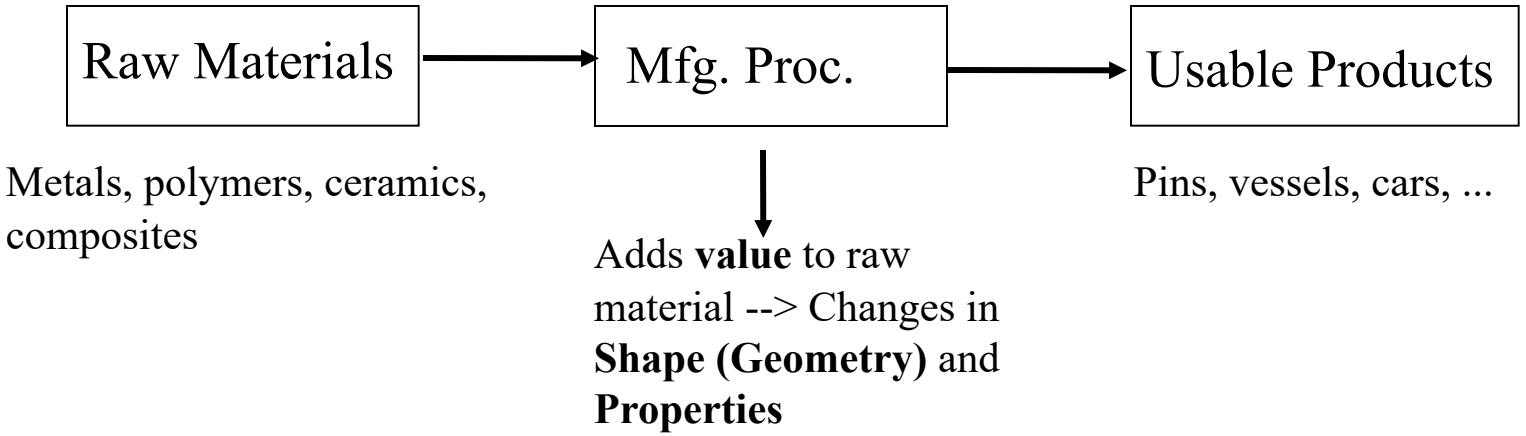
Introduction to Manufacturing

Outline

- Introduction to manufacturing
- Mass reducing processes
- Mass conserving processes
- Mass addition processes

Definition

- *What is Manufacturing?*
  - derived from the Latin word *manufactus*
  - *manus* = hand, *factus* = made
  - practical definition: *process of converting or processing raw materials into usable products.*

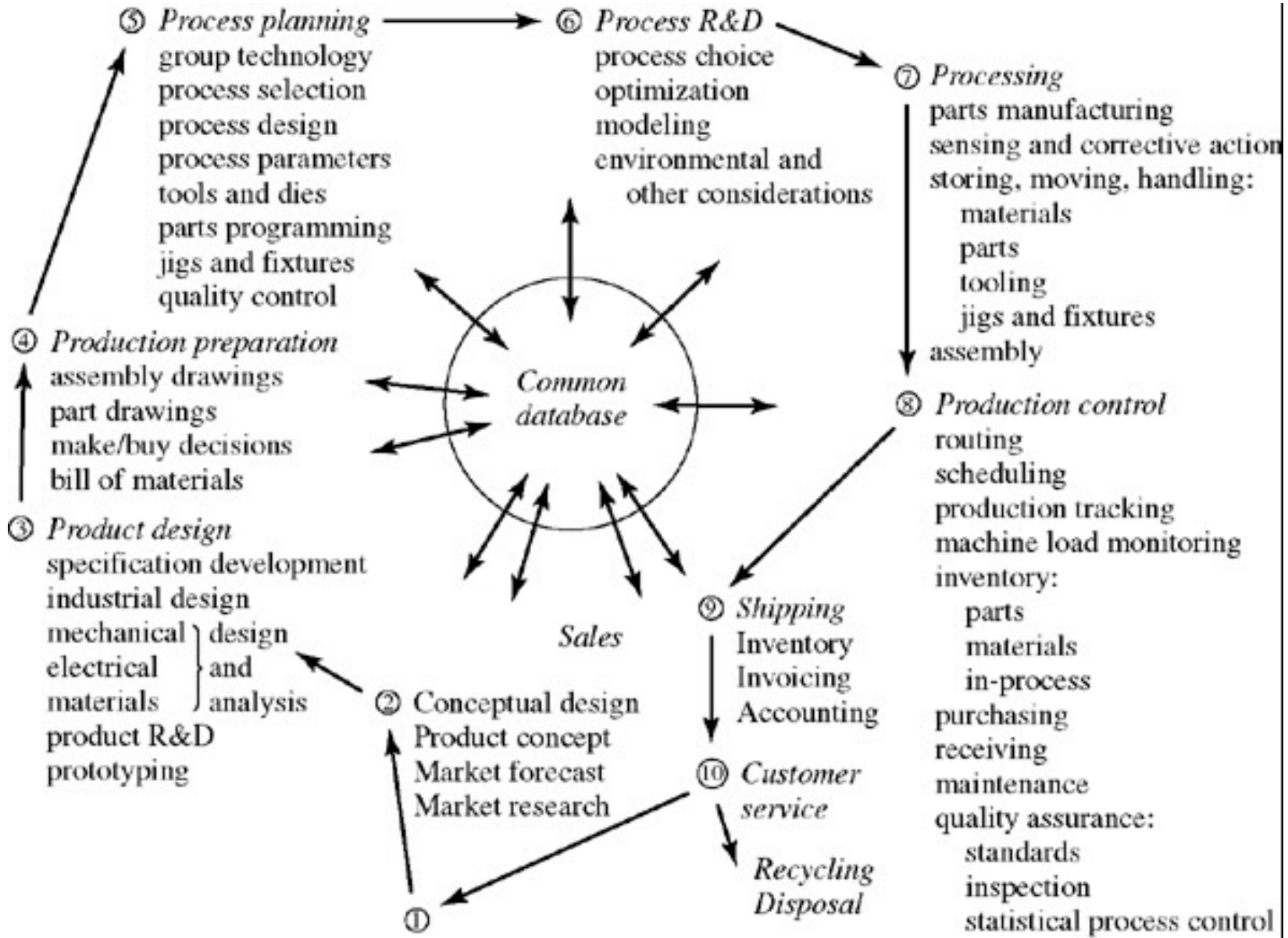


What is Materials Processing?

- Imparting changes in material :
  - Geometry
  - Material properties:
    - Strength
    - Hardness
    - Toughness
    - Etc.

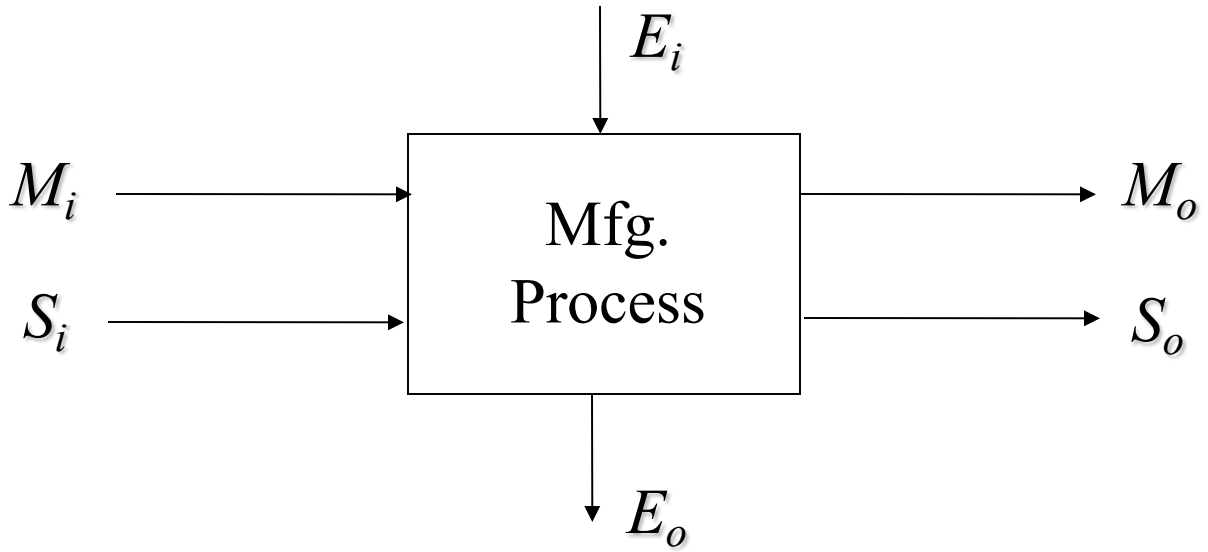
Systems-Oriented Definition

- Manufacturing as a system or enterprise
  - "*A series of interrelated activities and operations involving design, materials selection, planning, production, quality assurance, management, and marketing of discrete consumer and durable goods"* (CAM-I)
  - a highly complex, interdependent activity that is dynamic in nature.


