Introduction to Design & Manufacturing

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PREMA
PRECISION ENGINEERING & MANUFACTURING

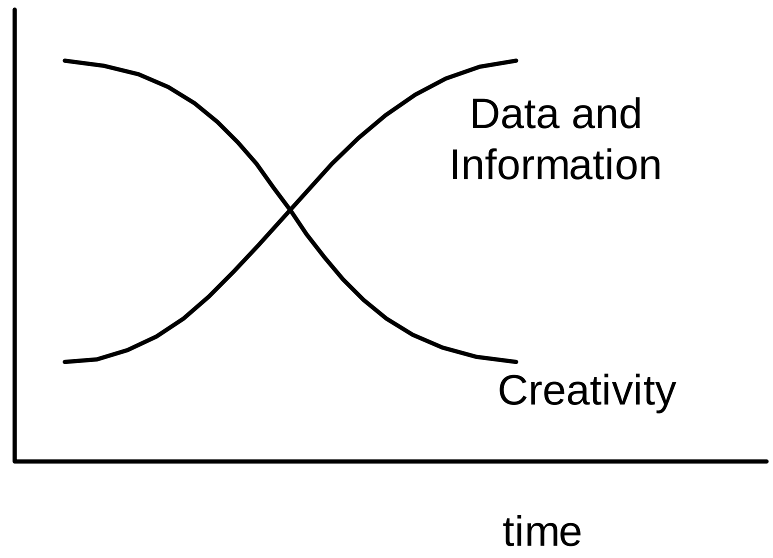
Design Process

- Problem Identification
  - Background, Data, Causes, Effects, Needs, Economics
- Preliminary Ideas (Conceptualization, Creativity)
  - Brainstorm, List Ideas, Notes, Sketches
- Problem Refinement (Synthesis, Creativity)
  - Scale Drawing, Physical Properties (Weight, Volume), Shapes and Forms (Angle, Length)
- Analysis
  - Science, Mathematics, Graphics, Engineering, Logic, Experience
- Evaluation and Decision
  - Simulation, Cost, Physical Model
- Implementation
  - Formal Drawing, Manufacturing, Marketing

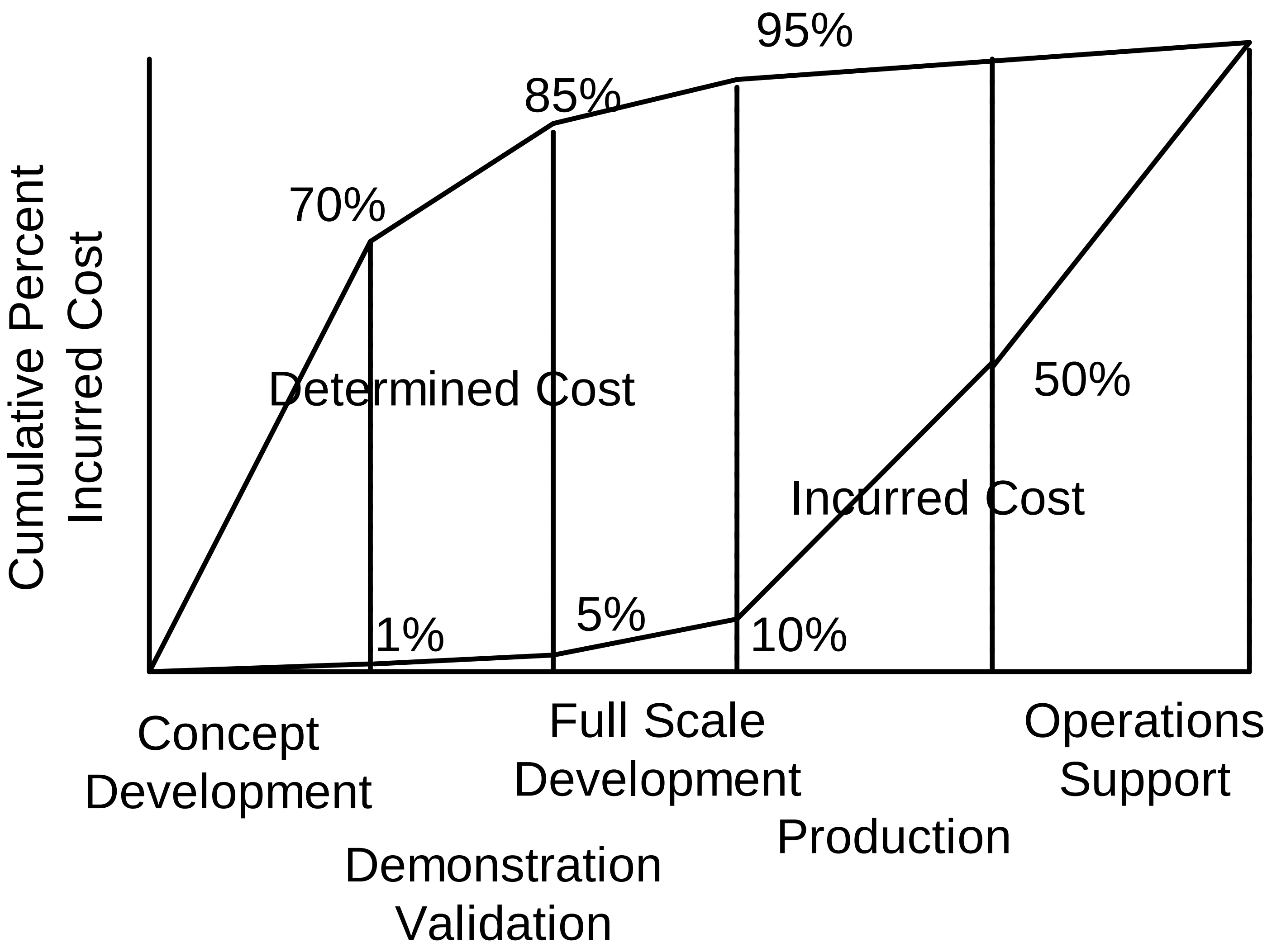
Design Problems

Design Problems

- Scheduled Deliverables (Not enough time for Alternatives)
- Producibility is considered only at a later stage
- Fragmented Database
- Design intent is lost
- Designer does not have cost information



Design Cost Curve

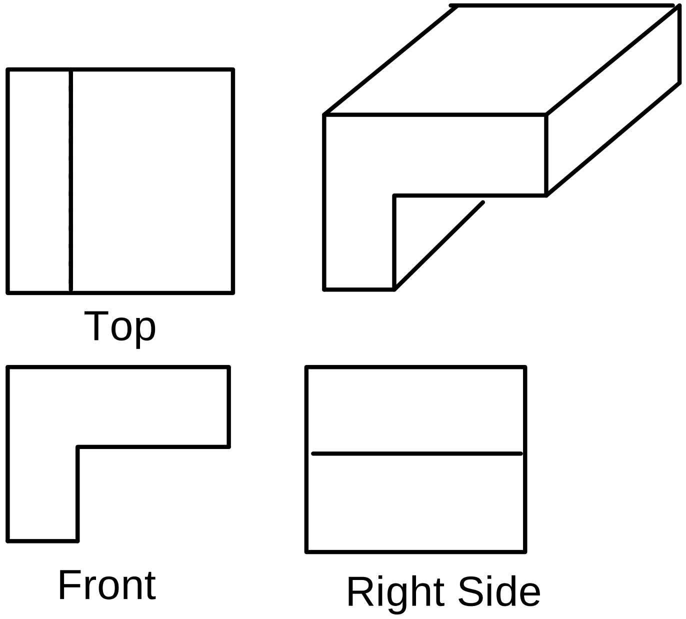


Design Drafting

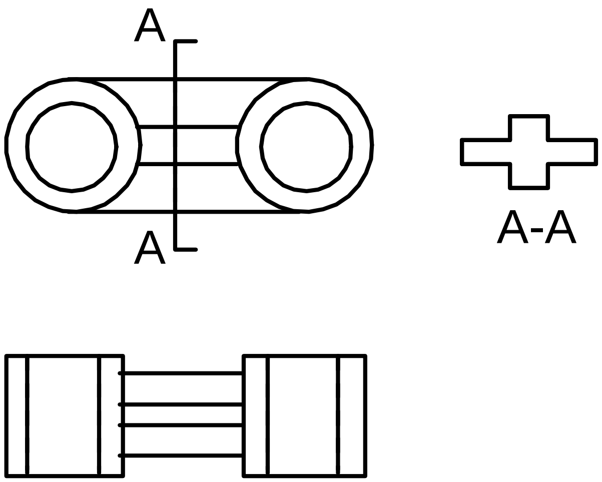
Design => Representation => Manufacturing

