MS101: Makerspace Laboratory

Topic: Manufacturing Techniques

Ref:
[1] Groover, Fundamentals of Modern Manufacturing
[2] Kalpakijan and Schmidt, Manuacturing Technology

Acknowledgement:
Profs. Rakesh G Mote and K. P. Karunakaran,
for contents in slides

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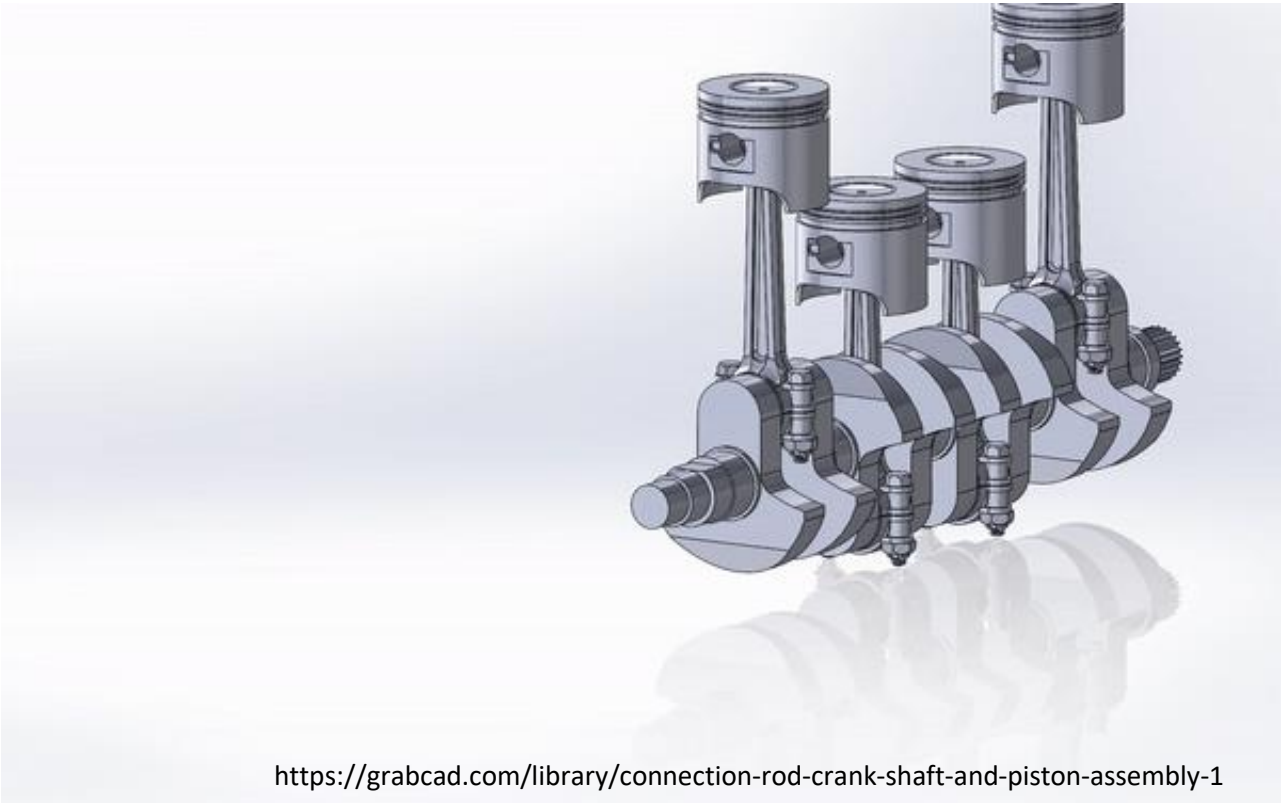
Lecture - 1

- Introduction to manufacturing
- Bottom-up approaches
- Casting
- 3D Printing
- Forming
- Welding

- Lecture 2: Machining and Material removal

Structural or load bearing component

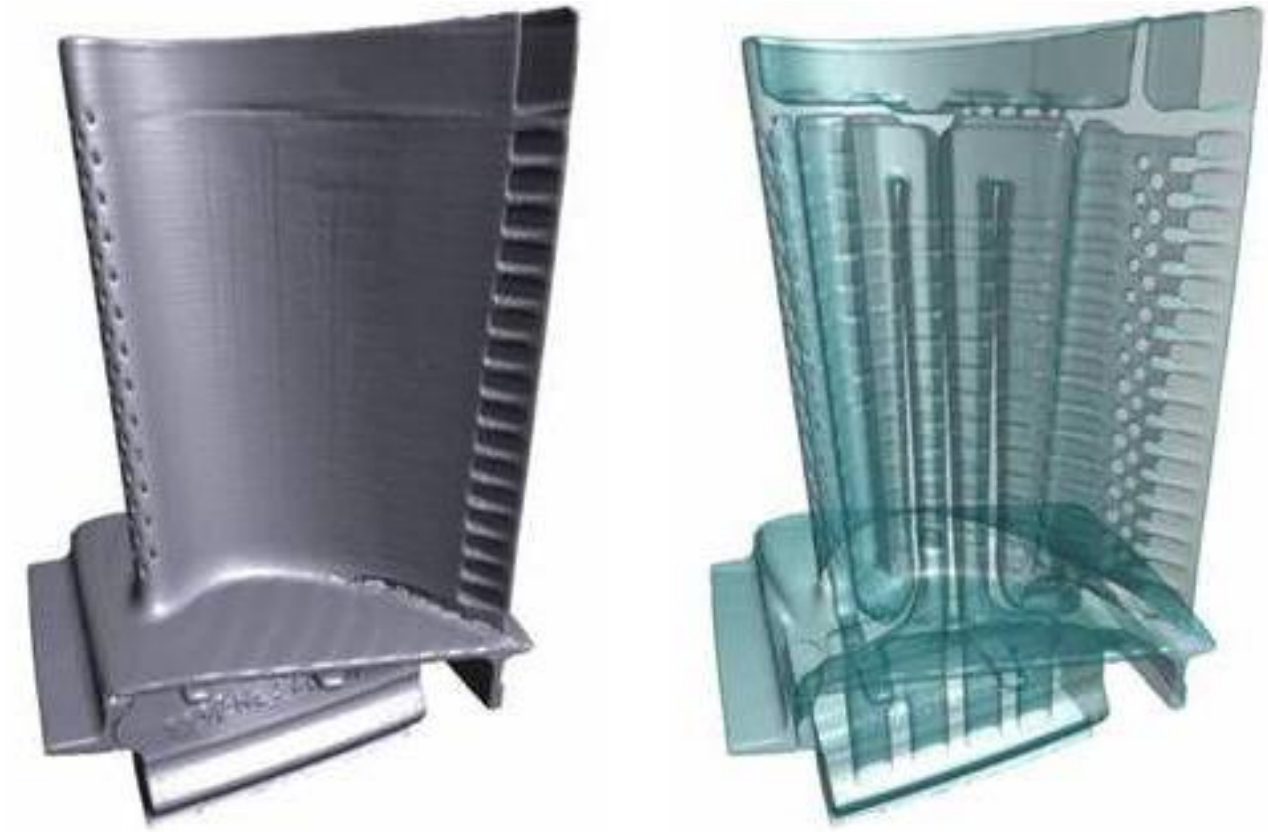


https://grabcad.com/library/connection-rod-crank-shaft-and-piston-assembly-1

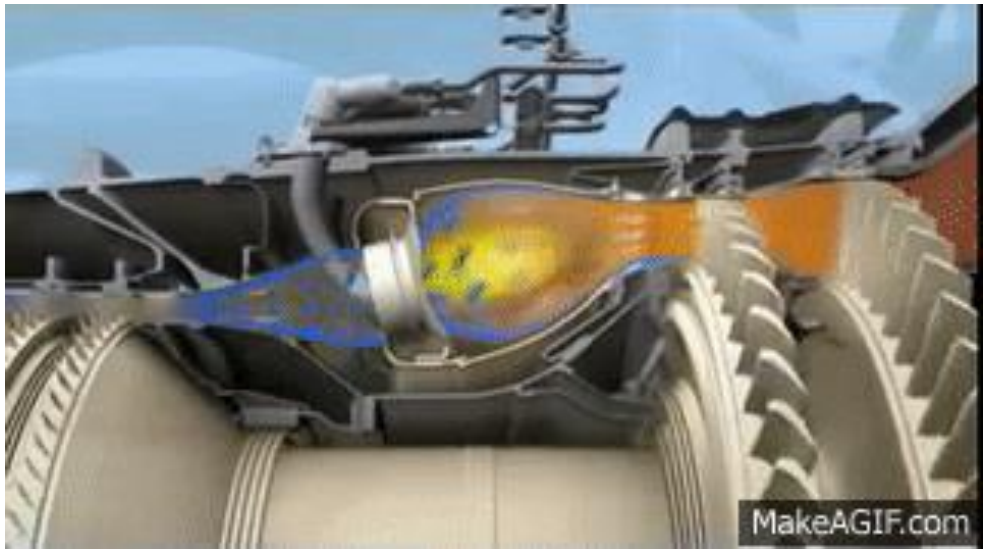
How can this be manufactured? – if so, is a million parts possible per year?