⑤ Process planning
group technology
process selection
process design
process parameters
tools and dies
parts programming
jigs and fixtures
quality control
⑥ Process R&D
process choice
optimization
modeling
environmental and
other considerations
⑦ Processing
parts manufacturing
sensing and corrective action
storing, moving, handling:
materials
parts
tooling
jigs and fixtures
assembly
④ Production preparation
assembly drawings
part drawings
make/buy decisions
bill of materials
Common database
⑧ Production control
routing
scheduling
production tracking
machine load monitoring
inventory:
parts
materials
in-process
purchasing
receiving
maintenance
quality assurance:
standards
inspection
statistical process control
③ Product design
specification development
industrial design
mechanical
electrical
materials
design and analysis
product R&D
prototyping
Sales
⑨ Shipping
Inventory
Invoicing
Accounting
② Conceptual design
Product concept
Market forecast
Market research
⑩ Customer service
Recycling
Disposal
①

Classification of Unit Manufacturing Processes

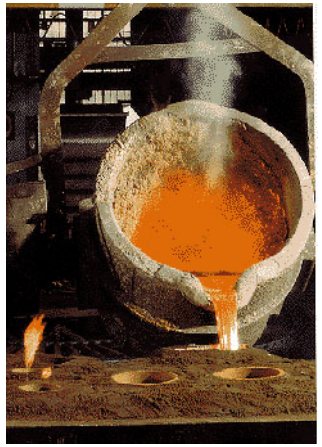
- Based on:
  - process type e.g., shaping vs. non-shaping (Mass change)
  - state of workpiece material e.g., solid or liquid
  - processing energy e.g., mechanical, electrical,…



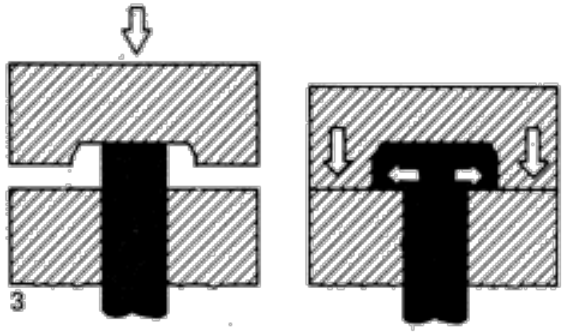
Classification of Unit Manufacturing Processes

- Shaping process classification
  - Mass reducing, $dM < 0$
    - examples: conventional and unconventional machining
  - Mass conserving, $dM \sim 0$
    - examples: casting, bulk forming, powder processing
  - Mass adding, $dM > 0$
    - examples: joining processes, additive manufacturing

Further sub-classification is possible based on processing energy and workpiece state considerations



Casting ($dM \sim 0$)

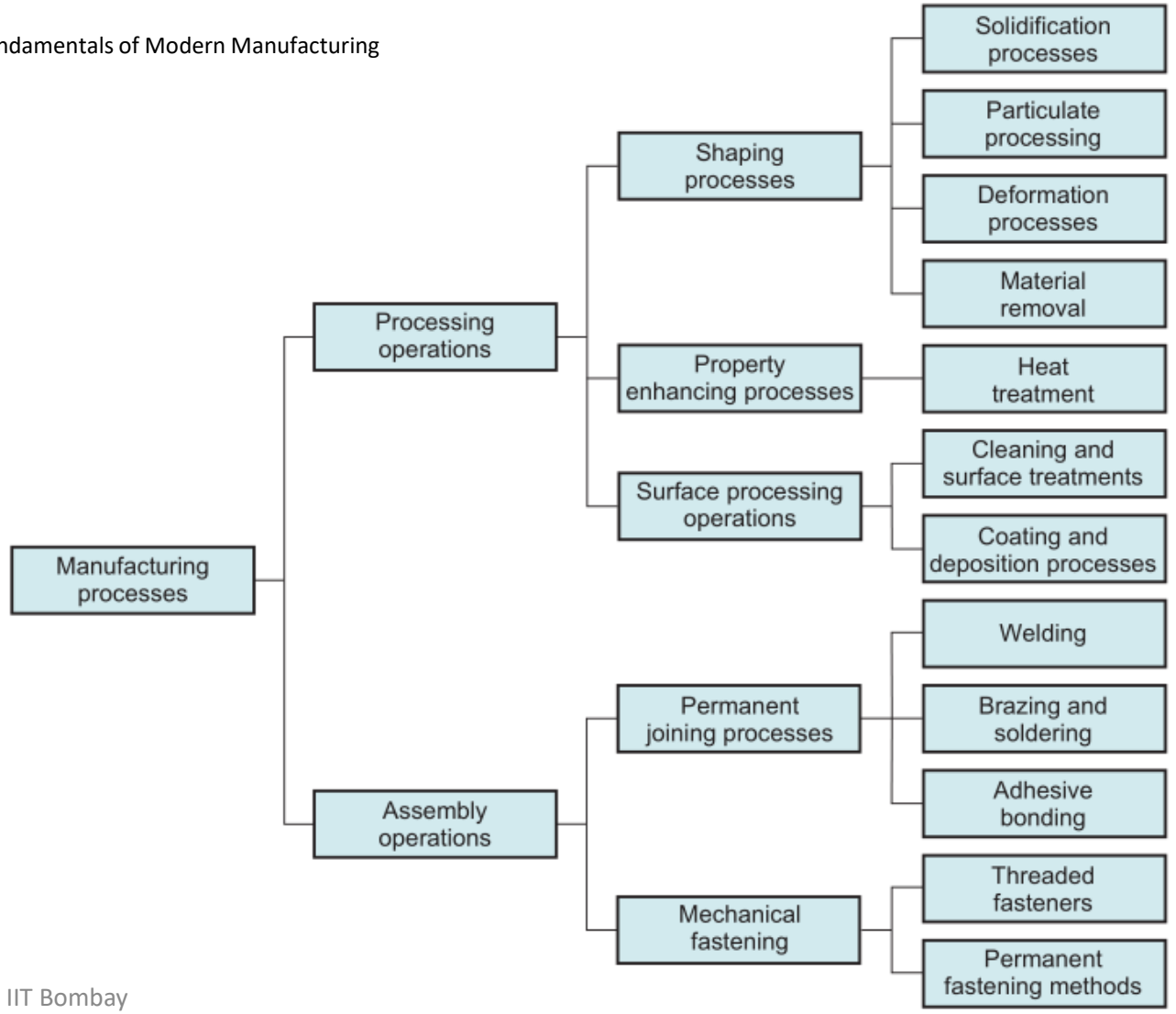


Forging ($dM \sim 0$)

Cutting ($dM < 0$)

Welding/Additive ($dM > 0$)

