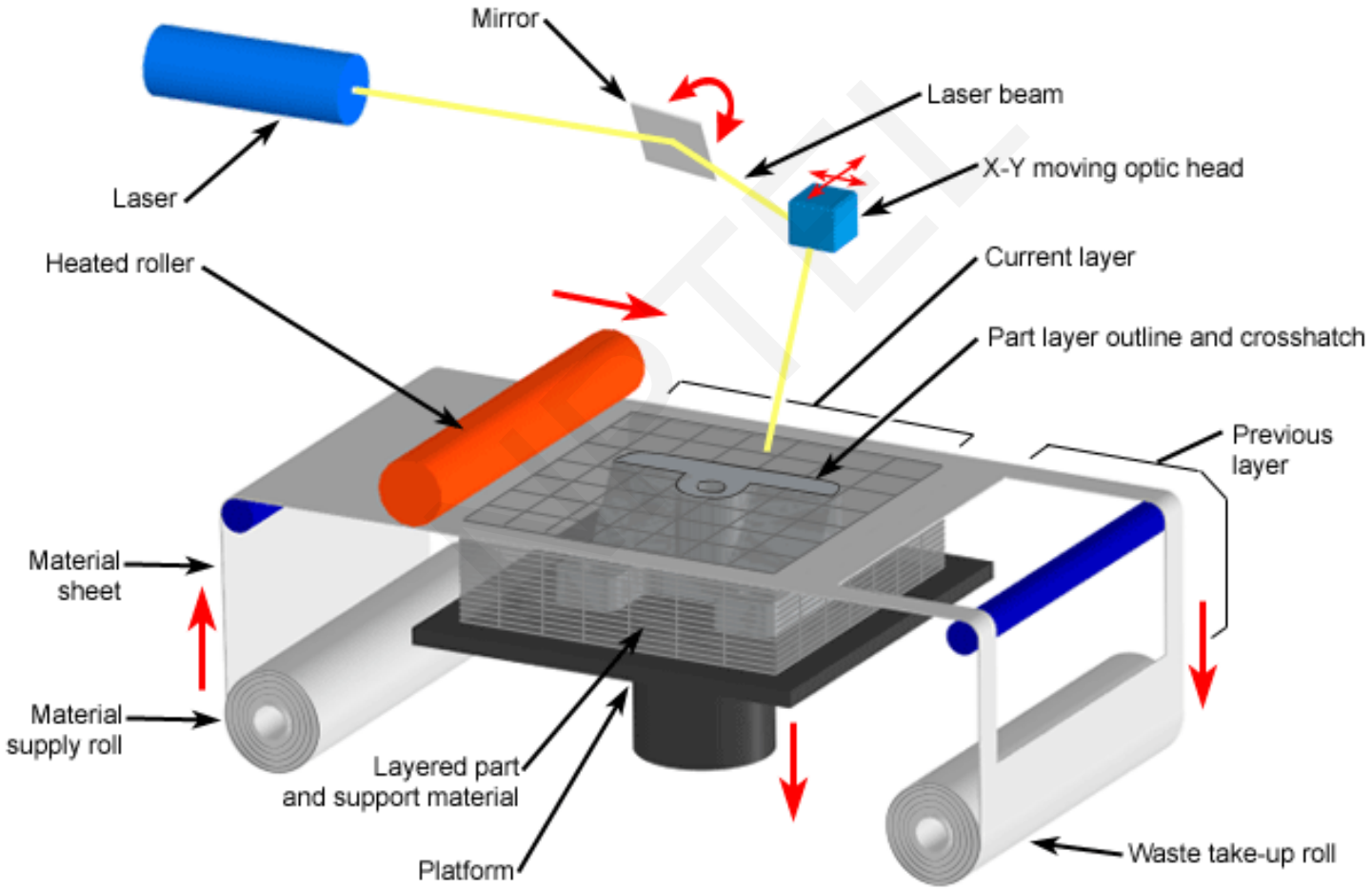
Sheet Stacking Technologies



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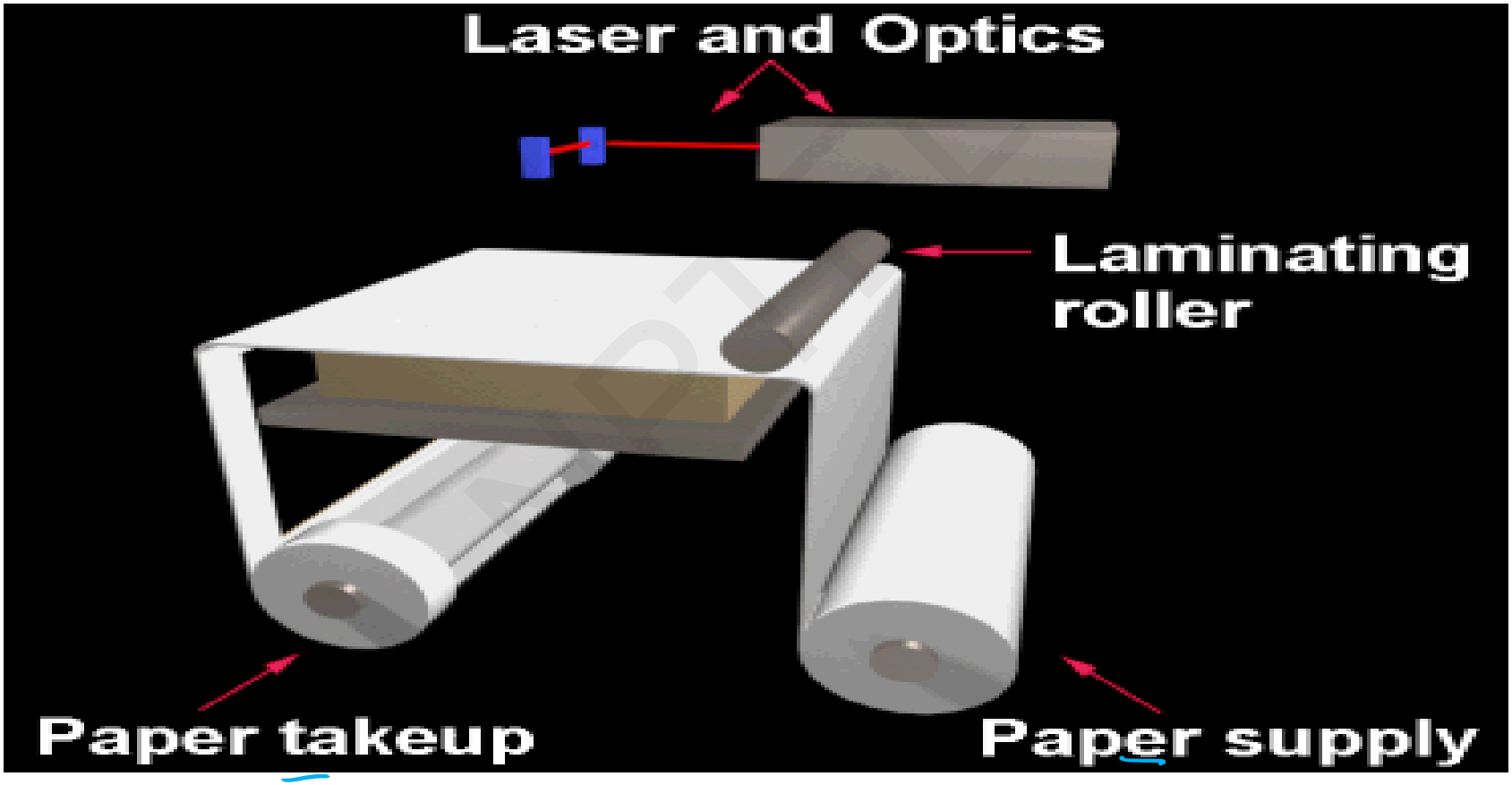


https://gifer.com/ru/CaHx

Rapid Tooling

Pattern → mold
↓
final Pro

- With RM techniques, there is only a limited range of materials from which prototypes can be made.

- Functional testing of prototypes often is not possible due to different mechanical and thermal properties of prototype compared to production part .