Feasibility and Scale

Another one



Turbine blade – external and internal



Turbojet engine – loading on blades

Context:

Engineering a structural component

Idea

- Converting linear motion to rotation
- Sketches and Drawing

Analysis of strength

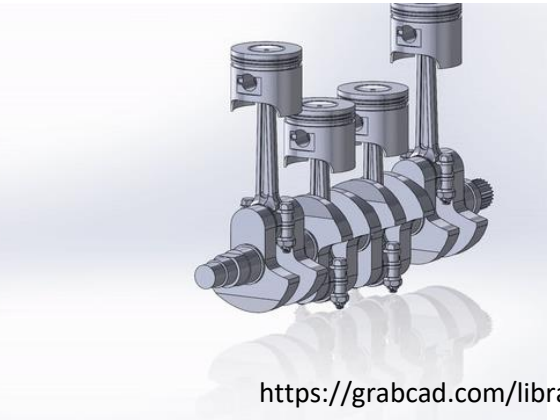
- Check whether a material can satisfy operational requirement
- Conditions of high temperature etc

Sketches and Drawing

- Geometric compliance with the requirement
- 3D Views for manufacturing

Manufacture

- Choose a method that gives the required properties
- To have some idea as to what can be used?



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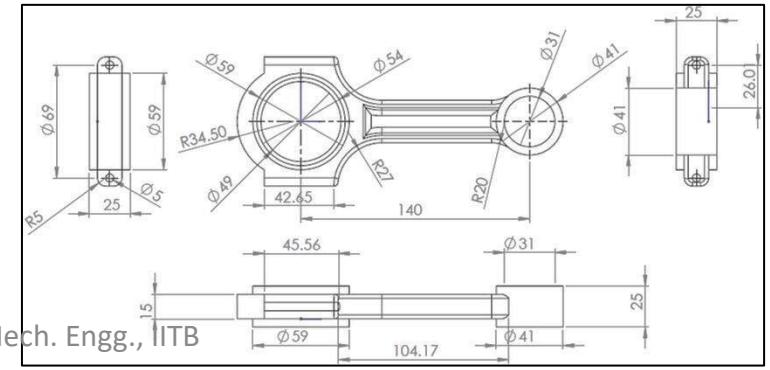
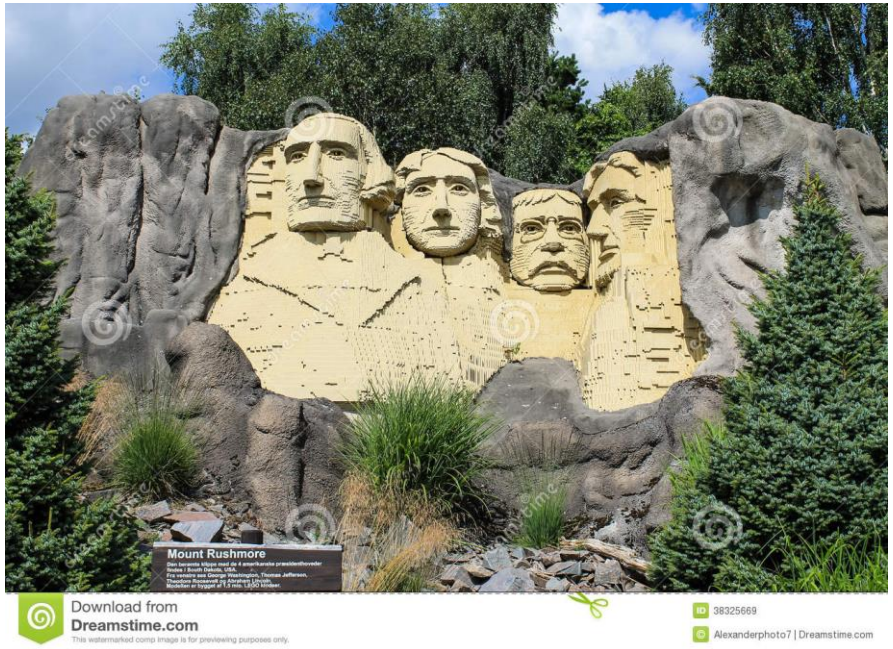


Bottom-up vs Top-down Approach



Introduction: Manufacturing

- Manufacturing is physical realization.
- We will discuss here only mechanical/discrete/solid manufacturing It is shape realization. That means our focus is limited to solids.
- Our aim is to achieve the geometry (external – shape/form, size, color) & matrix (internal – composition, porosity etc.) of the solid.
- The following two most common ‘mechanisms’ associated with manufacturing

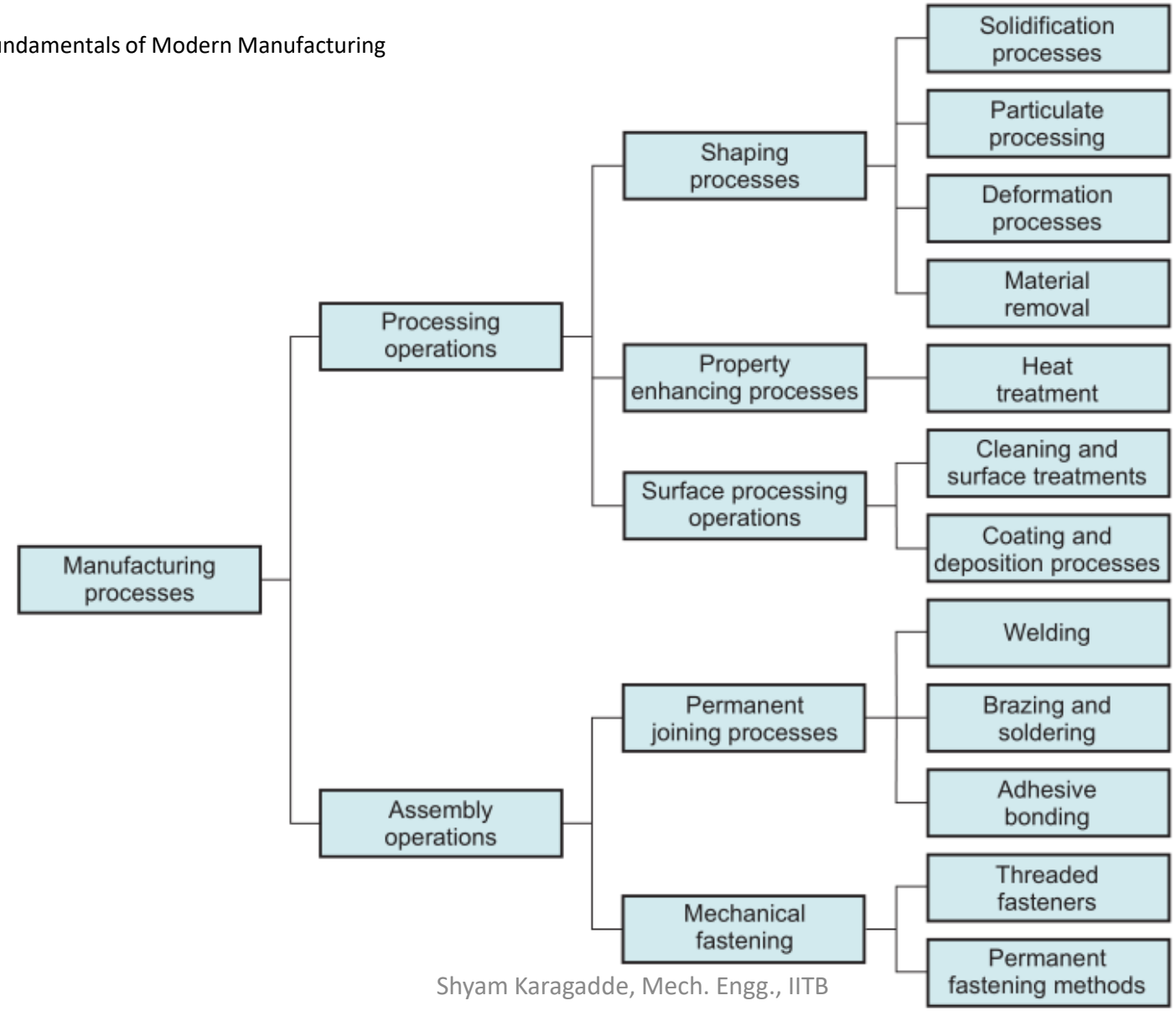
1. Heat
2. Force or pressure

Based on the starting material

- **Liquid** – pour the liquid metal into the shape and allow it to freeze (casting)
  - Requires heating alone
- **Semi-solid and 'softened' solid** – Deform the material 'forcefully' to realize the shape (forming and forging)
  - Heating and force/pressure
- **Solid:**
  - Powder/wire: heat and pressurize the powders or melt the powder/solid to deposit (**Sintering, 3D printing**)
  - Blocks: Remove the unwanted portion by cutting (**Machining**), force alone will suffice
- **Joining / Assembly:** Fastening, Fusion joining - welding