List of Manufacturing Processes

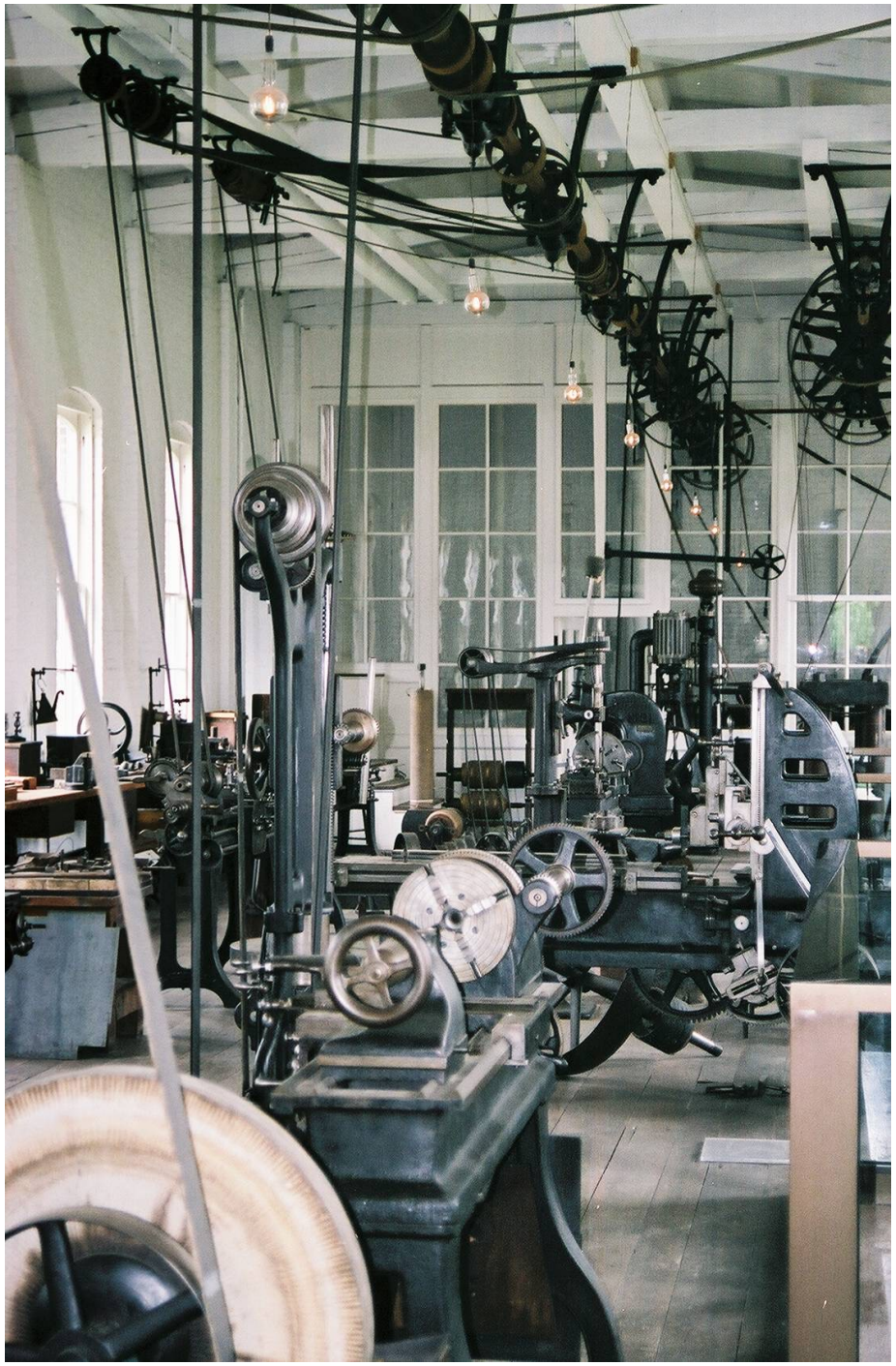


Manufacturing of Locomotive in 1938

MASS REDUCING OR SUBTRACTIVE PROCESSES

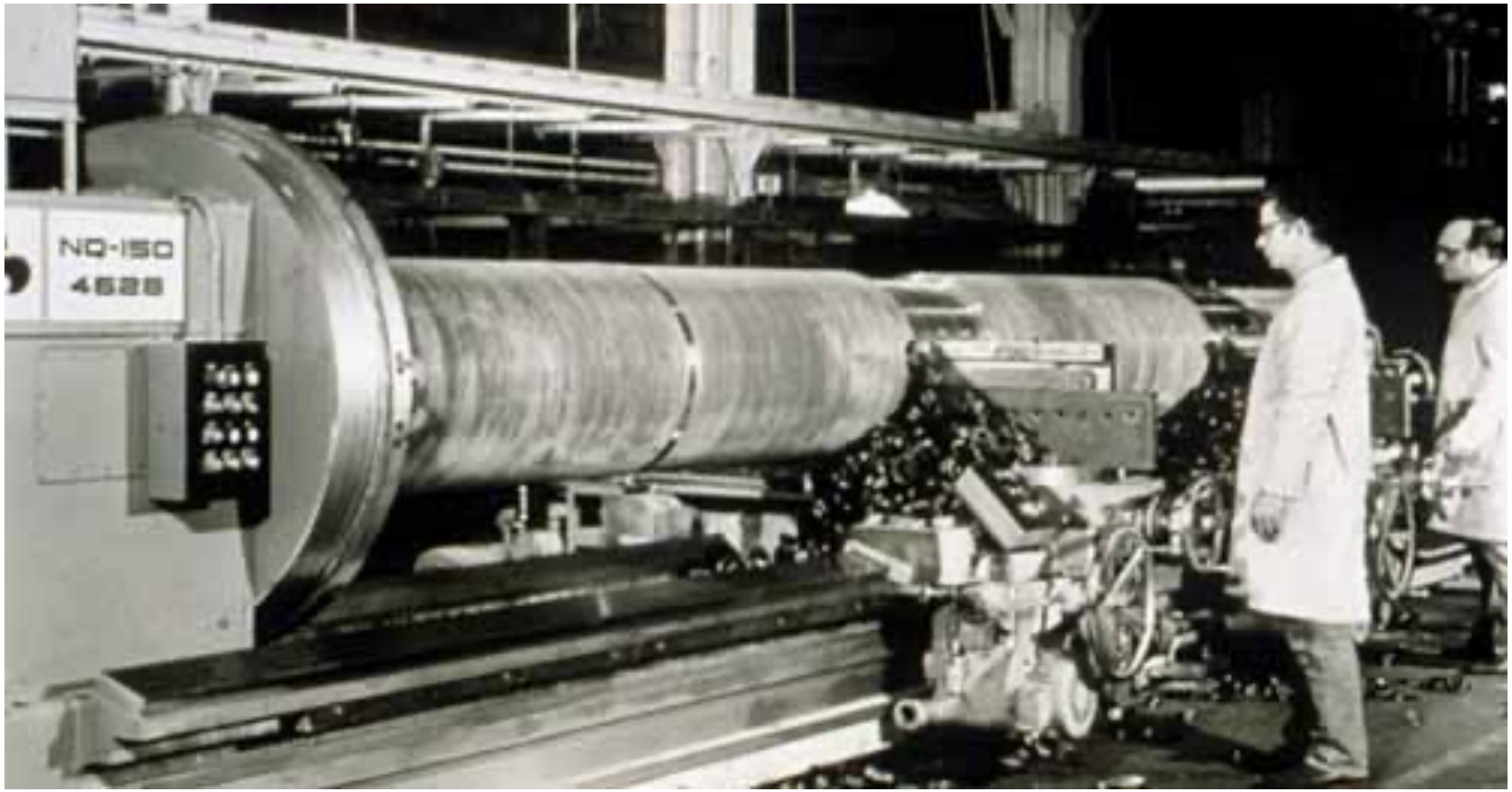
ME 206: Manufacturing Processes I
Instructor: Ramesh Singh; Notes: Profs. Singh/Melkote/Colton

Old Machine Shop – Edison's lab



Machining = Chip formation by a tool

Big lathe with big chips



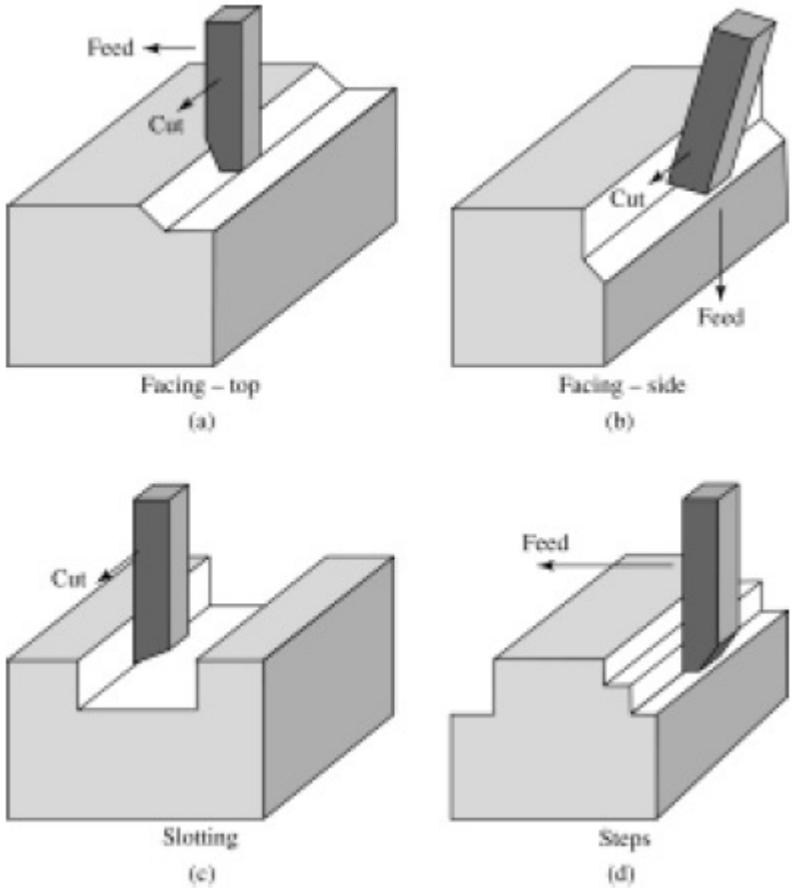
Giant Lathe

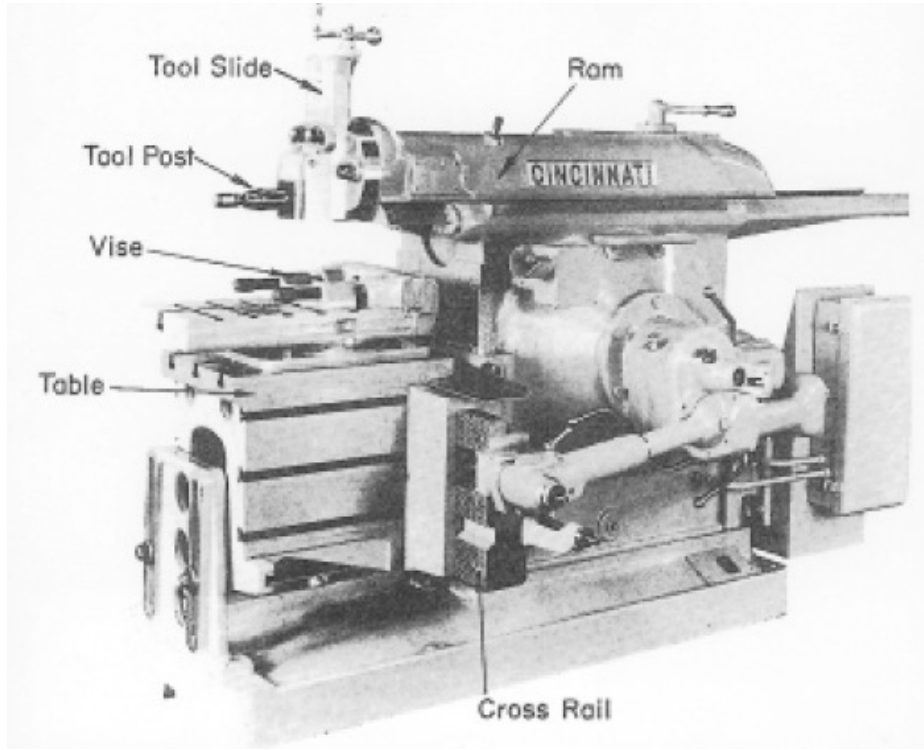
Machine Tools and Processes

- Turning
- Boring
- Milling
- Planing
- Shaping
- Broaching
- Drilling
- Filing
- Sawing
- Grinding
- Reaming
- Honing
- Tapping