- Rapid Manufacturing techniques are not economical when more prototype needs to built for the same component.

This gives the Concept of Rapid Tooling

Rapid Tooling(RT) is a term used to describe a process which either used a rapid prototyping model as a pattern to create a mould quickly or uses a rapid prototyping process directly to fabricate a tool for a limited volume of prototypes.

RT Process Classification

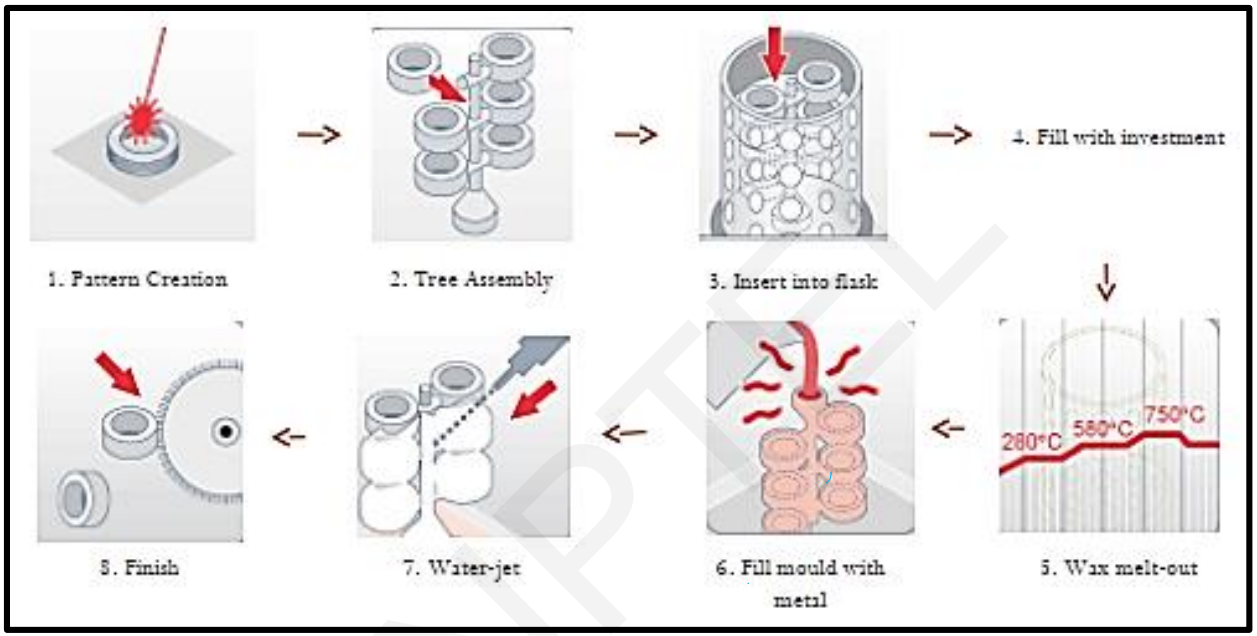
Rapid tooling is classified in two different categories

1. Direct routes – uses the CAD file to produce the tool in the final material

2. Indirect routes – uses a rapid prototyping model as a master pattern or case to make the moulds by established, more traditional, routes

3. The most common rapid tooling methods are:-
    a) Keltool
    b) Sprayed metal tooling
    c) ACES
    d) investment casting
    e) Selective laser sintering
    f) Stereolithography

Rapid Tooling process and parts



https://www.slideshare.net/KerrieNoble/rapid-tooling-presentationupdate

Geometrical Freedom

- Rapid Manufacturing major benefit is to make virtually any complex geometry at no extra cost.
- This ability leads us to a new dimension of “Manufacturing for Design” rather than the conventional “Design for Manufacturing” philosophy.
- This enables a fast, flexible and reconfigurable manufacturing that gives enormous benefits to manufacturers and customers.
- Areas of particular interest that enabled by the freedoms afforded by the RM include:-

1. Design Complexity / Optimization
2. Parts Consolidation
3. Body-fitting customization
4. Multiple assemblies manufactured as one

1.Design Complexity / Optimization

- Design freedom in RM, will enable increasingly complex designs to be realized that are fully optimized for the function that they are required for.
- Design optimization is common in the construction and machinery industry.