Manufacturing Processes

Source: M Groover: Fundamentals of Modern Manufacturing



Typical Process

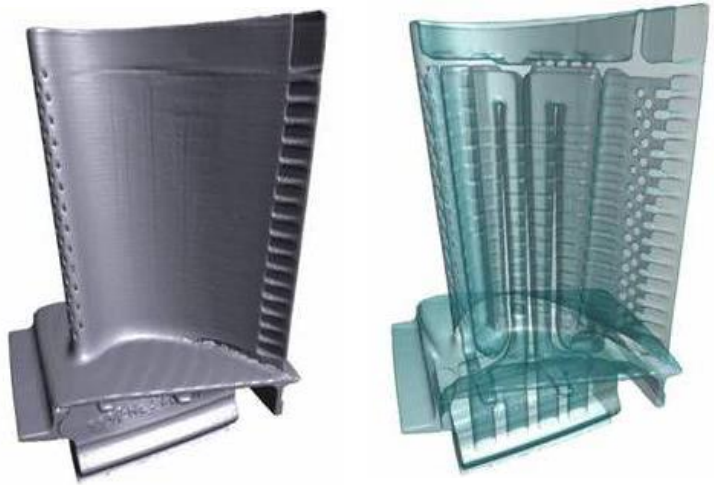
- Cast by pouring liquid into shapes
- Form by compressing softened material into shapes
- 3D-Printing: Form shapes directly by adding layer by layer

Casting

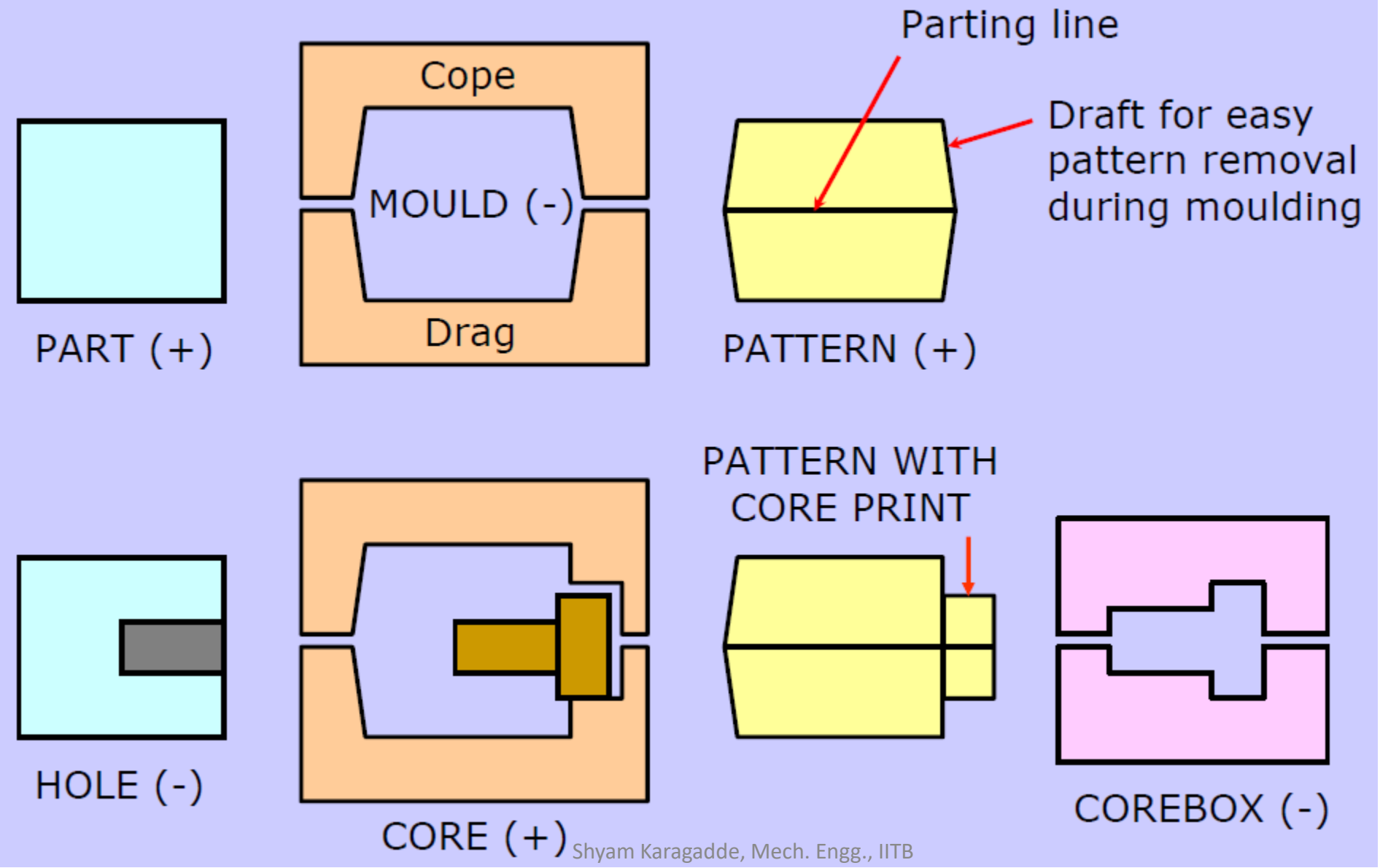
- Casting is the production of a solid metal item by allowing liquid metal to solidify in a shaped mould/die

- “You are never more than 10 feet away from a casting”

- Cars, dishwashers, fire hydrants, storm sewer inlets, grills, golf clubs, tools, kitchenware, or even the wheels and casters that make your office chair glide or move that commuter train from point A to point B.



Sand casting – Simplest and DIY-type



Other methods

- Investment casting → coat a polymer pattern with ceramic slurry and harden the slurry by heating. The polymer is melted and drained out. The hardened ceramic contains the negative replica of the polymer pattern so that liquid metal can be poured

- Die casting → Metallic dies are prepared by machining a cavity. Two or more such dies (molds) are assembled to create a cavity.
- When liquid is poured under gravity → gravity die casting
- Filled under high pressure (100s of MPa) → high pressure die casting

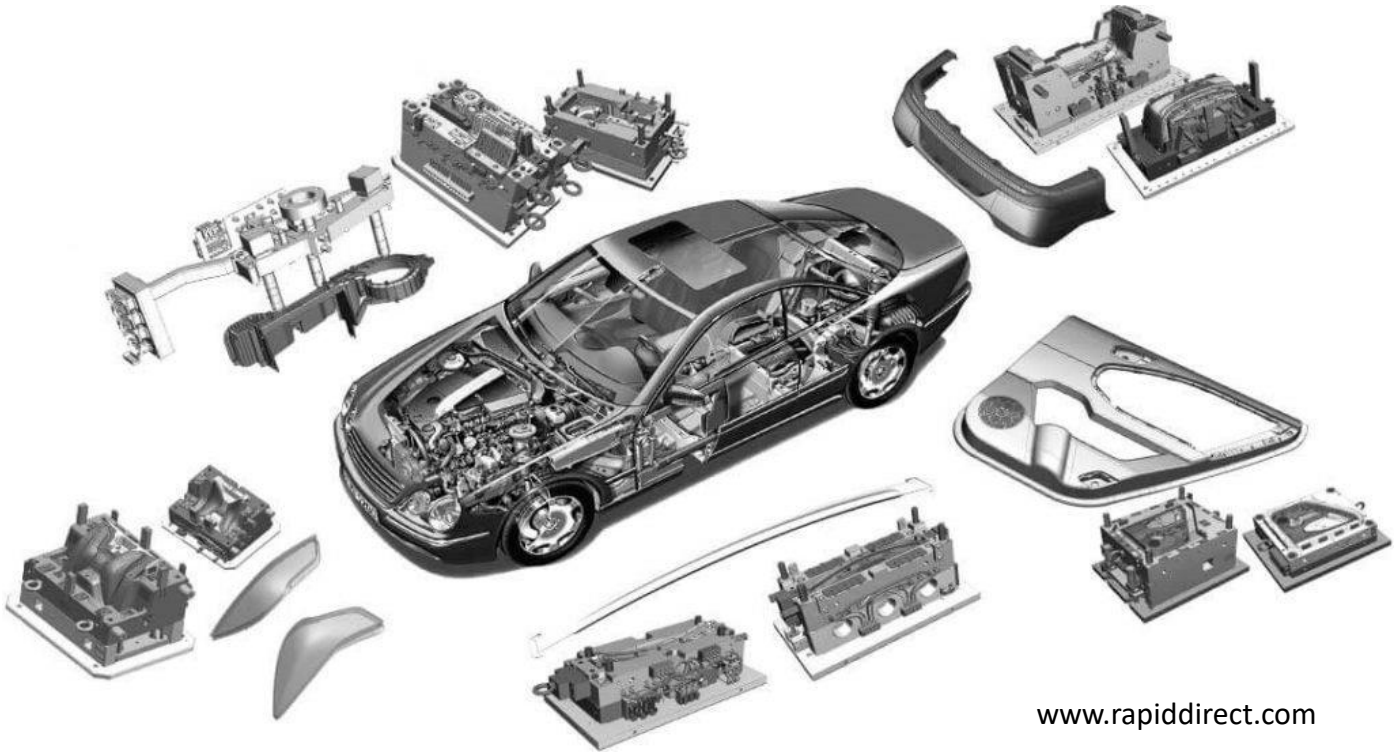
- Continuous casting: Rectangular slabs or circular billets are continuously produced by pouring in a metallic or ceramic dies for uninterrupted production