- Verbal
- Sketch
- Orthographic Drawing
- CAD Drafting
- Solid Model
- Feature-Based Representation

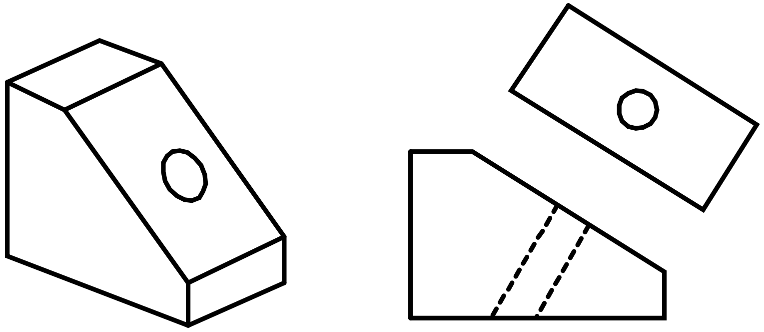
Third Angle Projection
(Object in 3rd Quadrant)



Design Drafting



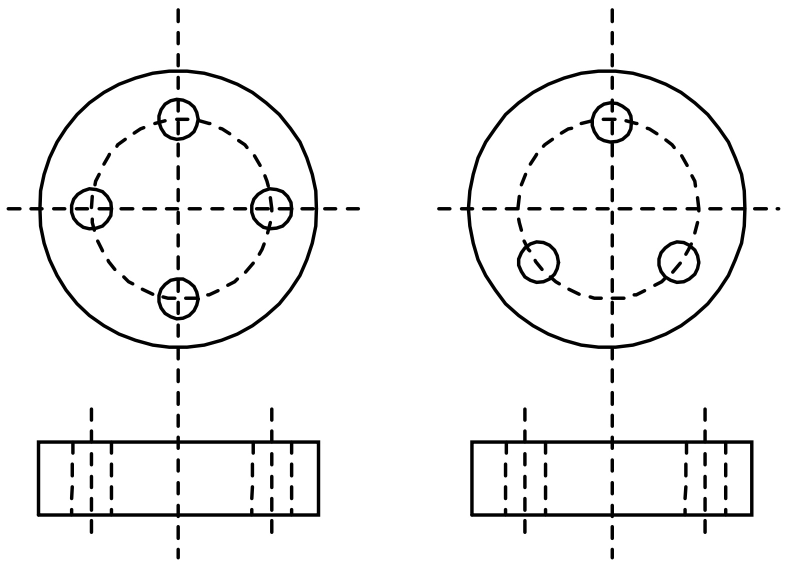
Cut-Off View



Auxiliary View
(In order to avoid distorted view)