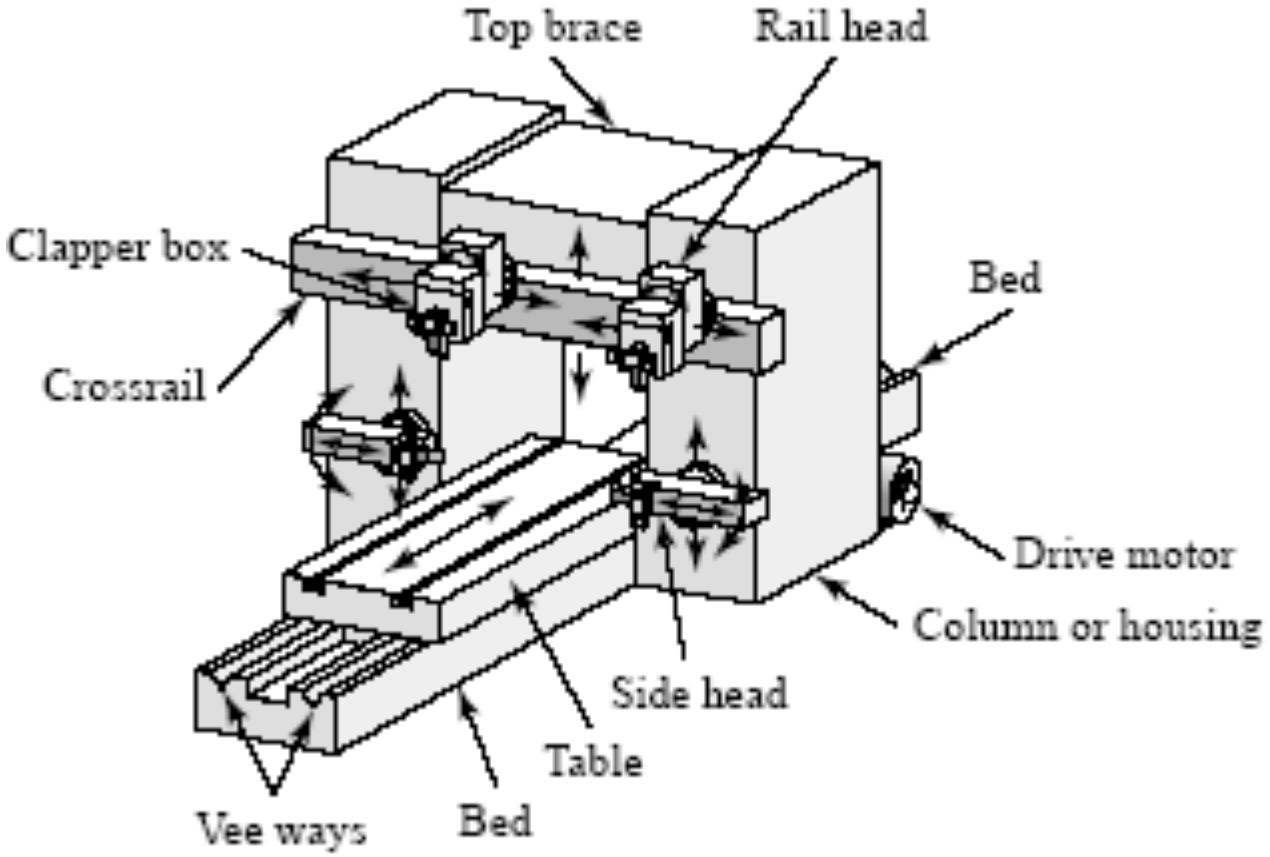
Video of Machining Processes

Shaping


Feed
Cut
Facing – top
(a)
Cut
Feed
Facing – side
(b)
Cut
Slotting
(c)
Feed
Steps
(d)


Tool Slide
Ram
Tool Post
CINCINNATI
Vise
Table
Cross Rail

Planing


Top brace
Rail head
Clapper box
Bed
Crossrail
Drive motor
Column or housing
Side head
Table
Vee ways
Bed

Shaping & Planing

- Material removal rate, $MRR = Vwt_0$
  - V is cutting velocity, w is width of cut and t_0 is uncut chip thickness
- Cutting power, $P_c = u\,MRR$
  - u is the specific cutting energy; Energy required/Volume removed
- Machining time, $t_m = L/V$
  - L is the length of cut

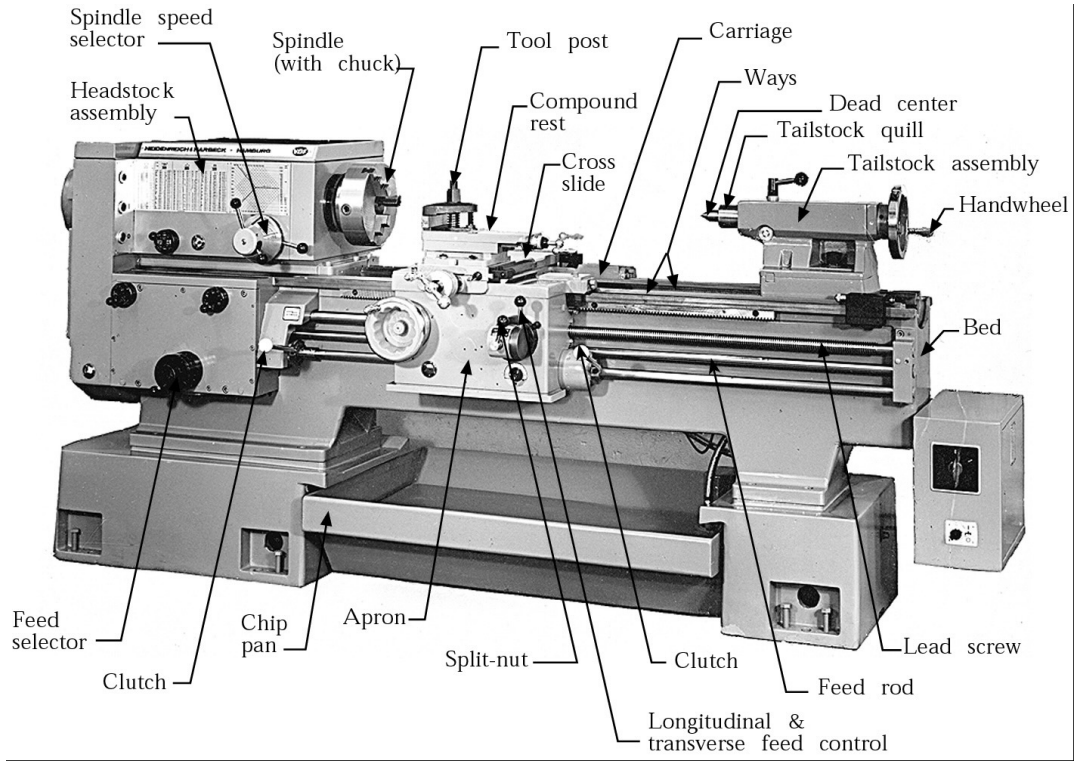
u is composed of:

- u_s, the shear energy per unit volume
- u_f, frictional energy per unit volume
- chip curl energy
- chip acceleration kinetic energy
- surface energy of new surfaces

Where does cutting energy go?

- 90% to chip
- 5% to tool
- 5% to workpiece

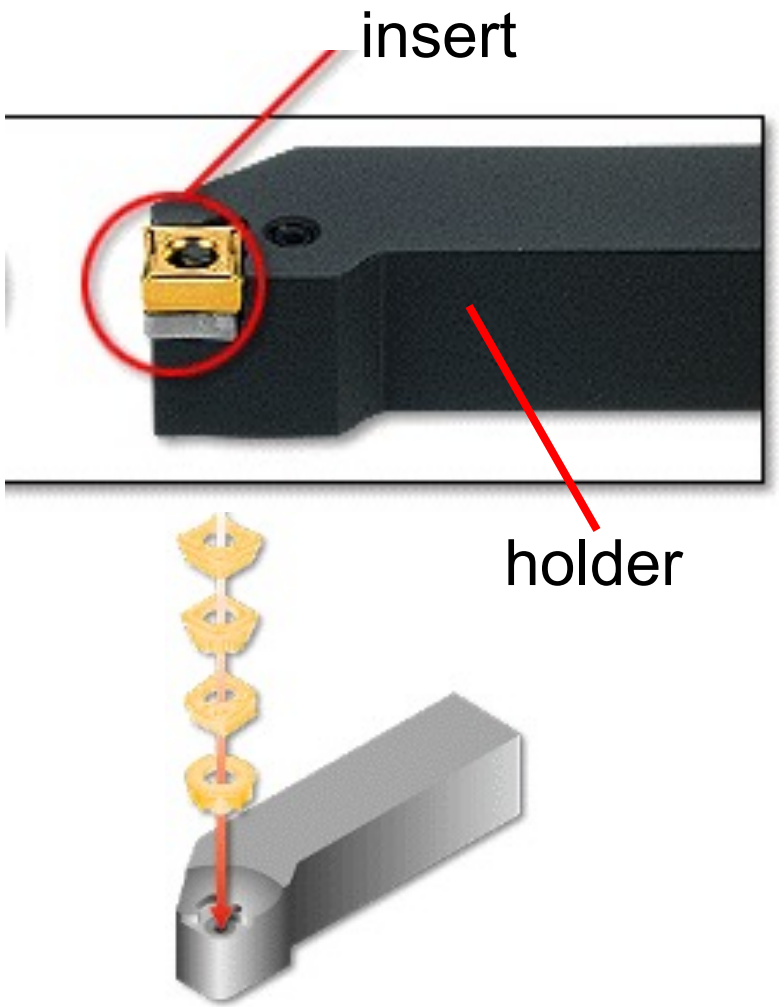
Lathe (for turning)