3D Prototype of the Stadium

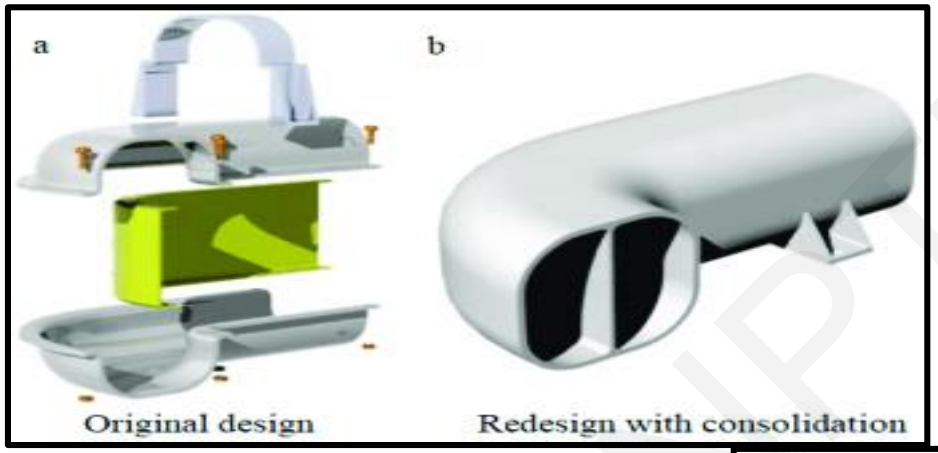
Actual construction of the Stadium

Beijing National Stadium designed by Arup

- Stadium was designed with the combination of design optimization and genetic algorithm to produce a truly unique structure which is structurally sound.

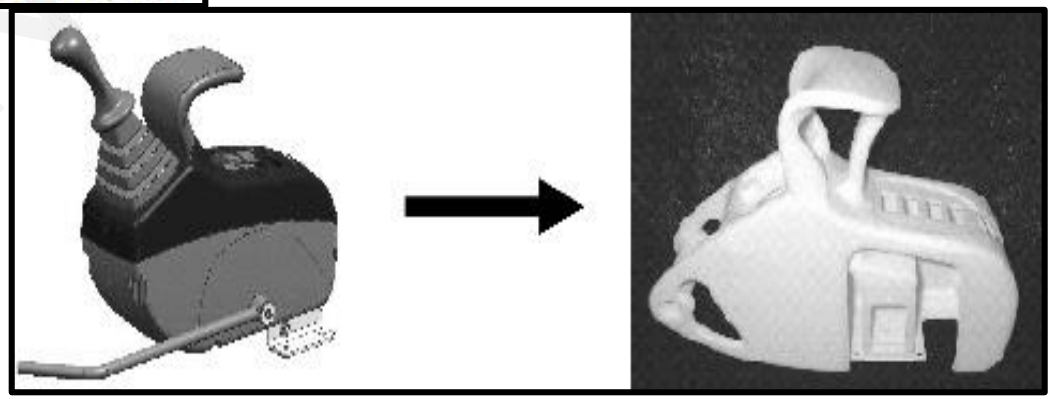
2. Parts Consolidation

- RM gives the potential to consolidate many component into one.
- Reduction in assembly of the components saves the cost, without making compromise with the design.



Aircraft ducting

- Assembly of control pad with 25 parts has been consolidated in just one single piece



Aircraft control pad

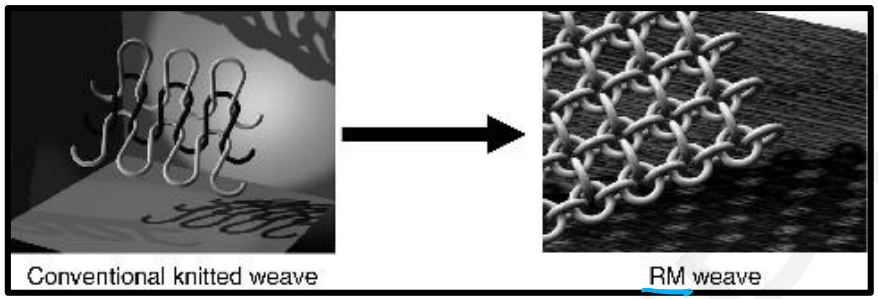
3.Body-fitting customization

- Conventional manufacturing especially body fitting costumed products, are out of the reach of the general public due to high cost.
- Customer were forced to buy mass-produced goods only.
- By RM and reverse engineering the product is now been customized according to the need of the customer.