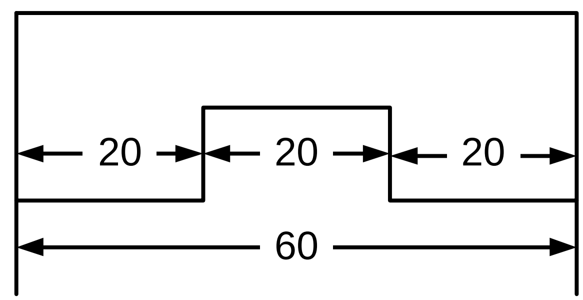
Design Drafting

Conventional Revolution



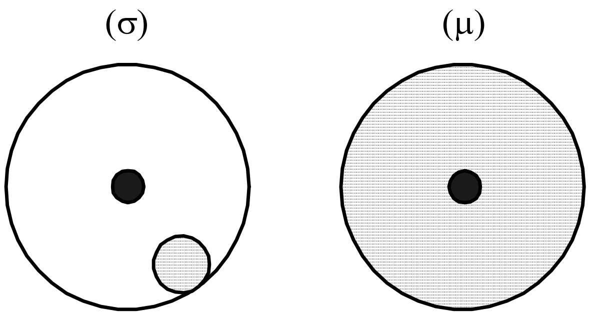
Dimensioning

- Unambiguous
- Complete
- No Redundancy

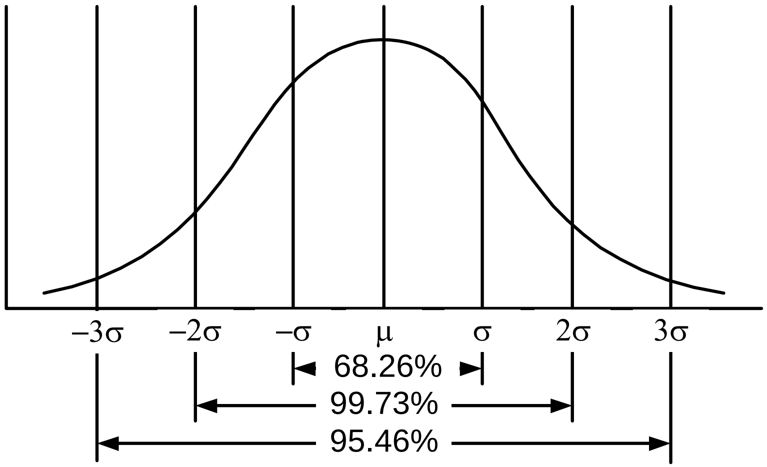


Metrology

Metrology: Science of Measurement



Precision Accuracy



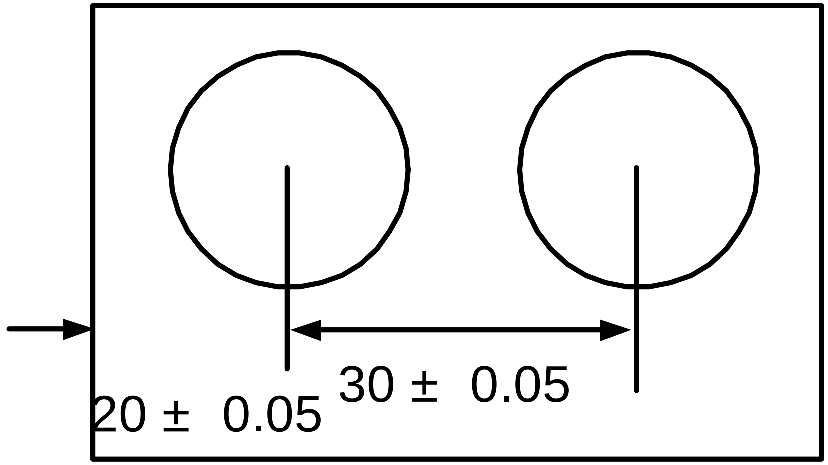
Tolerance

Tolerance

Undesirable but permissible variation of prod. dimension

-Bilateral 2.000±0.001 mm

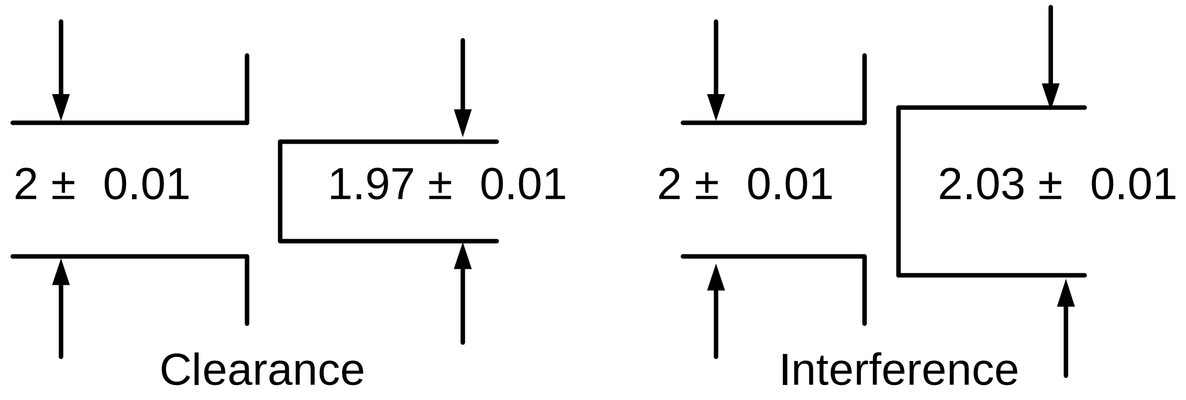
-Unilateral $2.000 \pm^{0.002}_{0}$ mm



Tolerance Stacking

Allowance

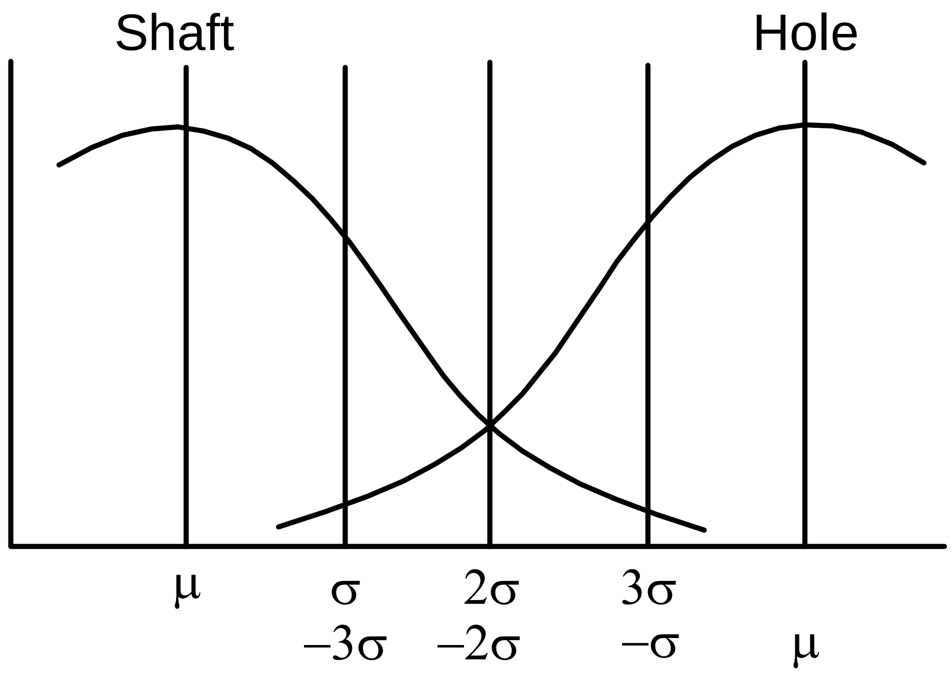
Intentional difference in dimension necessary to function properly. e.g. Machining allowance, Shrinkage allowance



Max. Mat. Cond. -smallest hole, largest shaft
Least Mat. Cond. -smallest shaft, largest hole

Eg. 2 mm Hole, Hole basis (Due to drill size), Tol.: ±0.01 mm,
Clearance all.: 0.02 mm, St. Dev: 0.01 mm
Then, Max. Hole: 2.01 mm, Min. Hole: 1.99 mm
Max. Shaft: 1.97 mm, Min Shaft: 1.95 mm

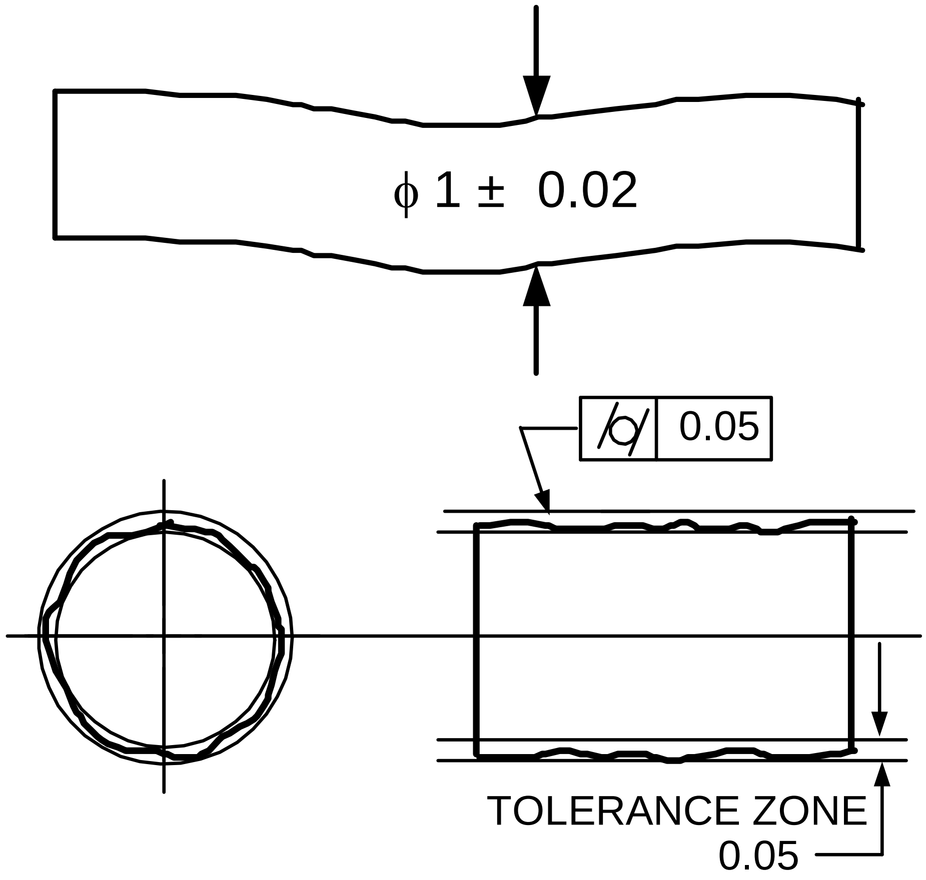
Metrology



6 out of 10,000 cannot be assembled.
Also consider clearance.

Geometric Tolerancing

Straightness, Flatness, True Position, etc.



Manufacturing

- Casting
  - Production of final shape in a single step (complicated shape)
  - Rough surface finish, Low strength
- Forming
  - High strength, Fast production
  - Medium cost. (High cost for low volume)
  - Medium surface finish
- Machining
  - Good surface finish (Precise)
  - Time consuming. Expensive
  - Turning, drilling, reaming, boring, tapping, milling, grinding, broaching, planing, shaping, sawing, EDM/ECM, laser...
- Ceramic Processing
- Polymer Processing
- Nontraditional Machining
- Assembly

Materials

Design, Material Selection, Production, Marketing

Delaurian: S.S Body, Al body
Al Transmission Box (Vibration)
Ceramic Engine
Polymer Fibering
Creep (Lead)
Fatigue (Aluminum)
Transition temperature (Alaskan Pipeline)

Casting

Casting process
- Mold Cavity
- Melting
- Pouring
- Solidification
- Mold removal
- Cleaning, finishing, inspection

Advantage
- Production of final shape in a single step
- Complex shape
- Low cost

Disadvantage
- Rough surface finish, dimension
- Low strength

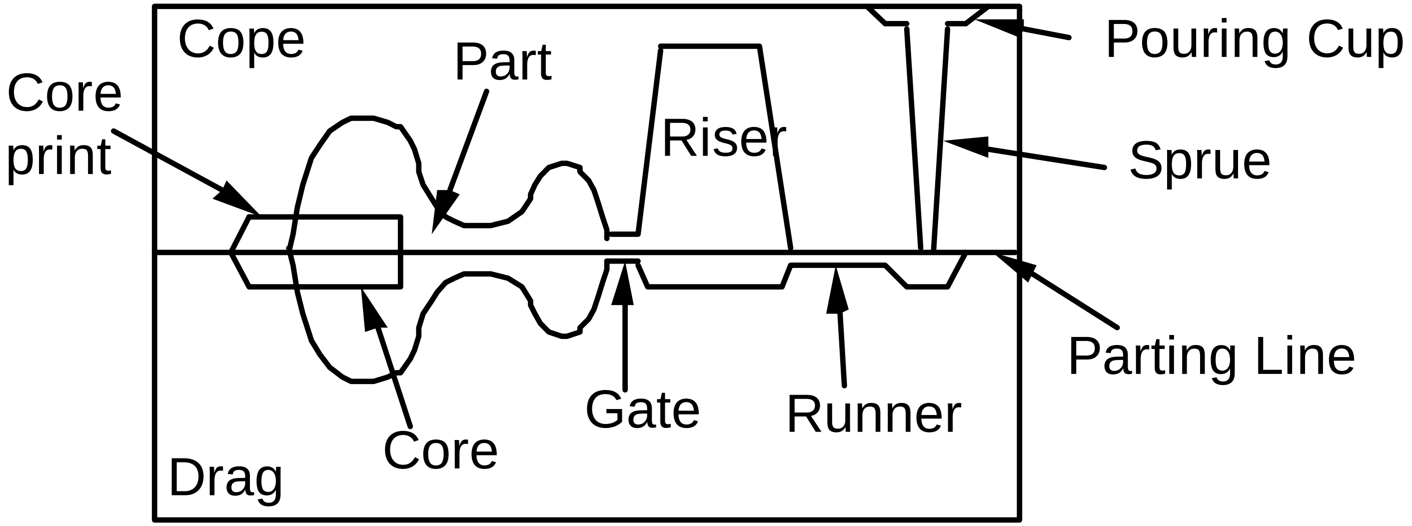
Sand Casting

Pattern: Duplicate Shape of part
- Wood: low quality (absorbs water, crack)
- Metal