Manual Lathe

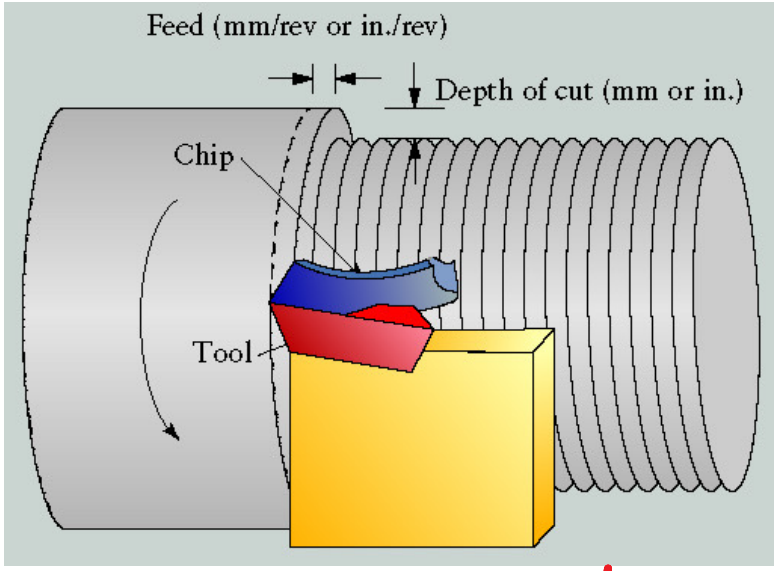
Computer Numerically Controlled (CNC) Turning Center

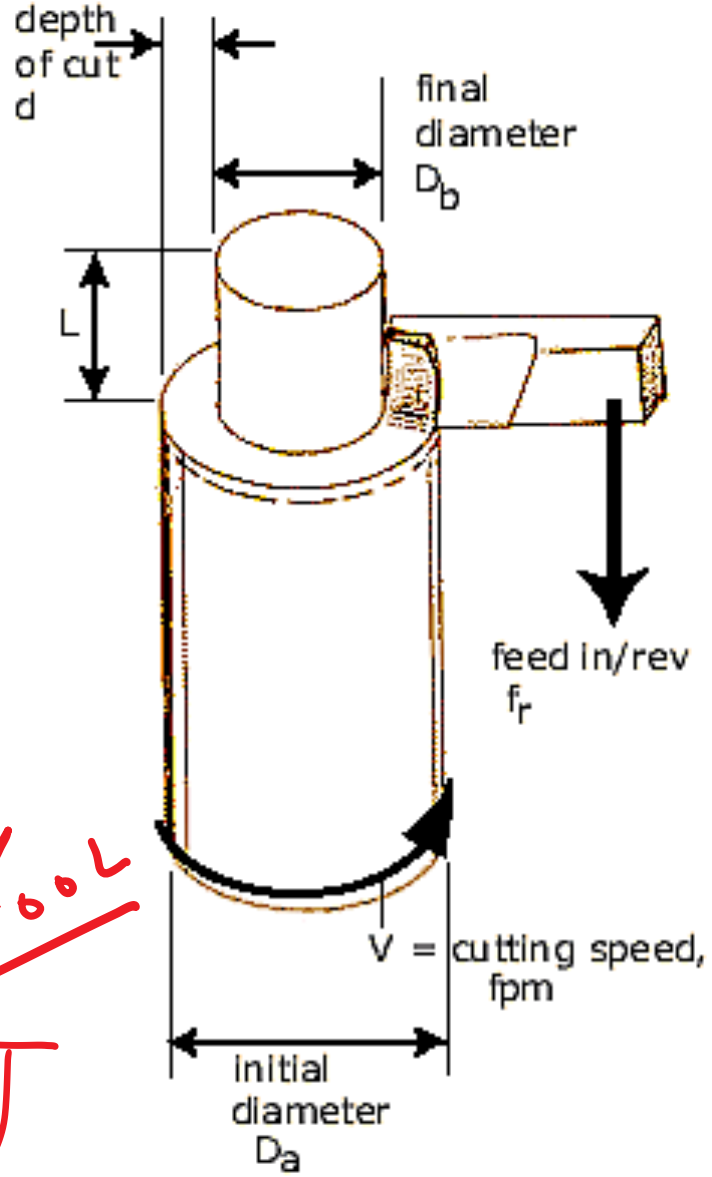
Typical Insert Cutting Tool



Pillars made on Lathe

Turning -MRR


Feed (mm/rev or in./rev)
Depth of cut (mm or in.)
Chip
Tool

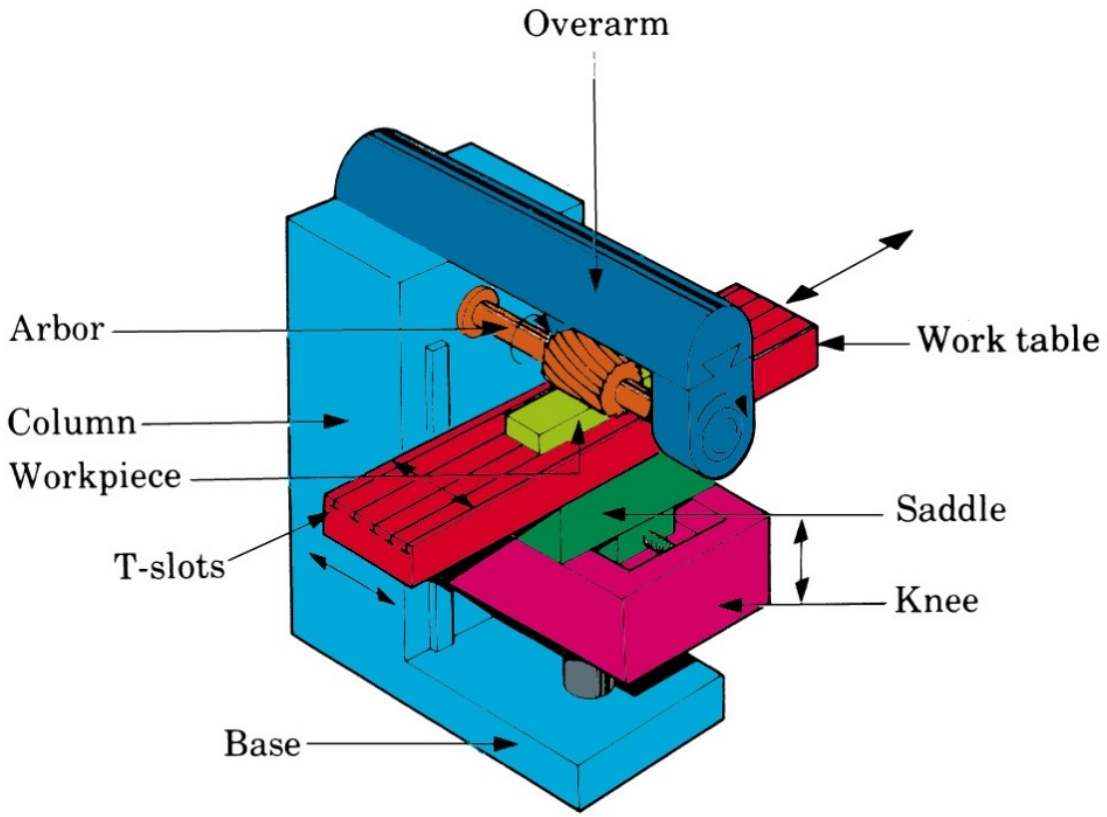

depth
of cut
d
final
diameter
D_b
L
feed in/rev
f_r
V = cutting speed,
fpm
initial
diameter
D_a


to
CHIP
TOOL

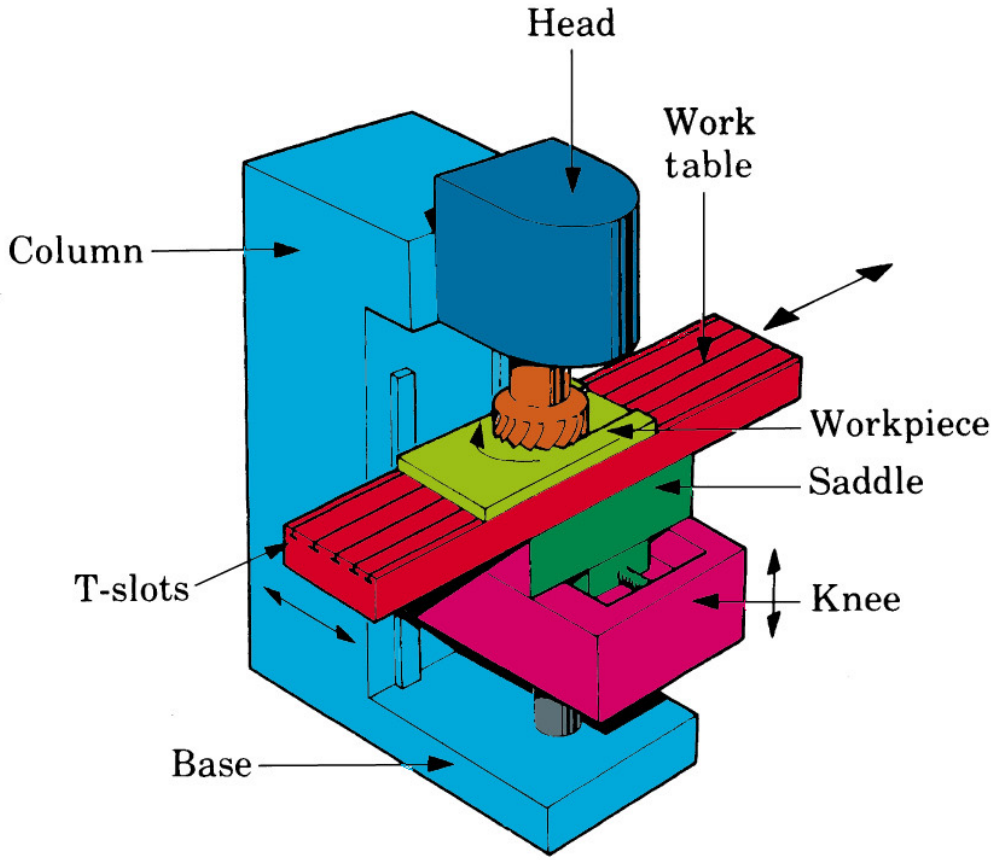
Turning

- Average cutting speed, $V_{avg} = \pi D_{avg} N$
  - D_{avg} is the average diameter of workpiece
  - N is the spindle speed in rpm
- Material removal rate, $MRR = V_{avg} df$
  - d is the depth of cut
  - f is the feed (units: mm/rev or in/rev)
- Cutting power, $P_c = u\,MRR = F_c V$
  - F_c=Cutting force
  - V = Cutting speed
- Machining time, $t_m = L/(fN) = L/F$
  - F is the feed rate (units: mm/min or in/min)