Important physical considerations

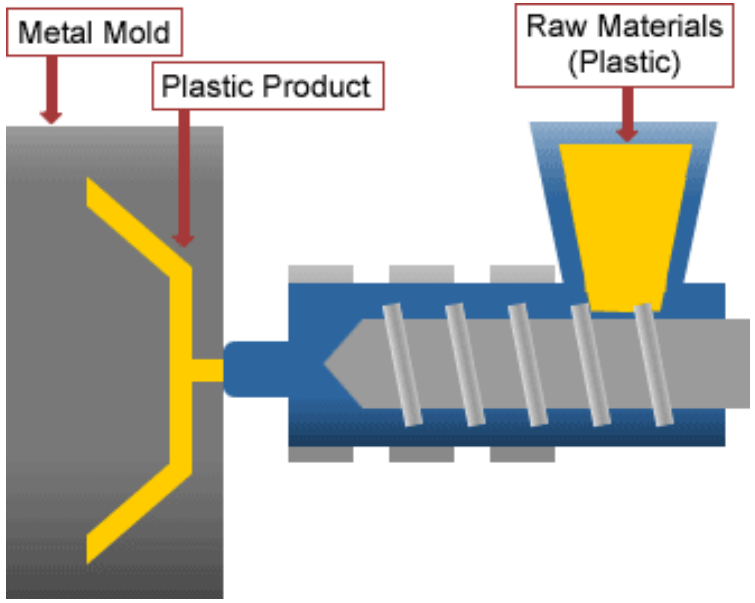
- Alloy in liquid state – thermodynamics and chemical considerations
- Fluidity – how easily it will flow into intricate parts
- Solidification – how materials solidify
  - Bulk freezing characteristics – soundness of casting etc
  - Micro-scale characteristics – small scale structures that dictate the mechanical property
- Residual stress formation
- Post-process operations such as rolling, heat treatment, surface finish etc

Injection Moulding

- Inject molten plastic materials into a mold cavity
- The melted plastic then cools and hardens, and the manufacturers extract the finished part.



www.rapiddirect.com

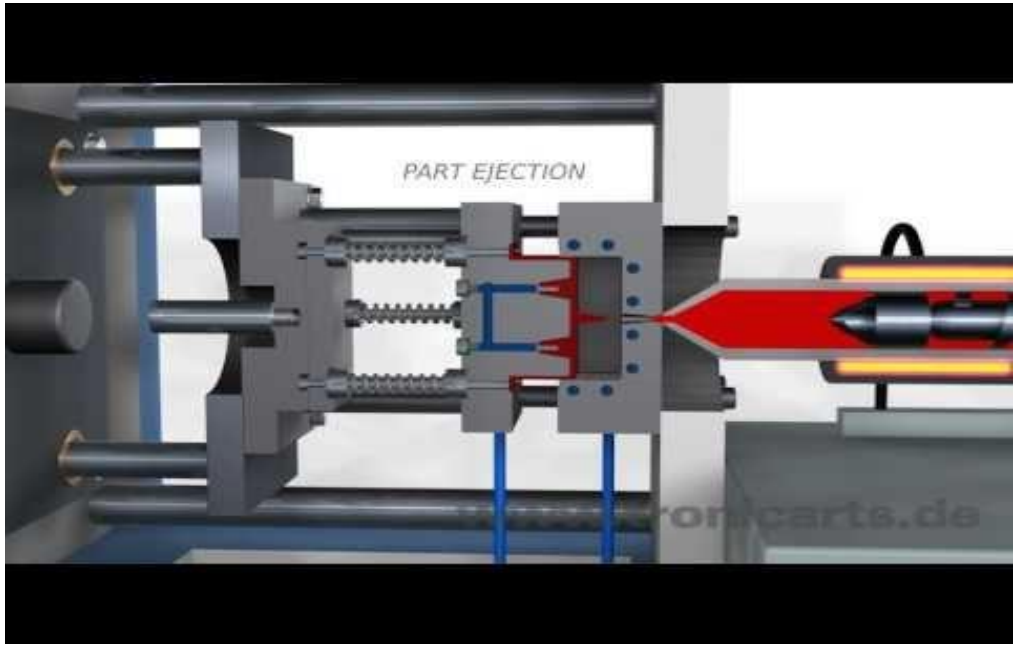


Practice

Metal Casting

https://www.youtube.com/shorts/B8kxhT98L00

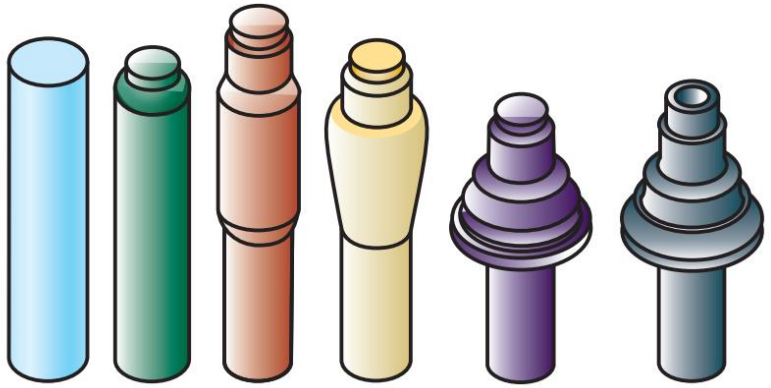
Polymer Injection Moulding

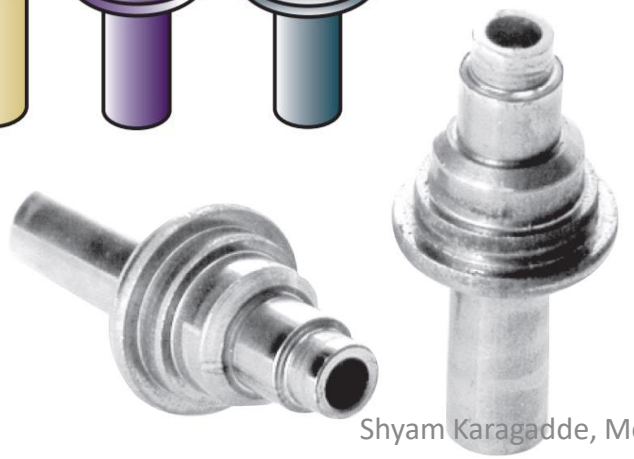


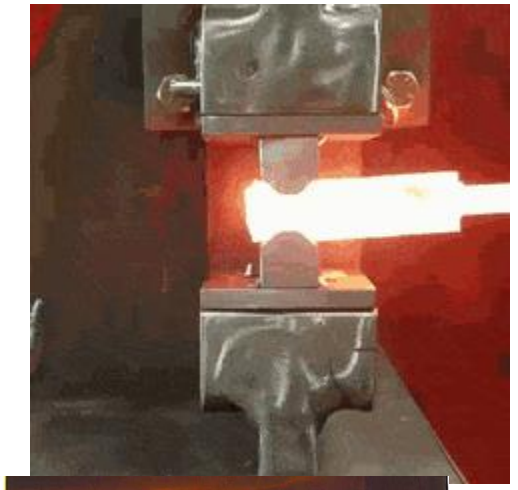
https://www.youtube.com/watch?v=b1U9W4iNDiQ

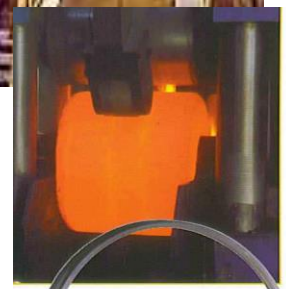
Deformation Processes

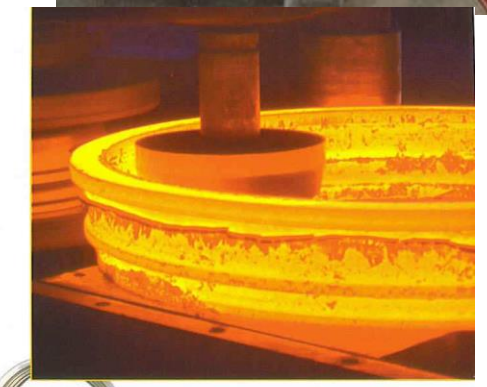
- Plastic deformation is used to change the shape of metal workpieces
- Constant volume process
- Favourable grain flow, strength!