Sand Mold: Cavity, Negative of part
- Sand: 89% Silica, 8% Clay, 3% Water

Packing

Green sand, bake, skin dry or CO_2 harden with Na_2SiO_3 additive



Other Casting

Die Casting: Toy car, Alloy wheel
Metal Mold

Investment Casting: Dental filling
Wax pattern

Metal Forming

Plastic flow in solid state

- Casting: fluidity
- Machining: Material Removal (Plastic deformation and fracture)

Advantage:

- Fast Production
- High strength
  - Fibering, Work hardening, Grain Refining, Homogenization, Defect closure

Disadvantage:

- High force (Heavy equipment)
- Die is expensive (Justified only for high quantity)

Better surface finish and tolerance than casting. Worse than machining

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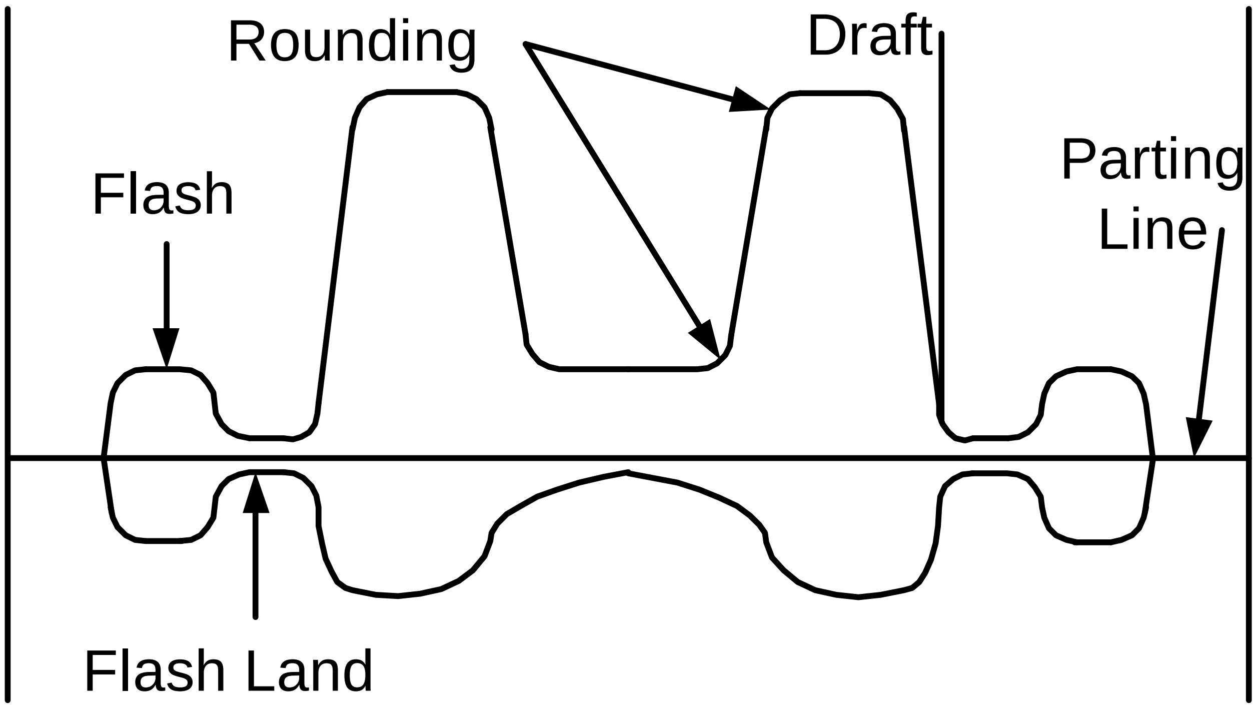
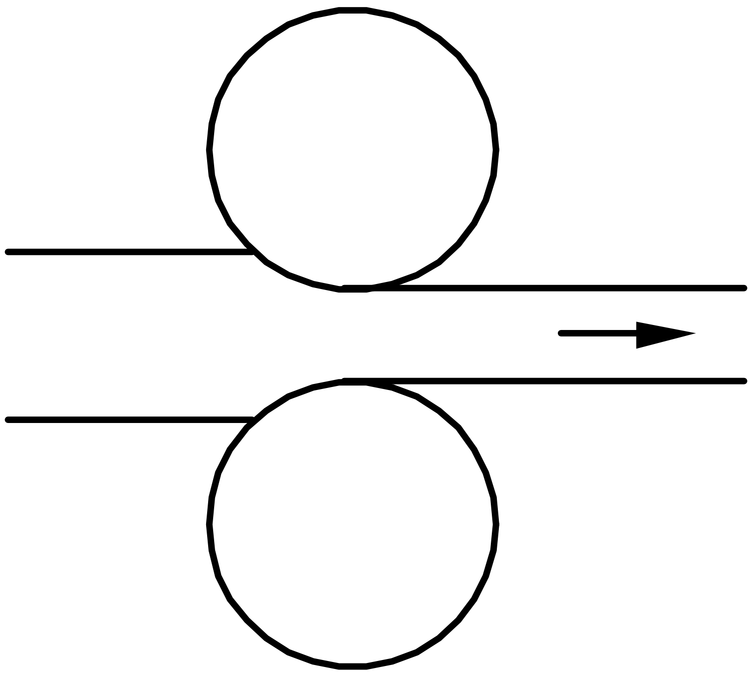
Forging

Open Die Forging
(Impression) Die forging

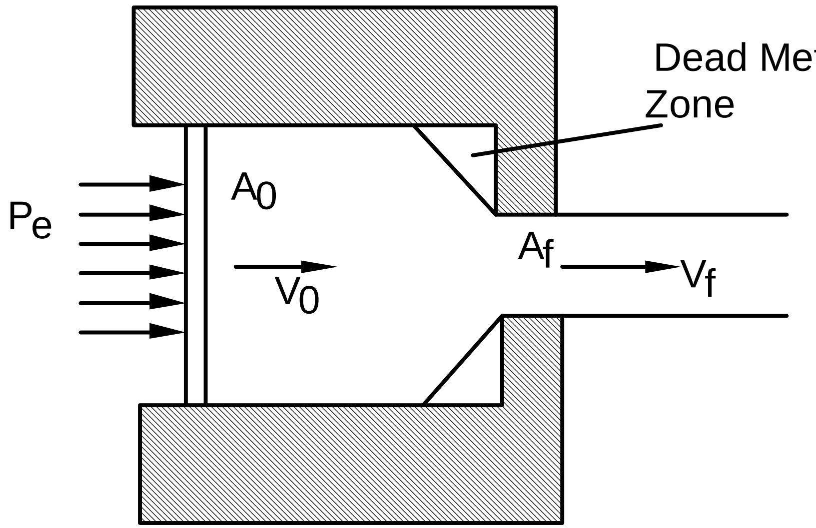


Rolling

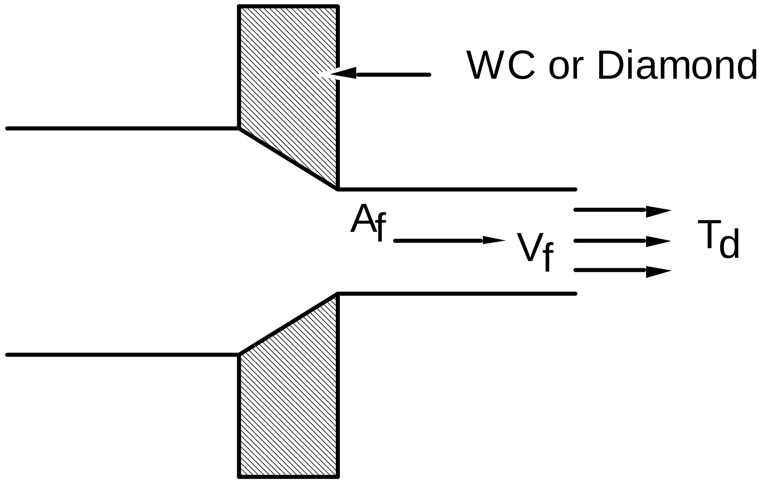
Ingot –> Billet, Slab –> Rail, Bar –> Beam, Rod, Plate, Tube
Friction drives the material