Horizontal Mill

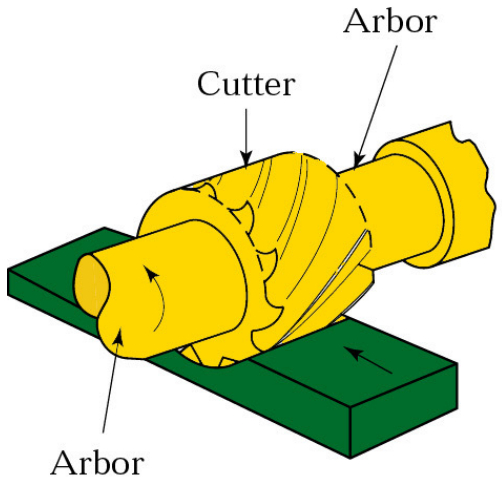


Vertical Mill

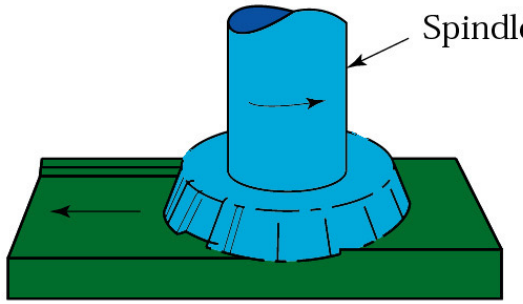


Milling

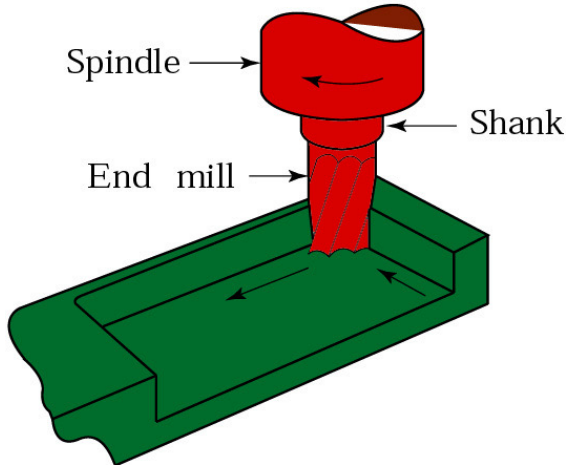
(a) Slab milling

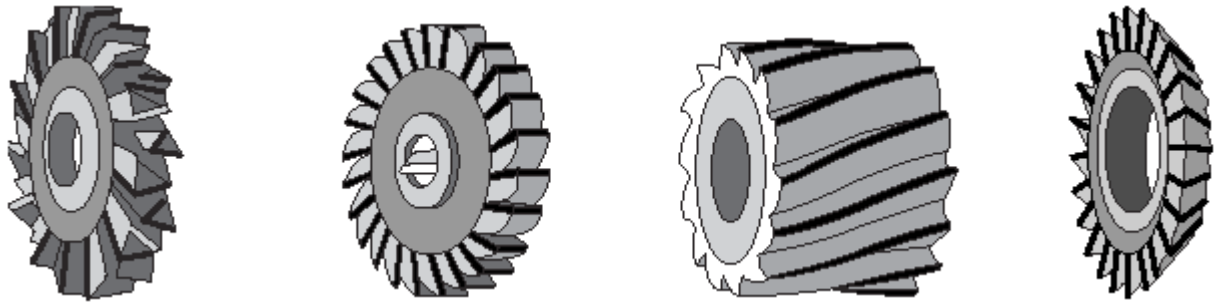


(b) Face milling



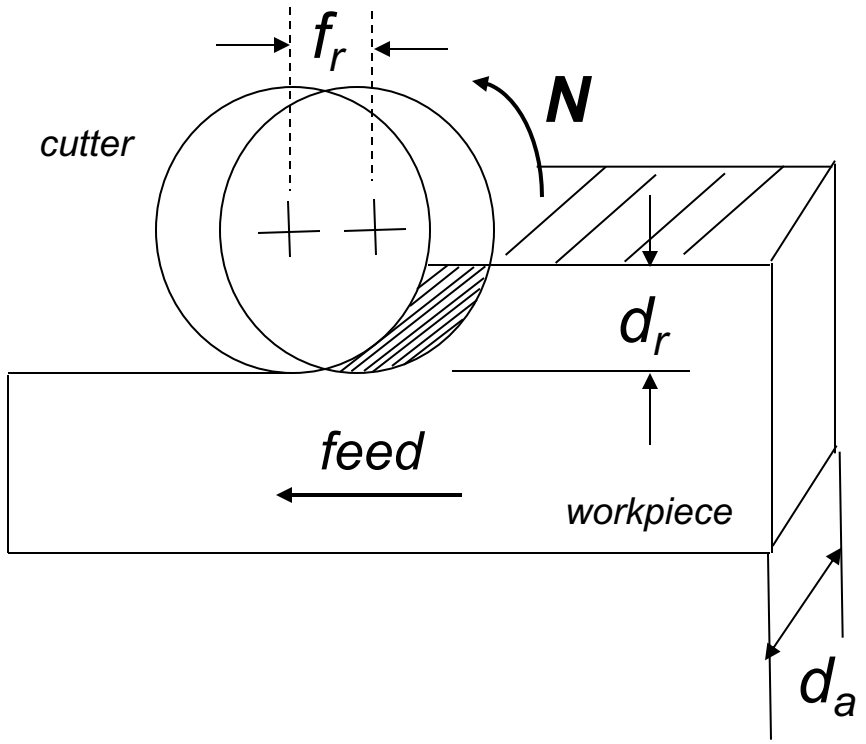
(c) End milling





Common HSS milling cutters.

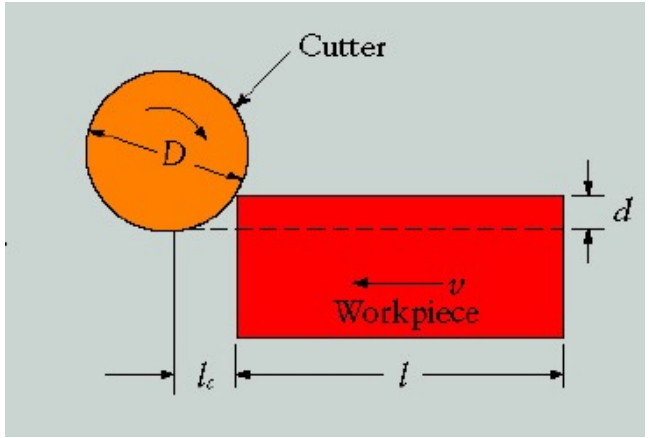
Milling



Milling

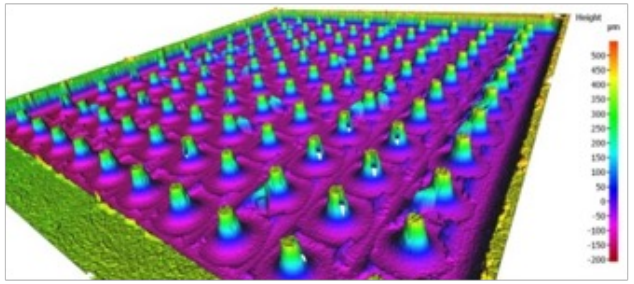
- Cutting speed, $V = \pi DN$
  - D is the cutter diameter

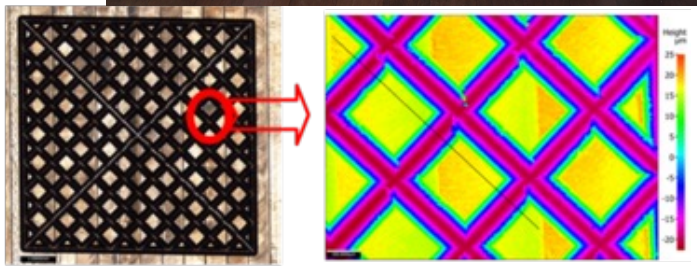
- Material removal rate, $MRR = fNd_a d_r = Fd_a d_r$
  - d_a is the axial depth of cut
  - d_r is the radial depth of cut
  - f is the feed per revolution (= $f_t N_t$; f_t is the feed per cutting edge/tooth and N_t is the number of teeth)
  - F is the feed rate (in/min or mm/min)

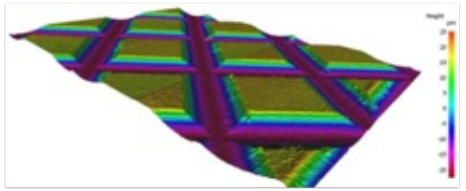


- Cutting power, $P_c = u\,MRR$

- Machining time, $t_m = (L + l_c)/F$
  - l_c is the length of the cutter's first contact with the workpiece



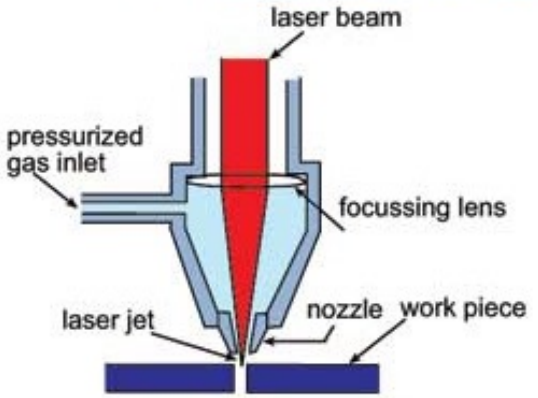




Machine has been commercialized by a start-up Micromach Innovations by my PhD students (www.micromach.in)

Laser Cutting

- Material removal
  - Melting
  - Vaporization
  - Chemical degradation



MASS CONSERVING PROCESSES

ME 206: Manufacturing Processes I
Instructor: Ramesh Singh; Notes: Profs. Singh/Melkote/Colton

Casting Basics

- A casting is a metal object obtained by *pouring molten* metal into a *mold* and allowing it to *solidify*.