- The products now, can be manufactured according to the best fit for the customer, and the concept of “mass customization” is now being possible.

4.Multiple assemblies : Textiles

- The RM has approaching towards in the field of Textiles, It has a vast potential for future applications in the field of smart textiles.
- The key for RM fabrics is to move from continuous fiber to individual links.



- Body fitting textiles, produced directly in its assembled state.
- Has a vast scope in micro level designing of textiles.

Automotive Application of RM

- Of all the potential areas of applications for Rapid Manufacturing, the automotive industry offers the most significant opportunities for the changes in the way manufacturing is carried out.
- Ergonomics for the comfort fit of the customers open broad spectrum for RM.
- Many automotive companies particularly at the cutting edge of motor sport and F1 are using RM for making there vehicles.

Automotive Application of RM

- RM provides:-
  1. Advent of materials with better functional properties
  2. Quicker Modification
  3. Light weight Material
  4. Lack of manufacturing design constraints
  5. Assemblies of parts reduced into single components
  6. Reduced Cost
  7. On demands parts reduced inventories

Automotive Application of RM

3D printed Car and its parts

https://www.popularmechanics.com/cars/a16726/local-motors-strati-roadster-test-drive/

Applications of RM in Architecture and construction industry

- Architectural models have a long been a staple application of 3D printing processed, for producing accurate demonstration models of a architect's vision .

- 3D printing offers a relatively fast, easy and economically viable method of producing detailed models directly from 3D CAD, BIM or other data architects use.

- Many firms using 3D printing products for their workflow for increased innovation and improved communication.

Construction: 3D printed houses

- Additive Manufacturing technology has a potential advantage for making automated houses and other various construction.

- Changes that led to the emergence of AM are:-
  1. Automation
  2. Quicker Construction
  3. Lower Labor Cost
  4. Less waste produced and greater material Utilization
  5. Synchronization of the production process
  6. Reduction in part count
  7. Early detection of design errors
  8. Increased capability to compute mass properties

- AM in a large scale may be well suited for construction of extraterrestrial structures on the moon or other planets where environment conditions are less conductive to human labor-intensive building process.

Applications of RM in Architecture and construction industry

https://iaac.net/project/3d-printed-bridge/

3D printed Eagle Beak

https://www.tah-heetch.com/post/animals-birds-ducks-buttercup-3d-printing-filler-3d-printer-fowl-k5ofgmdvdovurdfu.html

Disadvantages of Rapid Prototyping

- **Part accuracy:**
  1. Staircase appearance for a sloping part surface due to layering
  2. Shrinkage and distortion of RP parts

- **Limited variety of materials in RP**
  1. Mechanical performance of the fabricated parts is limited by the materials that must be used in the RP process

Disadvantages of Rapid Prototyping

- **CAD software's**
  1. Capabilities of CAD software's may cause bottleneck in producing parts.
  2. CAD software's conversion from CAD to .Stl formats may cause geometric contractions and irregularities.

- **Development of illegal products**
  1. RM may lead to the development of products like 3D printed Guns, bombs etc.
  2. There must be restrictions imposed on it for these type of products.

Summary

- Various types of Manufacturing processes?
- What is Rapid Manufacturing (RM)?
- What are the various Steps involved in RM?
- Classification of RM processes
  - Liquid based processes
  - Powder based processes
  - Solid-based Processes

Summary

- Difference between Solid Modelling & Surface Modelling
- What is Rapid Tooling (RT)?
- Steps involved in RT?
- Geometrical freedom for RM?
- Applications of RM
- Disadvantages of RM


Thank you!!