Extrusion, Drawing



Extrusion

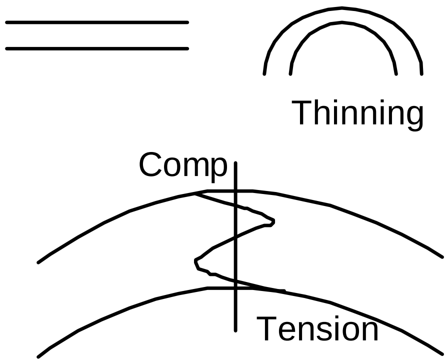


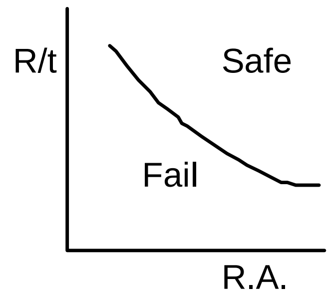
Wire, Tube
Drawing

Sheet Metal Working

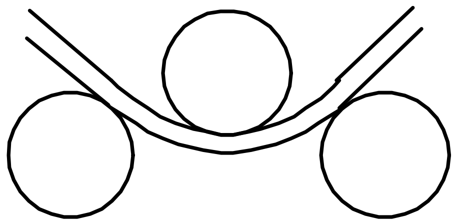
About 1/2 of total metal production => sheet