Gearbox casting

Aluminum manifold

Magnesium casting

Cast wheel

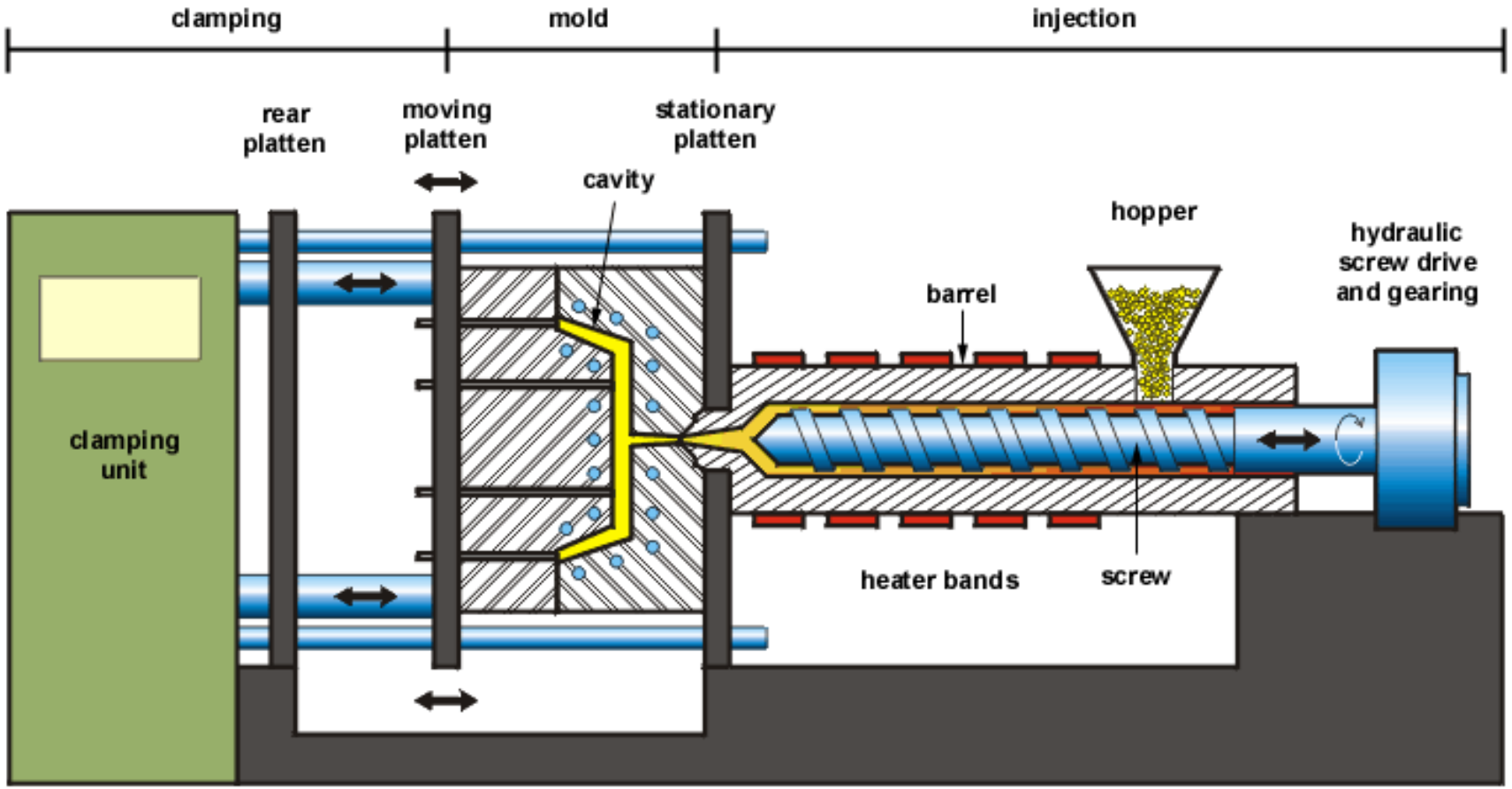
Bulk Deformation

- Bulk deformation (or forming): processes characterized by large amount of plastic deformation (large strains) carried out at elevated or room temperature
- Bulk plastic flow of material under uniaxial or multi-axial stresses dominated by compression
- Mass conserving processes → volume is constant

Aircraft bulkhead

Connecting rods

Injection Molding for Polymers



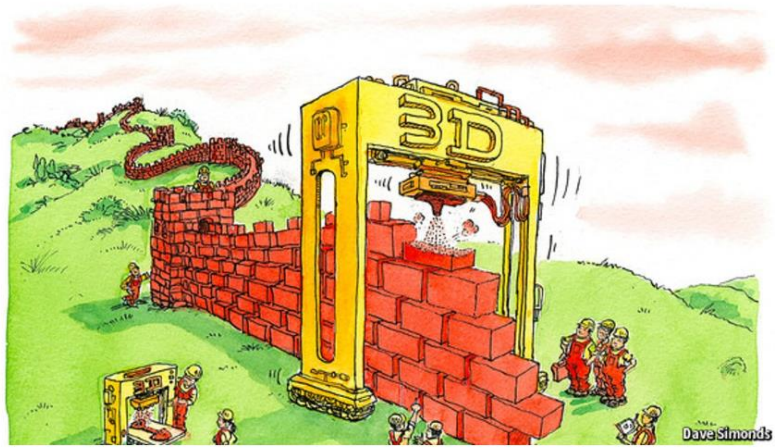
schematic of thermoplastic injection molding machine

MASS ADDITION PROCESSES: ADDITIVE MANUFACTURING/ 3-D PRINTING

MS 101
Instructor: Ramesh Singh; Notes: Prof. Mote

Additive Manufacturing

- 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

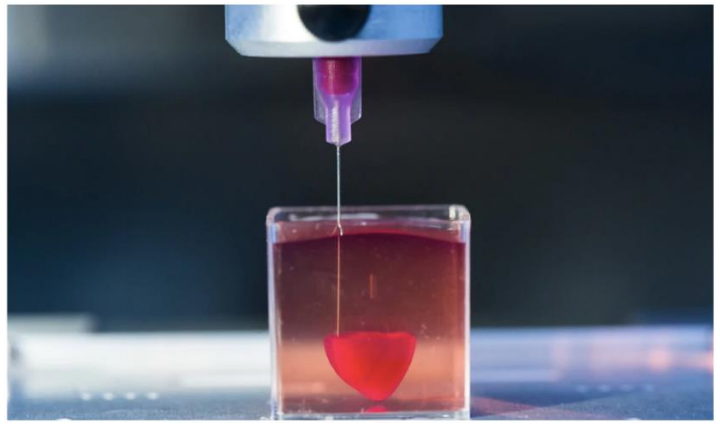
3D printing

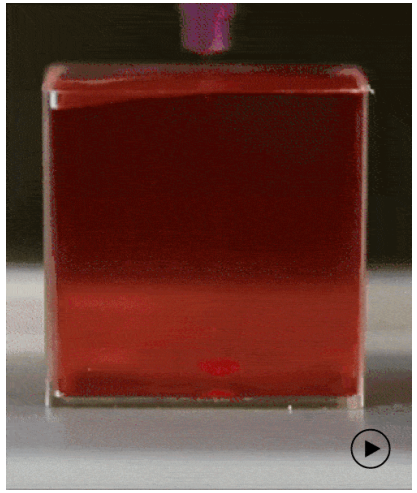
A new brick in the Great Wall

3D PRINTING NEWS MEDICAL

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

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





3-D Printing of Aerospace Parts

The Economist

Menu | Weekly edition | Search

Schumpeter | Additive manufacturing

Print me a jet engine

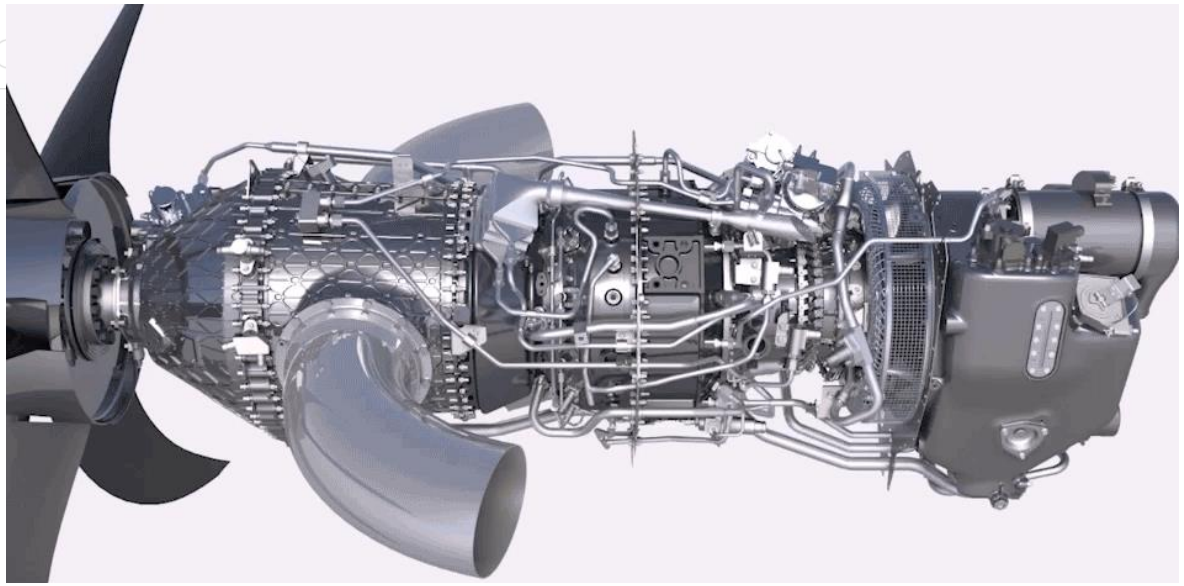
The acquisition of Morris Technologies is further proof that product innovation will increasingly go hand-in-hand with manufacturing innovation