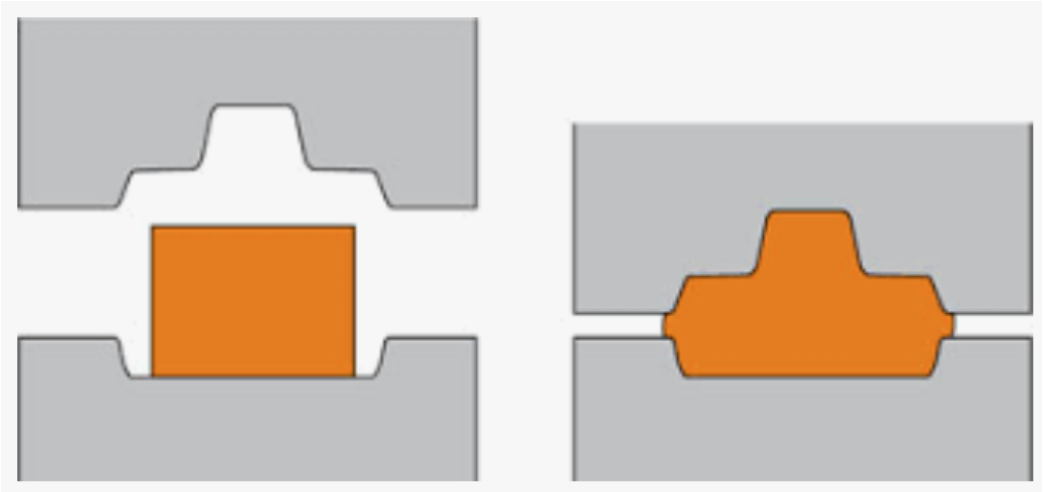






Physical considerations

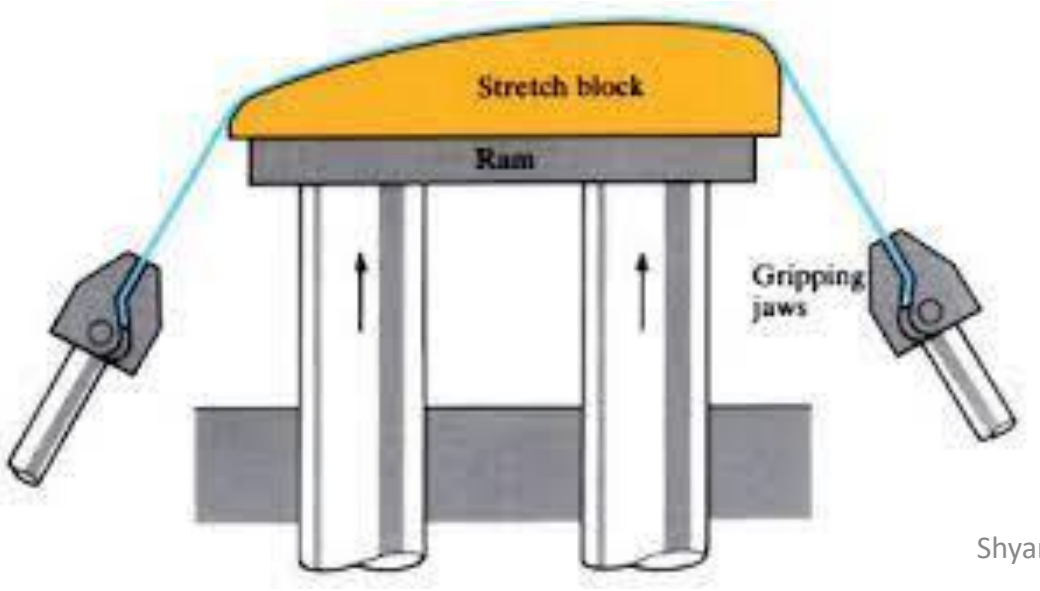
- Stress vs deformation behavior
- Elastic and Viscoplastic deformation
- Microstructural effects – recrystallization
- Strengthening mechanisms



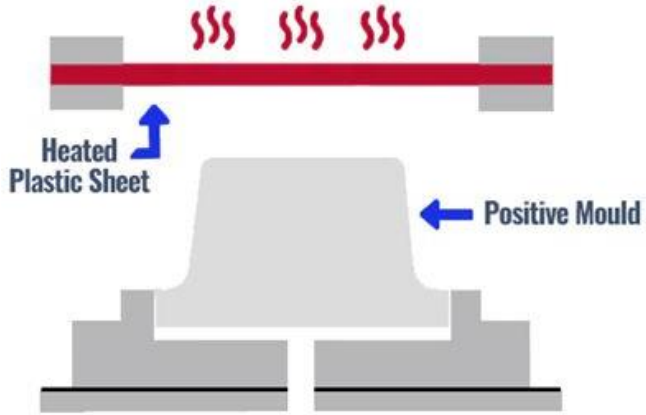
Forming: Sheet Metal Forming

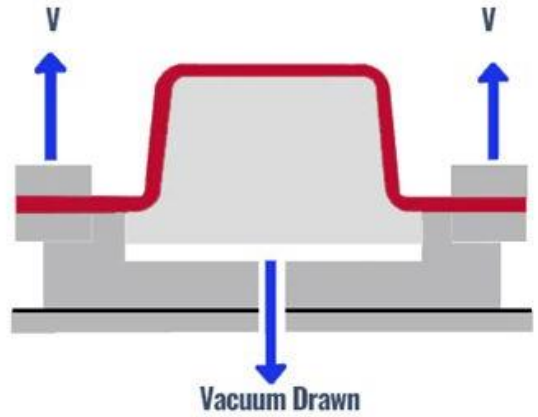
Stretch Forming

- Die will be a protrusion.
- The sheet is stretched on top of it to absorb its shape.
- Sheet may be metal as well as polymer.



Vacuum Forming

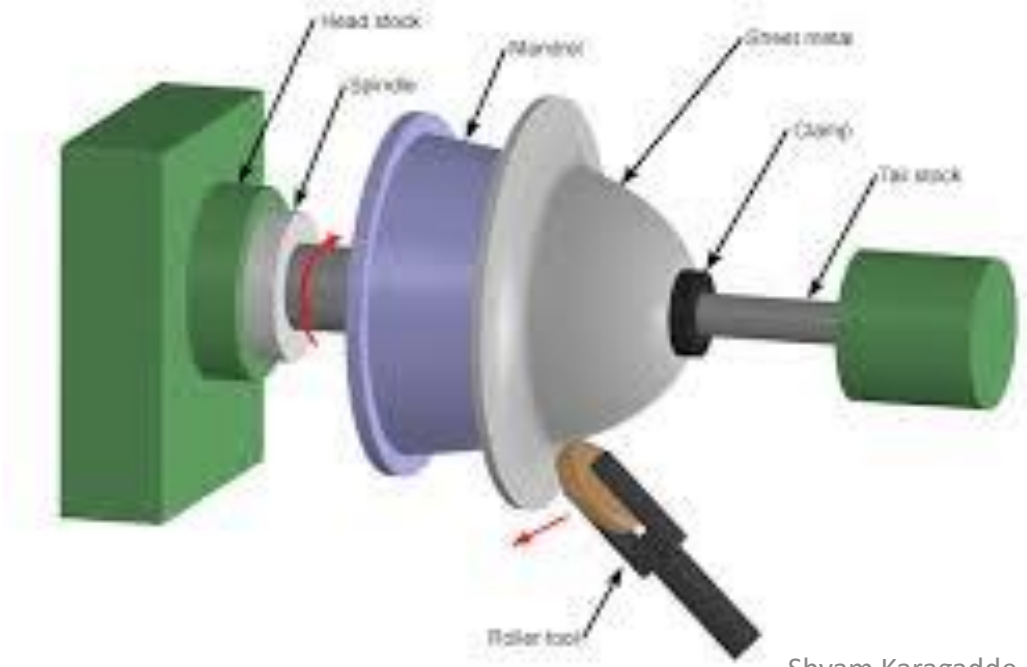




Forming: Sheet Metal Forming

Single Die Process: Flow Forming

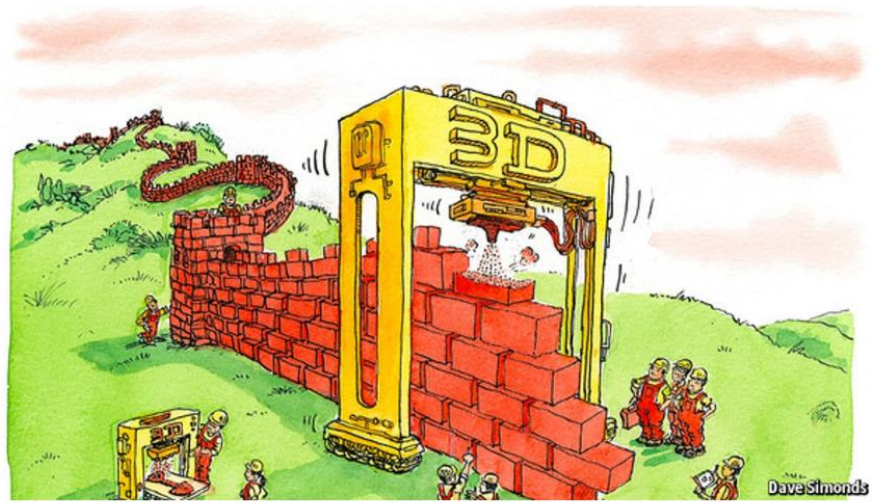
- Die will be a rotating axi-symmetric protrusion.
- The sheet clamped & rotating with the die is pressed against the die by a blunt tool with axial & radial movement similar to the lathe.