Aircraft, automobile body panel, can, house utility, watch gear

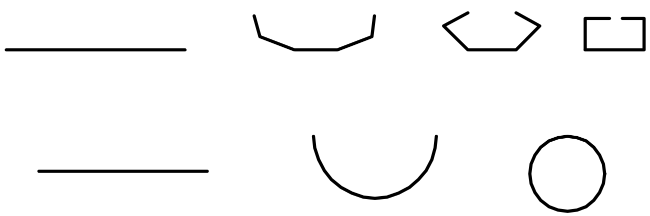




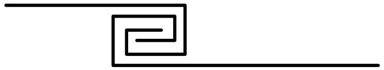
Bending



Bending

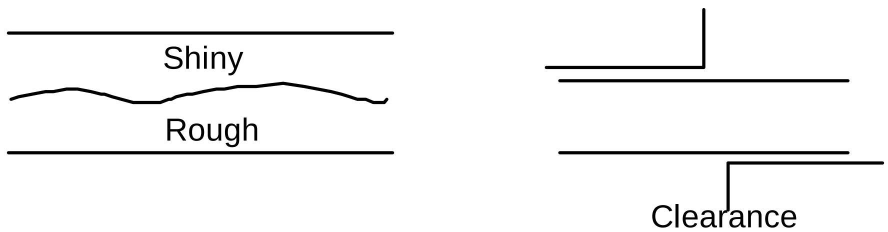


Roll Forming

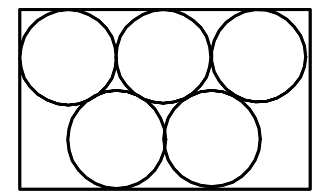


Seaming

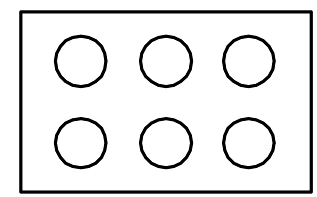
Sheet Metal Working



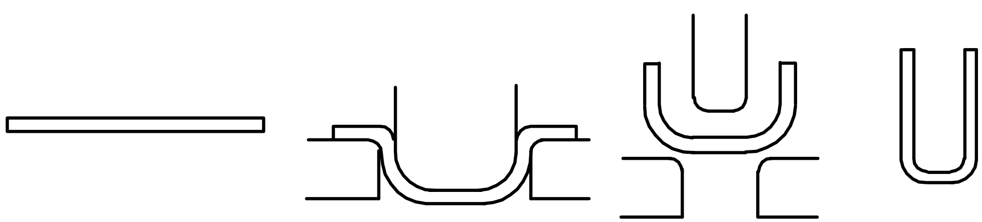
Shearing



Blanking

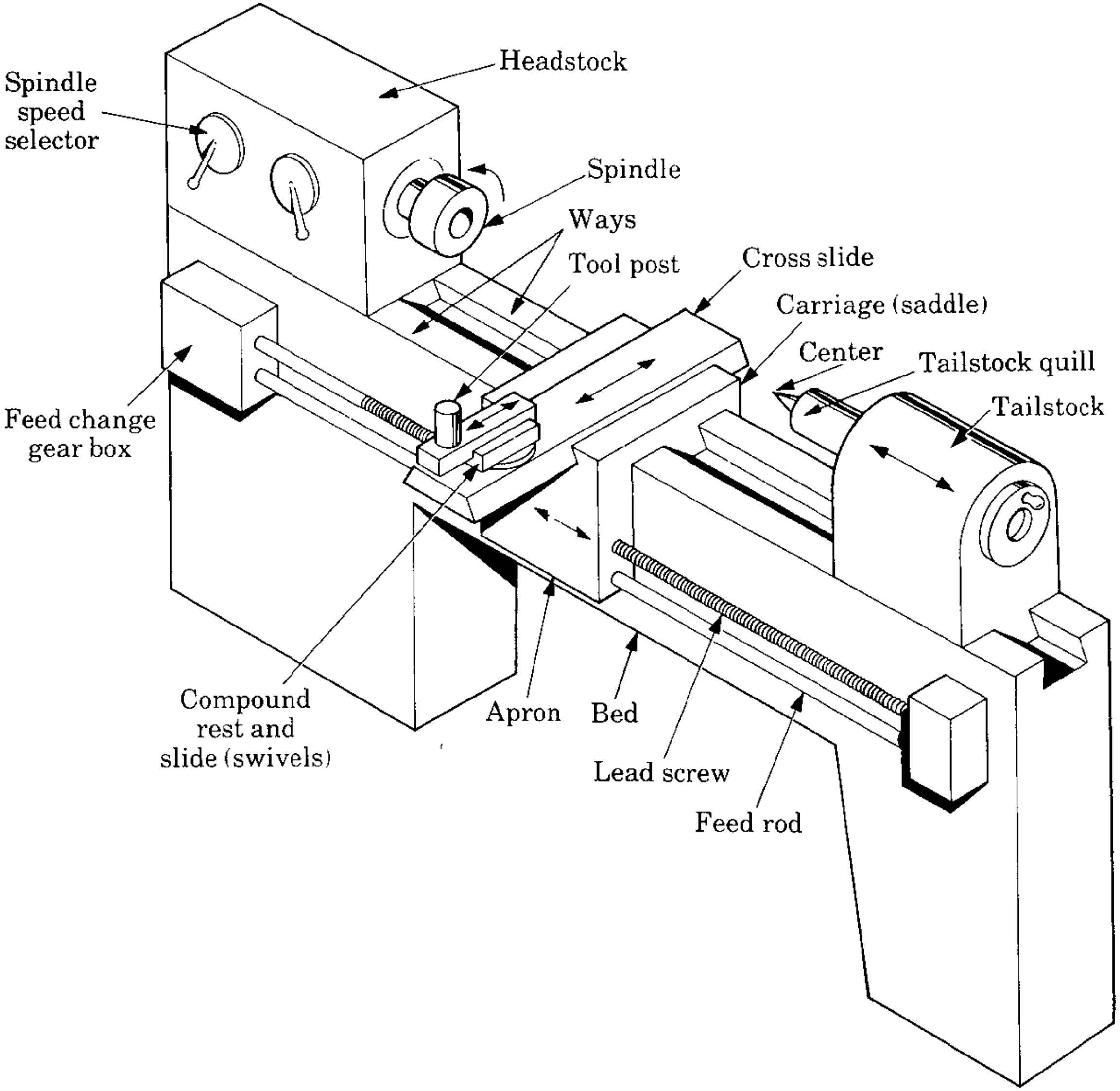


Piercing



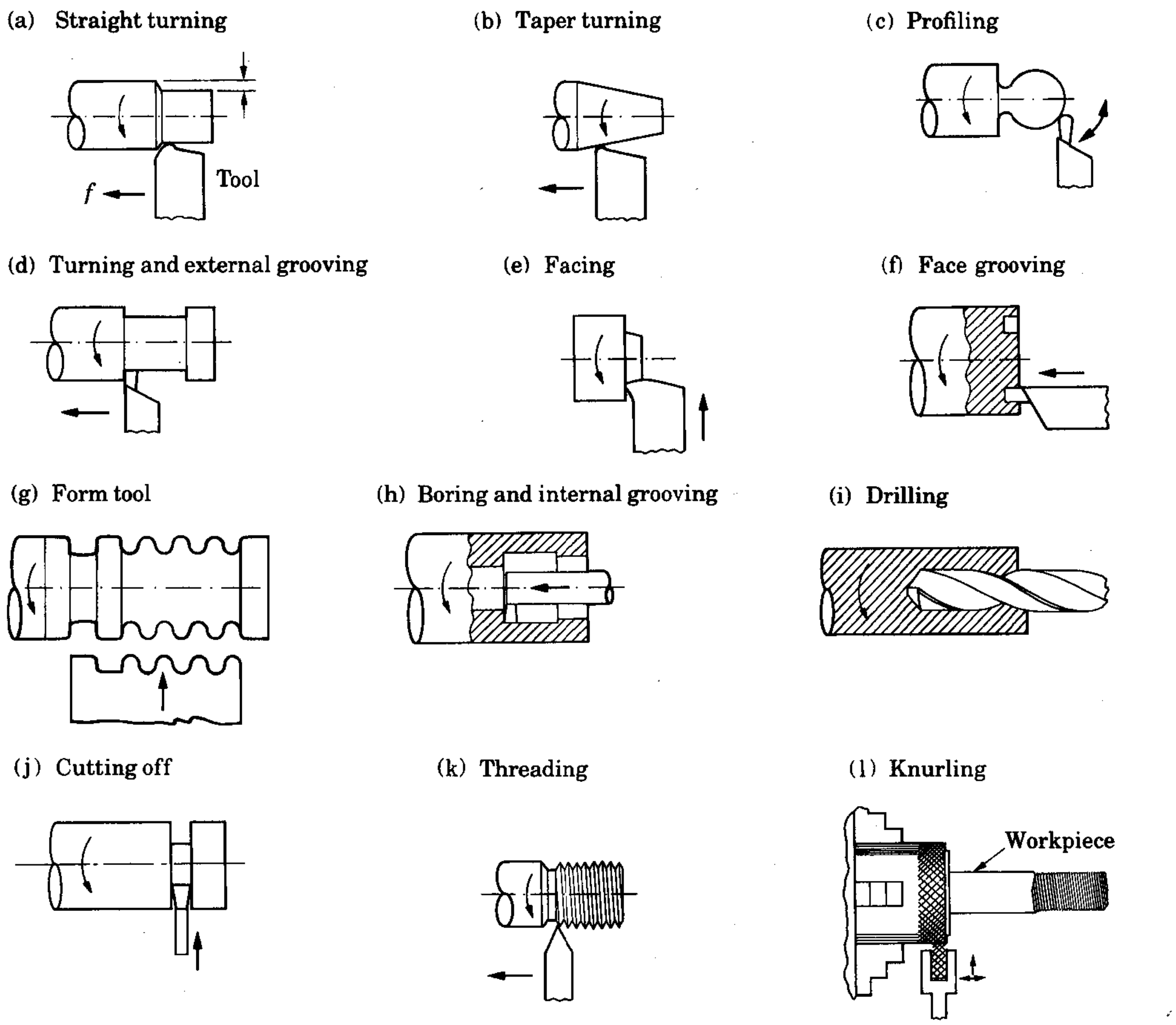
Drawing

Machining



High Precision
Good surface finish
Slow, costly

Turning



Most versatile
1800

Turning
Boring
Facing
Threading
Parting
Drilling
Tapering
Grooving

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Milling

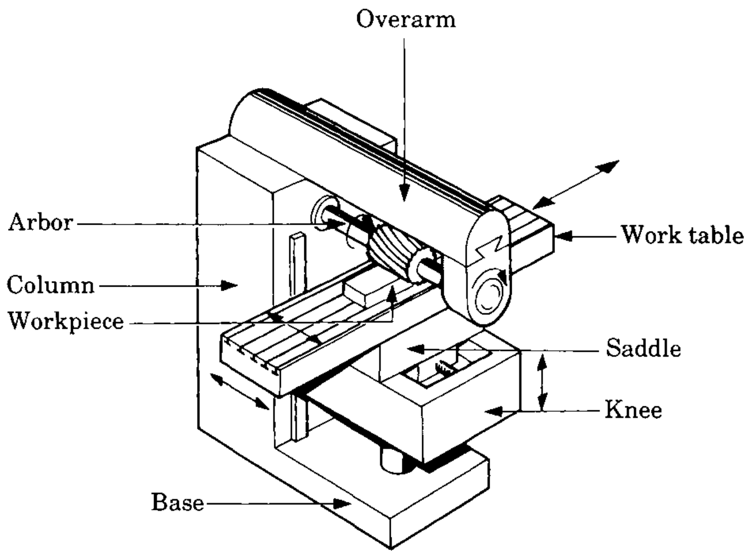
Most widely used for surface cutting (plane or curved), form milling (slitting, key slot, T slot)

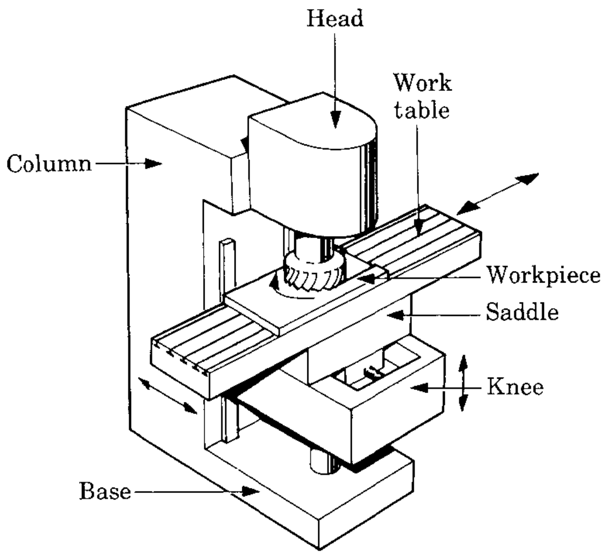
Profile duplication: copy milling or NC machine with ball end mill