Nov 22nd 2012

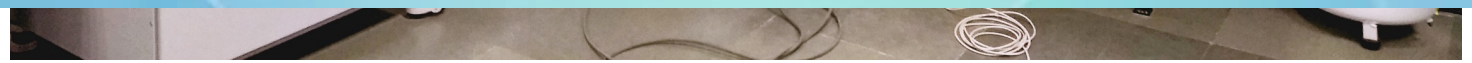
By P.M.

Turboprop Engine: GE Aviation

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



Robotic DED System (Mass Adding)



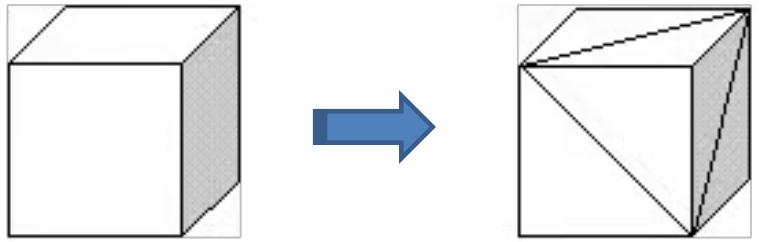
Steps in 3-D Printing

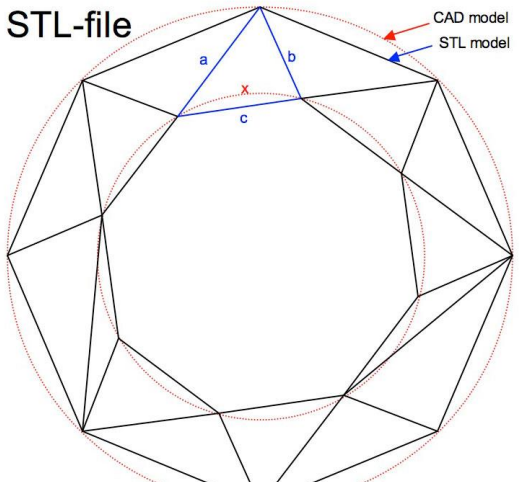
- Modelling in CAD
- Generating an STL or 3MF file
  - Surface geometry of 3D object
  - Orientation and Support structure
- Slicing (machine specific instructions)
  - Transforming an STL file into G-code (printer motions)
- Printing
- Post-processing
  - Finishing
  - Support structure removal
  -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

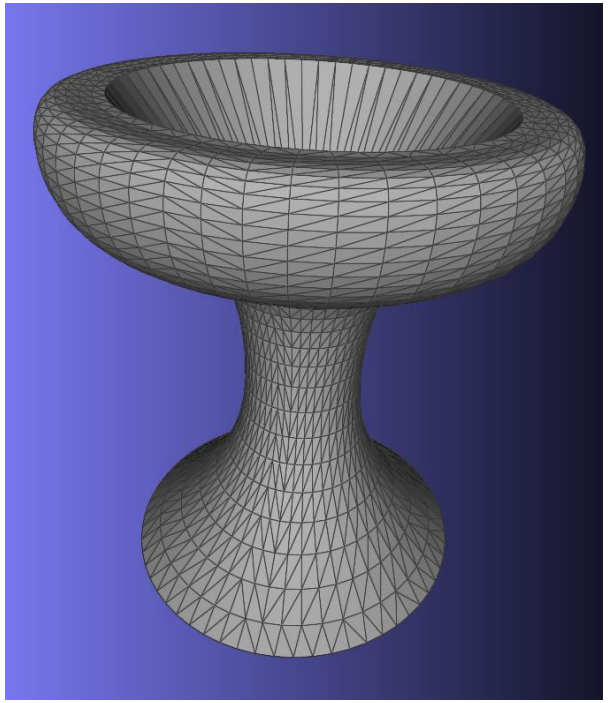
Layer by layer the printer will create the predetermined shape

.STL Files

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



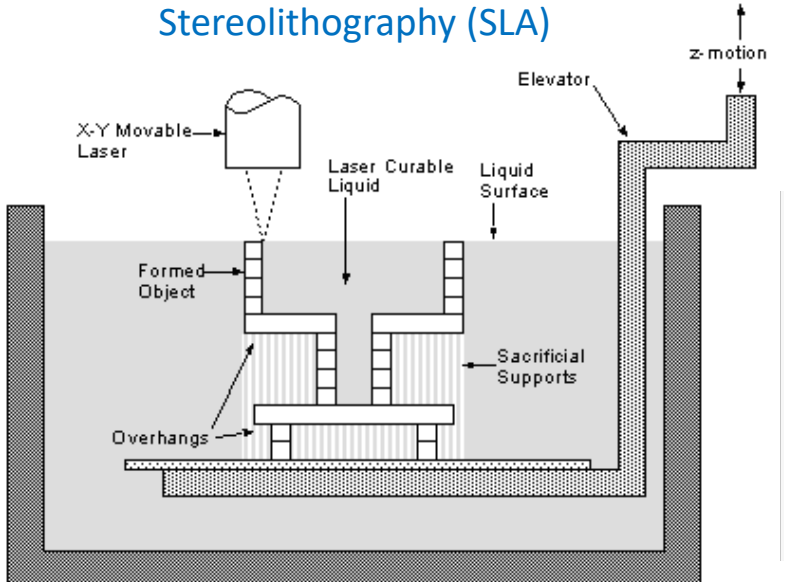




Polymer 3-D Printing Approaches

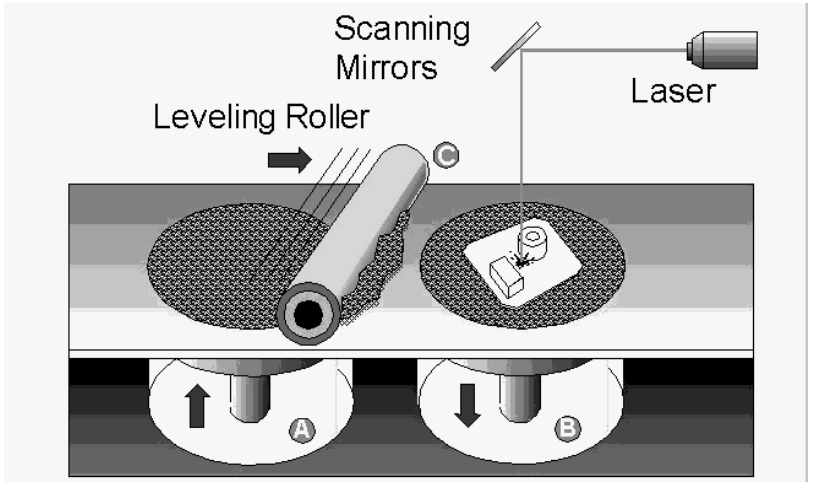
- Photopolymerization: Stereolithohgraphy (SLA)
- Powder fusion: Selective Laser Sintering (SLS)
- Fused polymer extrusion: Fused Deposition Modelling (FDM)

Stereolithography (SLA)



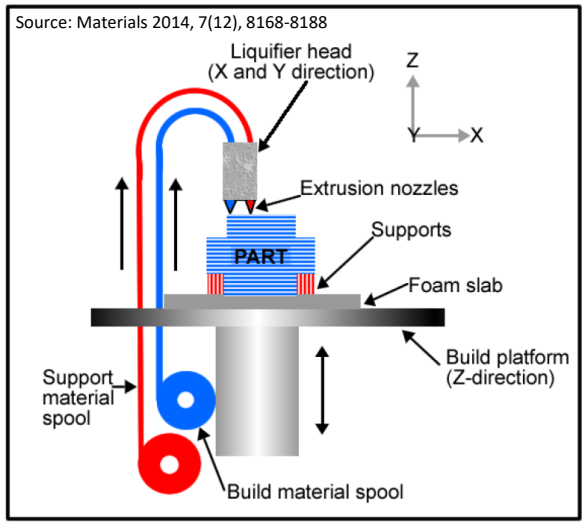
https://youtu.be/8a2xNaAkvLo

Selective Laser Sintering (SLS)



https://youtu.be/XyFSolk5OW8

Fused Deposition Modelling (FDM)



Summary

- Basic Manufacturing Processes
- Descriptions and videos of key machining processes with basic analysis
- Brief Description of Casting, Deformation and
- Information about additive manufacturing, primarily, polymer which will be used in the project