Bottom-Up Approach

Additive Manufacturing (AM) / Rapid Prototyping (RP) / 3D Printing (3DP)

- Additive Manufacturing (AM) refers to a production process in which components are created layer by layer on the basis of digital 3D design data



Science and technology

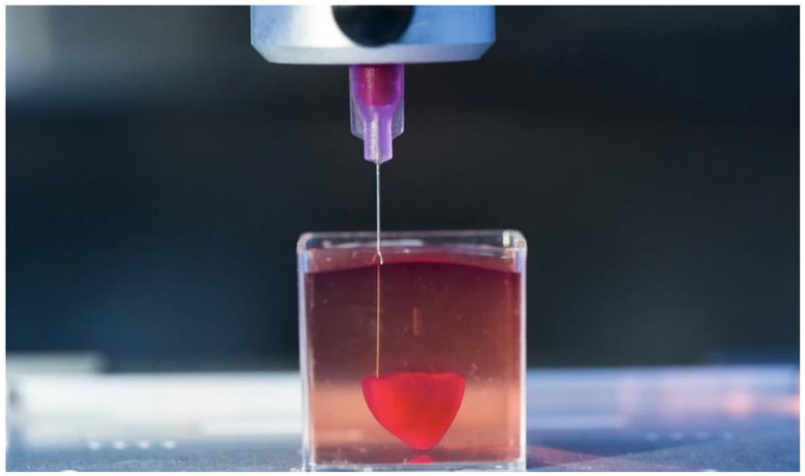
3D printing

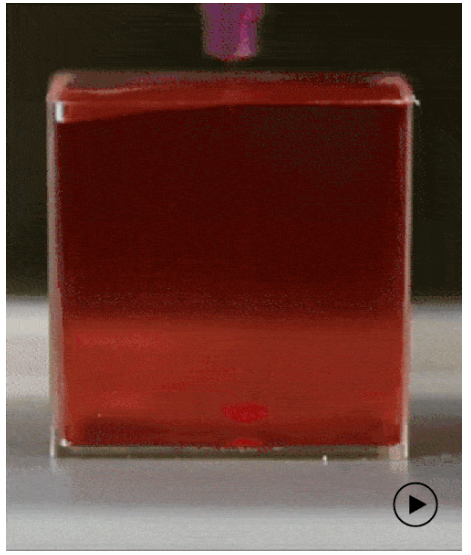
A new brick in the Great Wall

3D PRINTING NEWS MEDICAL

Researchers 3D print a heart with human tissue and blood vessels

Published on April 16, 2019 by **Carlota V.**





Additive Manufacturing / 3D Printing

The Economist

Menu | Weekly edition | Search

Schumpeter | Additive manufacturing

Print me a jet engine

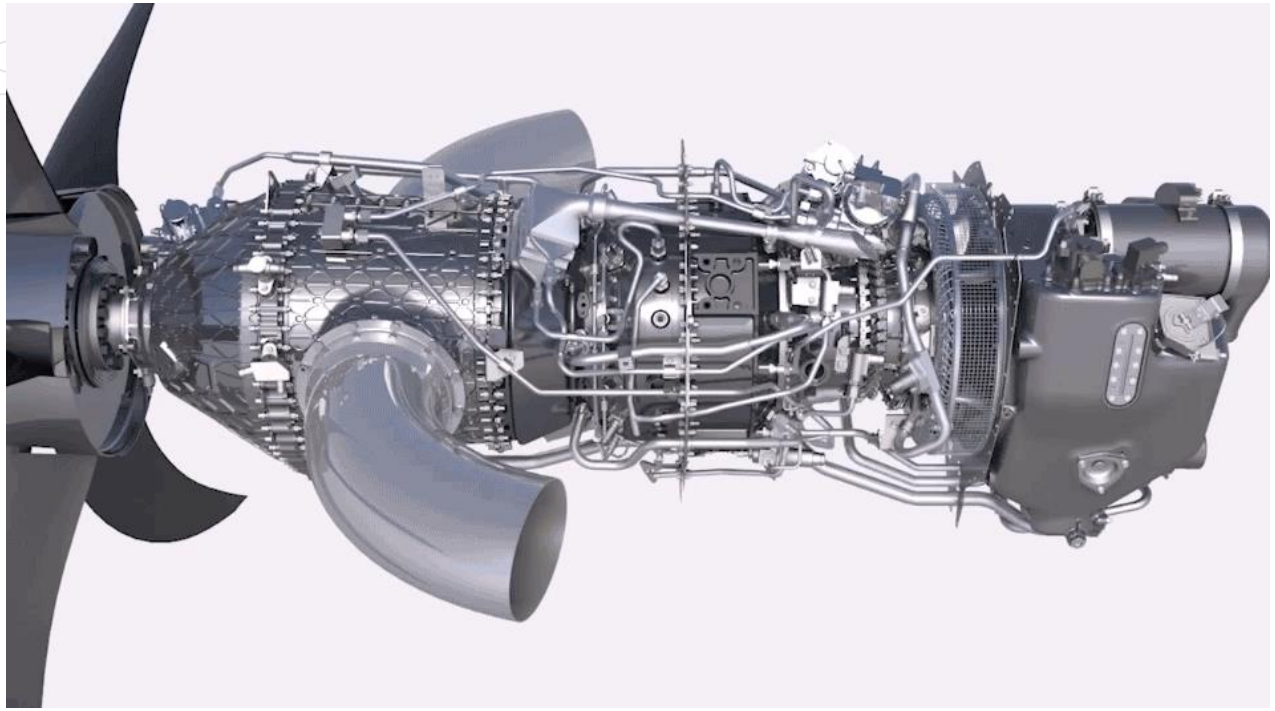
The acquisition of Morris Technologies is further proof that product innovation will increasingly go hand-in-hand with manufacturing innovation

Nov 22nd 2012

By P.M.

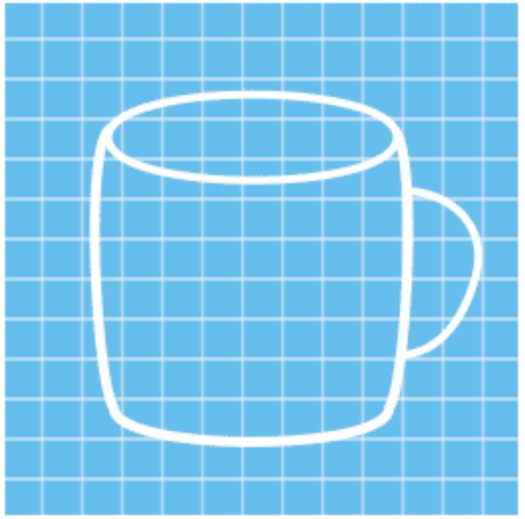
Turboprop Engine: GE Aviation

3D printing enabled the team to **combine 855 separate components into just 12**



3DP: Basic Process Flow

- Modelling in CAD
- Generating an STL or 3MF file
  - Surface geometry of 3D object
  - Orientation and Support structure
- Slicing (machine specific instructions)
  - Transforming an STL file into G-code (printer motions)
- Printing
- Post-processing
  - Finishing
  - Support structure removal
  - Heat treatment