Milling cutter: Multiple cutting edge

Periodic cutting force, discontinuous chip

Vertical, horizontal milling





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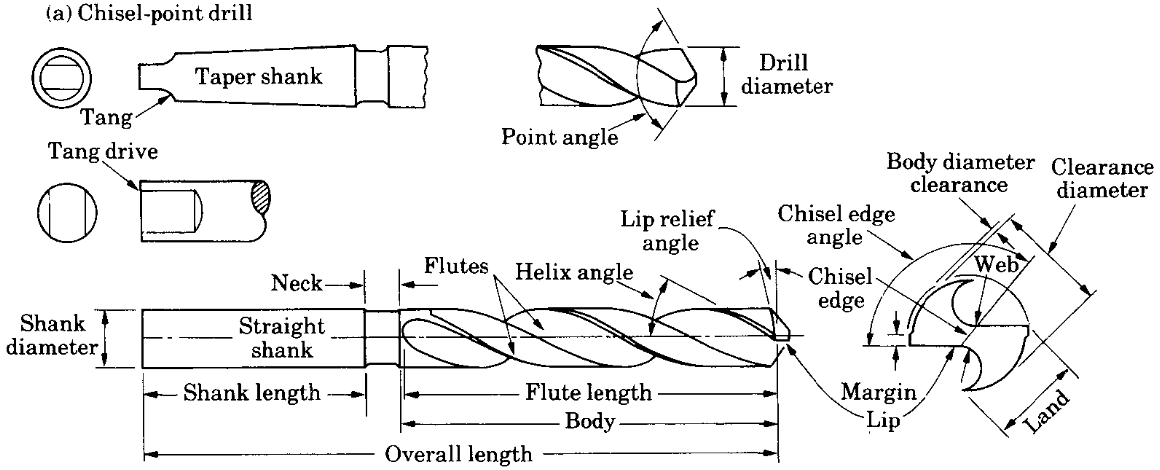
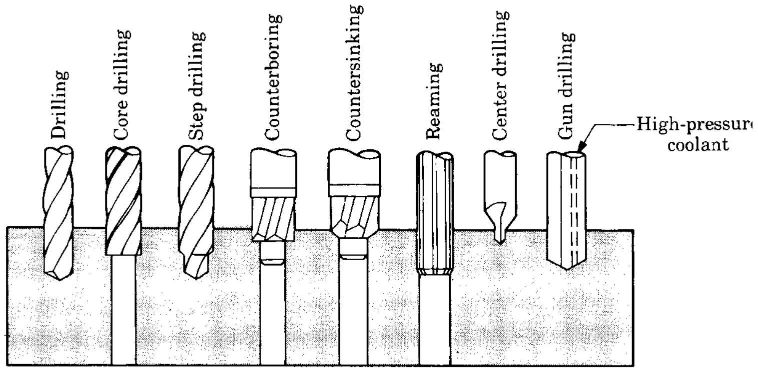
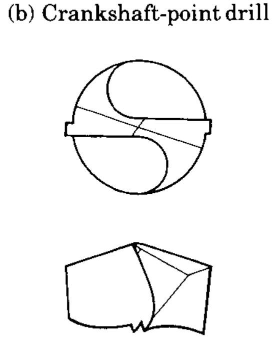
Drilling

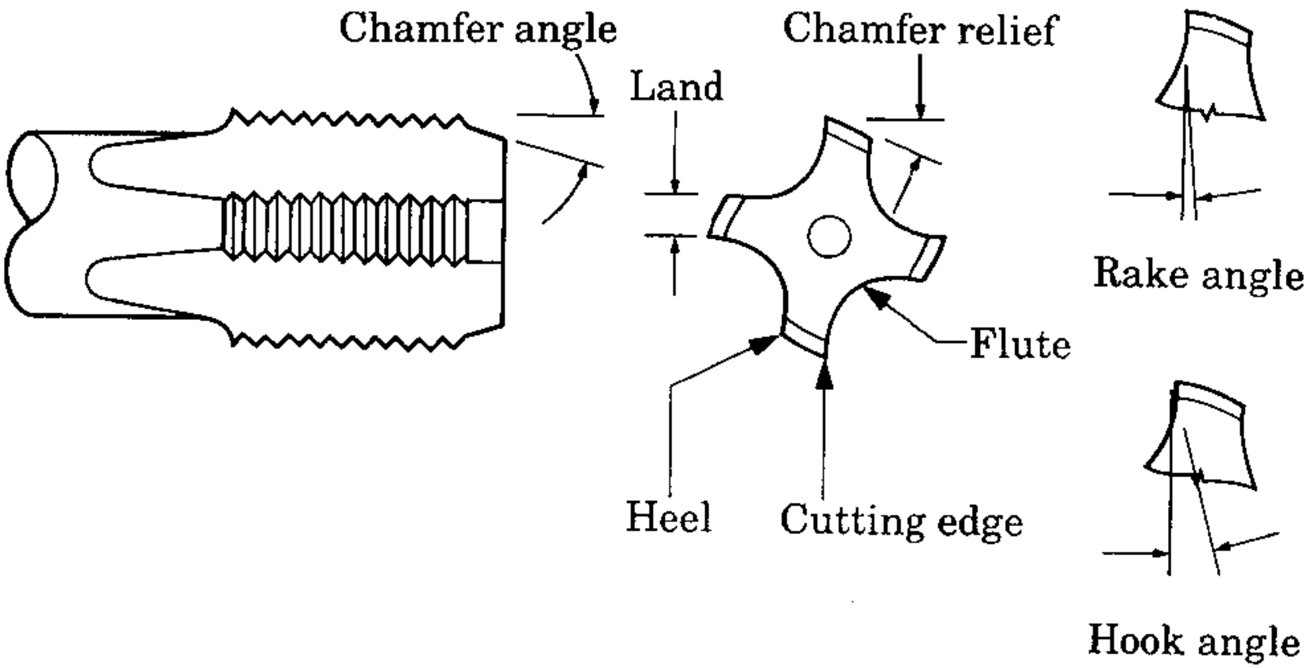
Two cutting edges
Drill bits are relatively flexible
Poor heat removal
Usually L < 5D
Poor accuracy
Center drill, ream







Tapping



Chamfer angle
Chamfer relief
Land
Rake angle
Flute
Heel
Cutting edge
Hook angle

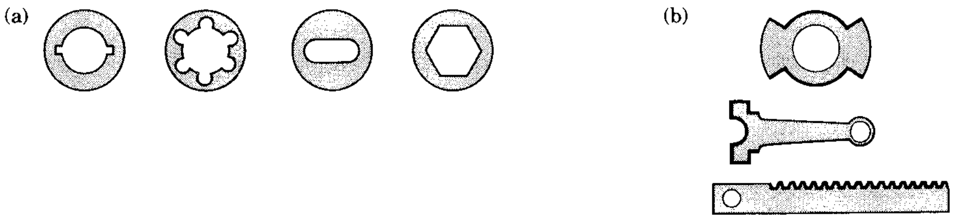
Sawing, Filing, Shaping

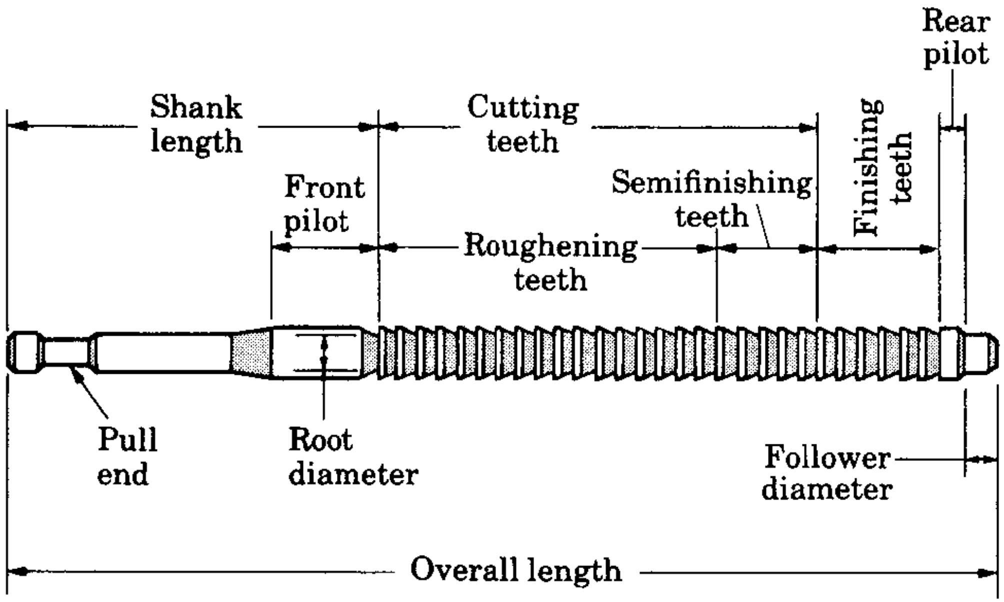
Sawing
- 2-3 teeth should be engaged to prevent snagging
- Hack saw, band saw, circular saw,
- friction sawing

Filing

Shaping, planning
- Shaping: Primary cutting motion by tool.
- Planning: Primary cutting motion by work piece.