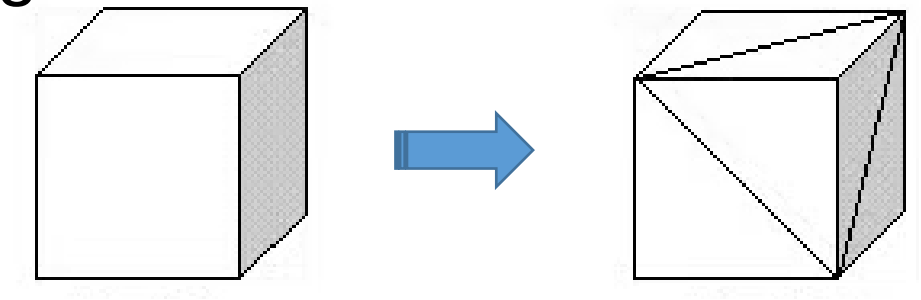


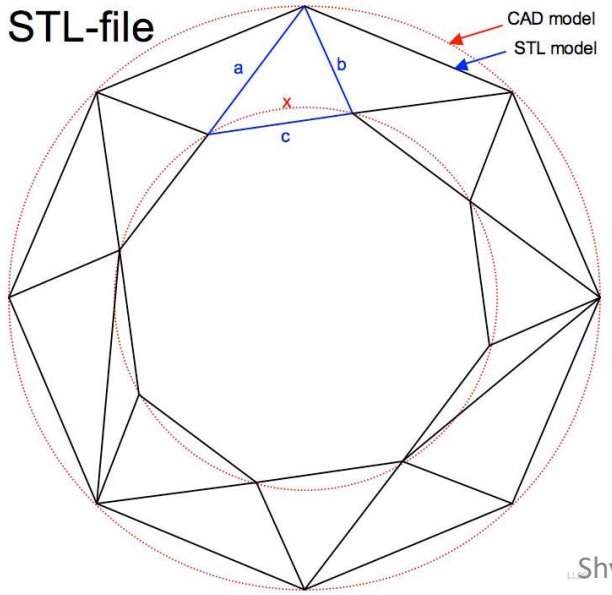
Start with a 3D CAD file either by creating the 3D model or scanned with a 3D scanner

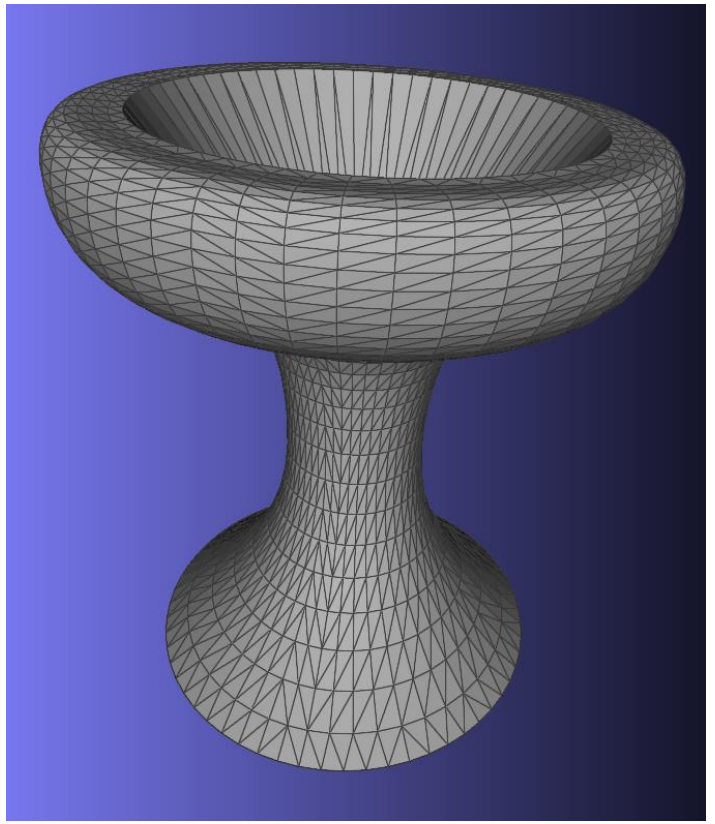
Source: https://3dprintingindustry.com

.STL files

- STereo Lithography or Standard Tessellation Language
- Approximates a 3D model by its outer surfaces using multiple triangles





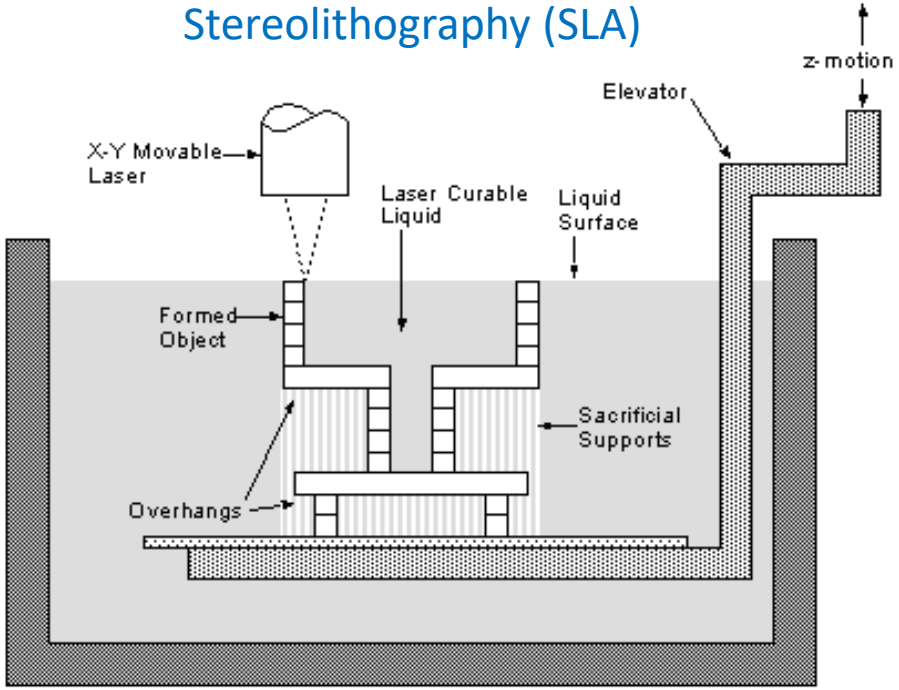


Source: Wikimedia Commons

3D Printing: Approaches

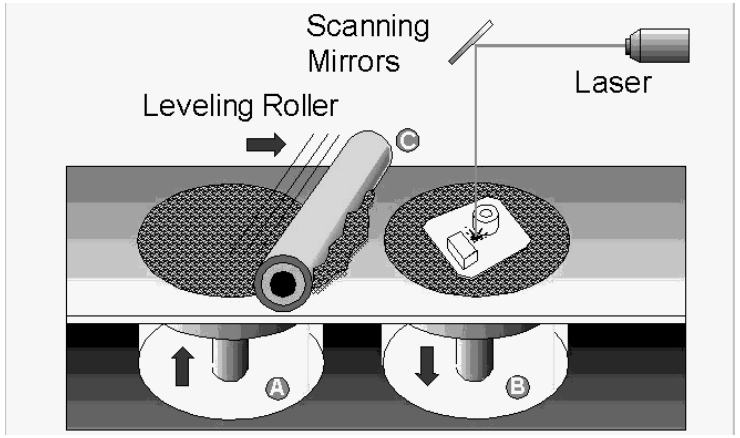
- Photopolymerization: Stereolithography (SLA)
- Powder fusion: Selective Laser Sintering (SLS)
- Fused polymer extrusion: Fused Deposition Modelling (FDM)

Stereolithography (SLA)



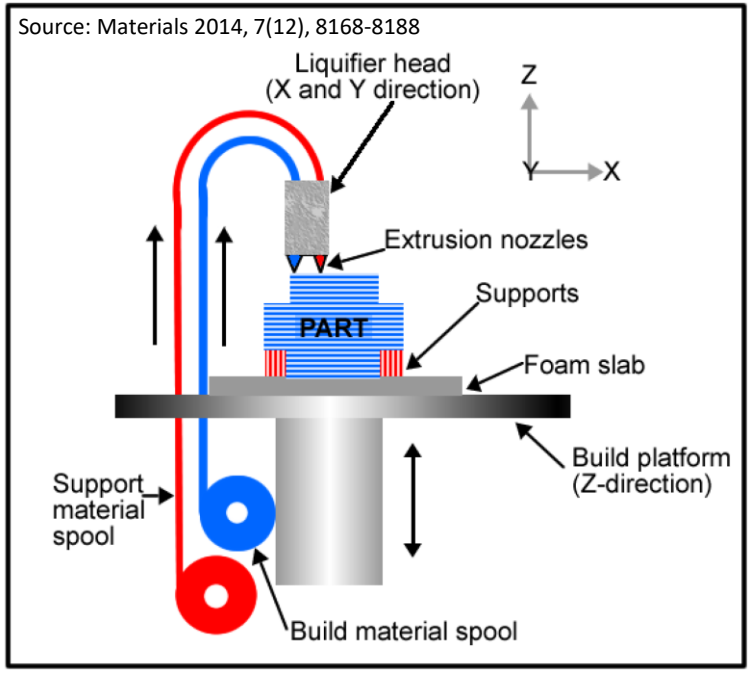
https://youtu.be/8a2xNaAkvLo

Selective Laser Sintering (SLS)



https://youtu.be/XyFSoIk5OW8

Fused Deposition Modelling (FDM)



FDM

https://youtu.be/WHO6G6GJbM

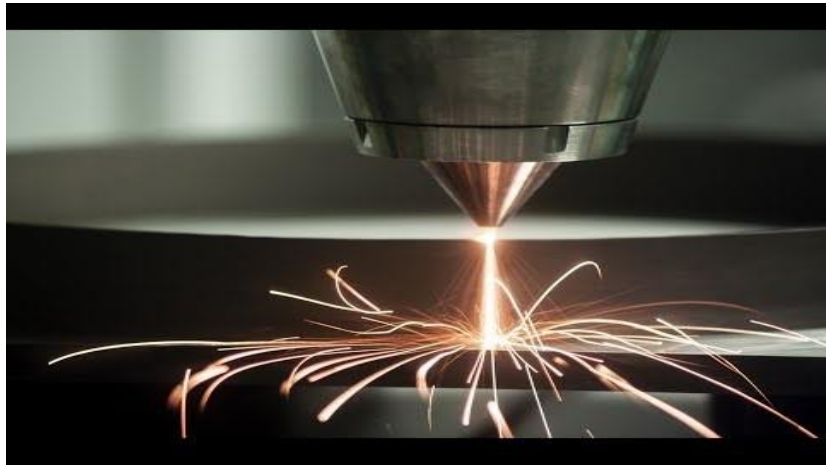
AM examples

3D Printing of plastics - FDM

https://www.youtube.com/shorts/YyWqD6Zcqjw

https://www.youtube.com/shorts/WUCBeeATyMU

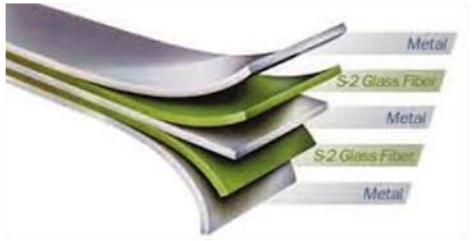
3D Printing of metals - Directed energy deposition of powders



https://www.youtube.com/watch?v=oL7bMhPTtDI

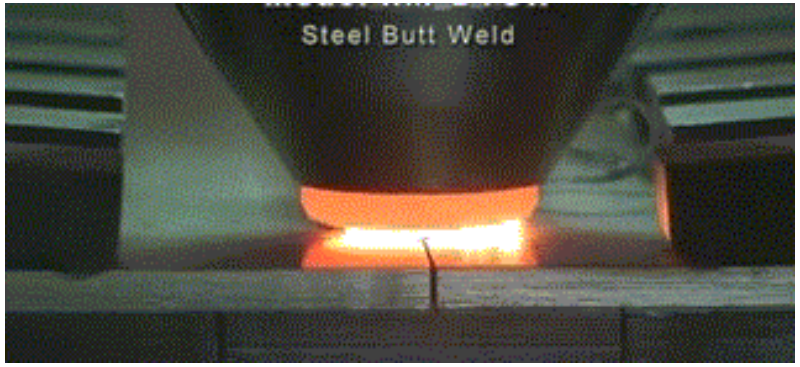
Joining Methods

- Adhesive Bonding
- **Welding**
- Mechanical Fastening



Nails, rivets, bolts, etc.

- Fusion
- Brazing & Soldering
- Solid State



Summary

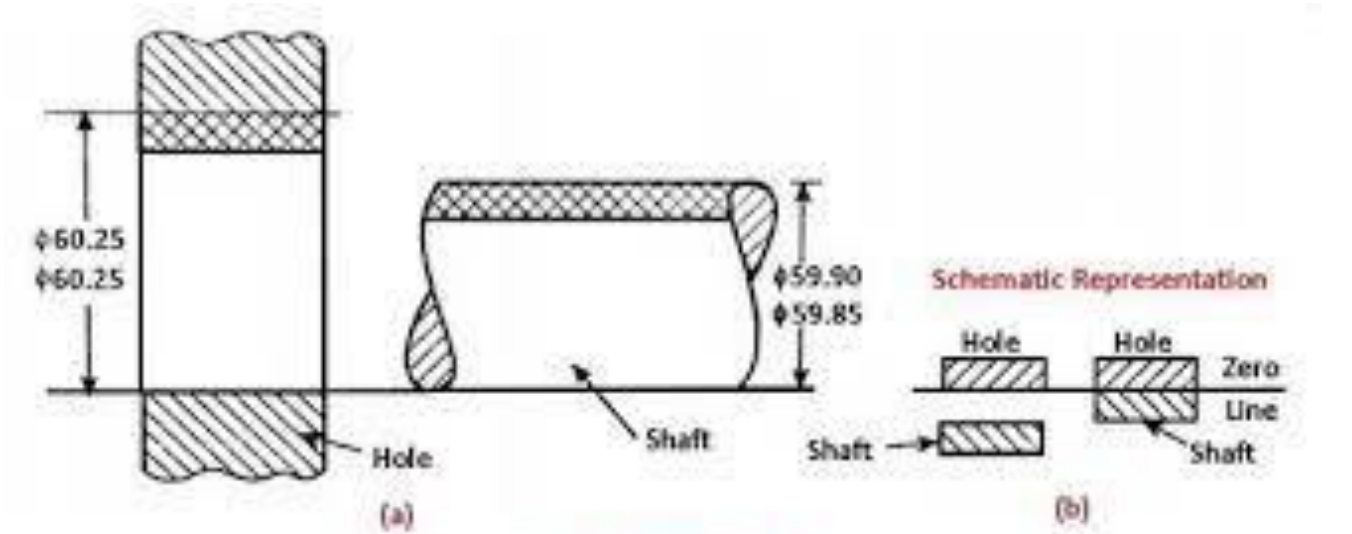
- Top-down Vs Bottom-up
- Forging, casting, moulding
  - Near parallel processing, productivity
  - Large scale production
- Additive Processes
  - Prototyping, tooling, fixtures
  - Very complex shapes, one of a kind jobs

Fits & Tolerances

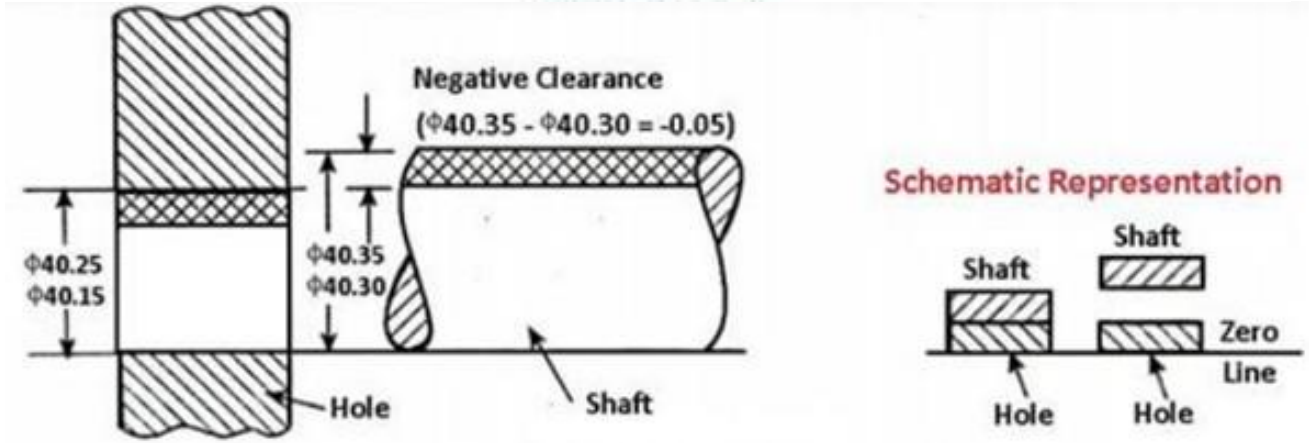
- No dimension can be exactly produced or measured. So, we define a range within which they can be realized. This is known as tolerance. Related term for the machine/process is process capability. Eg.: Reaming is limited to H5.
- Two types of tolerances are:
  1. Dimensional tolerances (length, angle etc.)
  2. Geometric tolerances (perpendicularity, concentricity, parallelism etc.)
- Capital letter is used for holes and small for shafts. Eg.:10H7 = 10.000 to 10.015; 10r6 = 10.019 to 10.028).
- Fit is assembly tolerance. (clearance & interference). 10H7r6 is an interference fit of 0.004 (largest hole & smallest shaft) to 0.028 (smallest hole& largest shaft). Transition fit is in-between them. Eg.: Chained watch, strapped watch & ear stud. Process related terms are: Drive fit, shrink fit, sliding fit etc.

Introduction

Fits & Tolerances



Clearance Fit



Interferance Fit

Useful Resources…

- Principles of Modern Manufacturing: Materials, Processes, and Systems, Mikell P. Groover, Wiley India Edition, 2018.
- Manufacturing Engineering and Technology (SI Edition), S. Kalpakjian and S. R. Schmid, Pearson Education; Seventh edition, 2018.
- Fusion 360 Tutorials on additive manufacturing
  - https://help.autodesk.com/view/fusion360/ENU/courses/AP-MFG-ADD-FFF
- How to 3D print using Fusion 360
  - https://www.youtube.com/watch?v=wPScDWi-X4s (practice upto time 3:05)