Broaching





- Special shape hole, slot contour
- Like a saw
- Machining completed in one pass (pull or push)
- Tool is expensive

Grinding, Lapping, Polishing

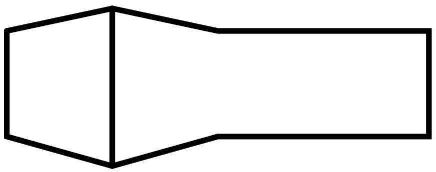
Grinding

- Precision, good surface finish.
- Hard, brittle material machining.
- 20 - 25% of machining cost. Low MRR
- Rake angle is slightly positive or negative
- Cutting, Plowing, Rubbing
- High specific energy
- Cutting speed is very high (5000 -15000 fpm, over 2000 rpm)

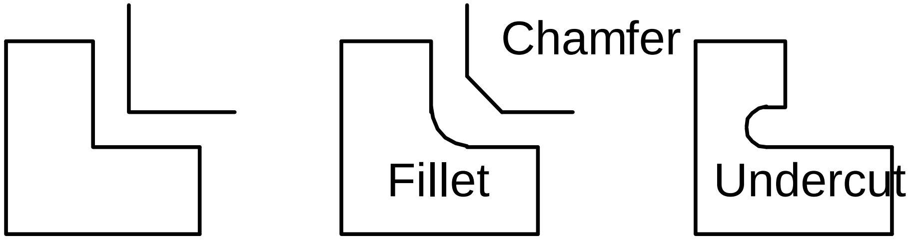
Lapping, Polishing

- Loose abrasive particles on metal or felt

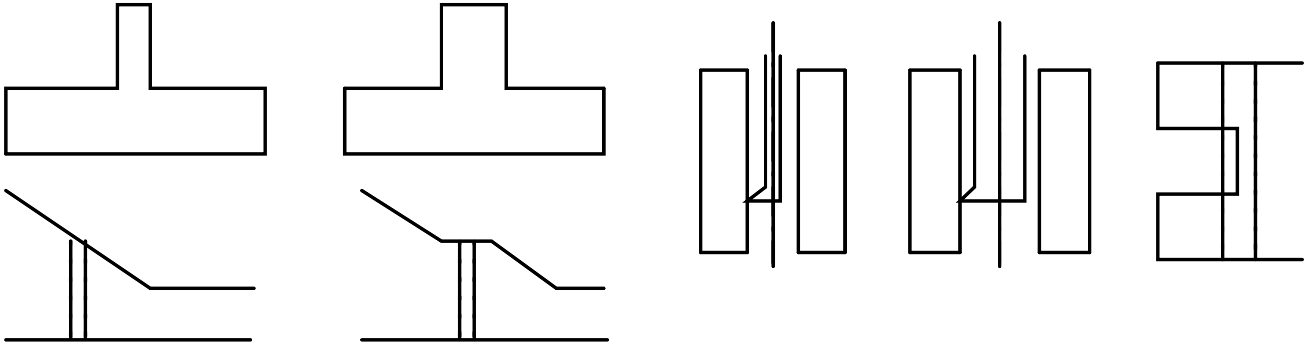
Design for Machining



Easy fixturing
Avoid parting line

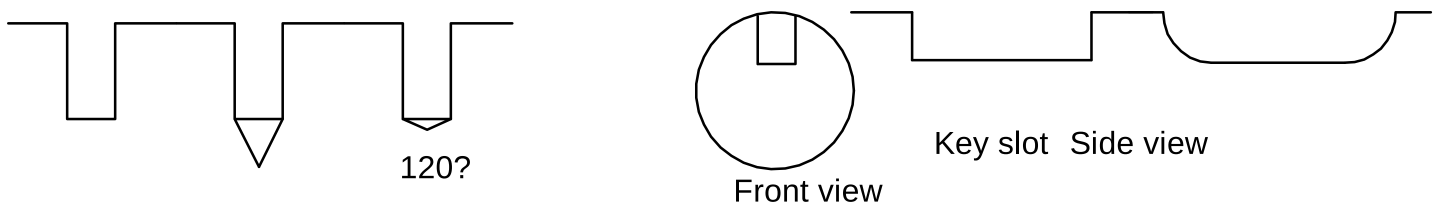


Avoid sharp corner, edge

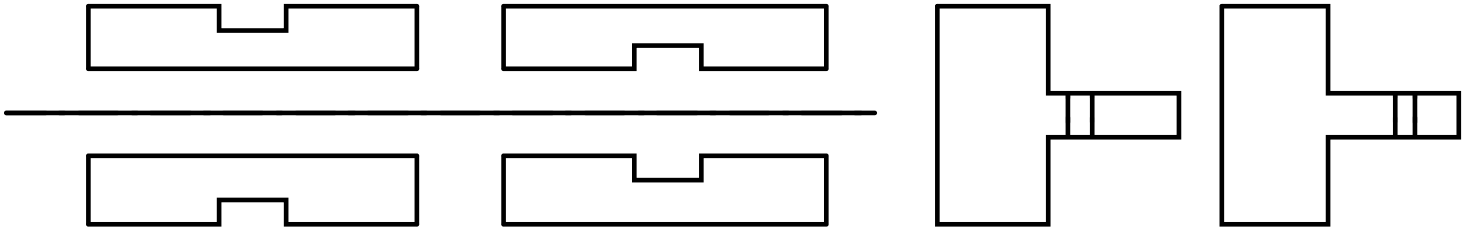


Part and tool rigidity

Design for Machining



Use simple feature and standard tool



Easy Tool access

Assembly (Joining)

Automobile: 15,000 parts are assembled
Airplane: 4,000,000 parts

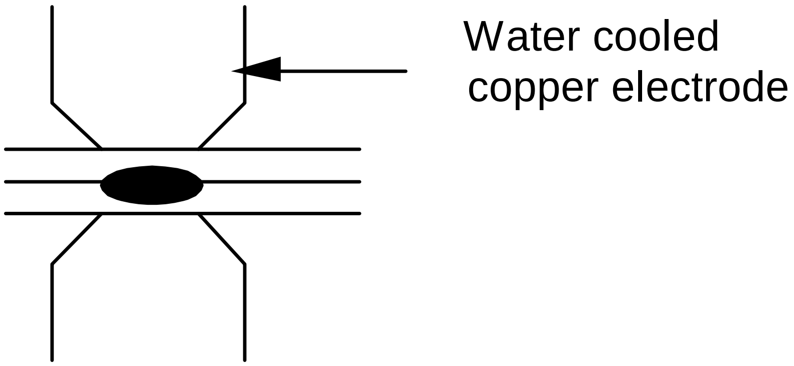
Easier to manufacture
Easier to service
Use different materials
Mass production and lower cost

Welding

Weld joint is similar to (or the same as) base metal

- Solid or liquid
- With or without filler

Easier to manufacture
Easier to service
Use different materials
Mass production and lower cost

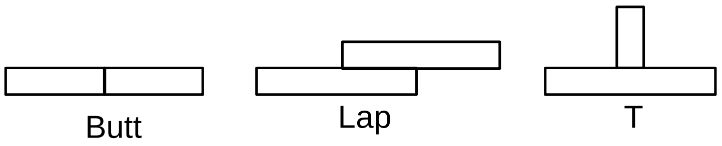


Resistance:
Contact resistance: electrode-workpiece
Faying surface resistance: workpiece surface

Pressure
Reduce contact resistance
Increased after solidification for forging

Brazing, Soldering

- Solid base, liquid filler
  - Filler material: different composition, low MP, lower strength
    - Braze: MP is above 425_C, Cu, Al, Ag, Ni, Zn
    - Solder: MP is below 425_C, Pb-Sn
  - Capillary action
  - Smaller HAZ
  - Quick, cheap, easy

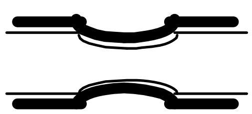


- Flux
  - Dissolve oxide, grease, dirt
  - Prevent oxide formation during brazing
  - Promote welding
  - Should be removed after brazing to prevent corrosion

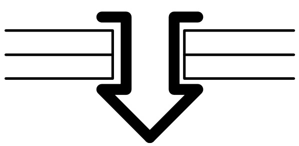
Other Assembly

Adhesive bonding
- Polymeric adhesive

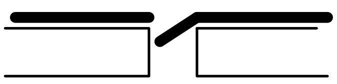
Mechanical joining
- Bolt, nut, screw, pin
- Rivet, Stitch, Staple,
- Shrink fit, Forge fit, seam,
- Snap-in:



Crimping



Spring clip



Lanced tab

Design for Assembly

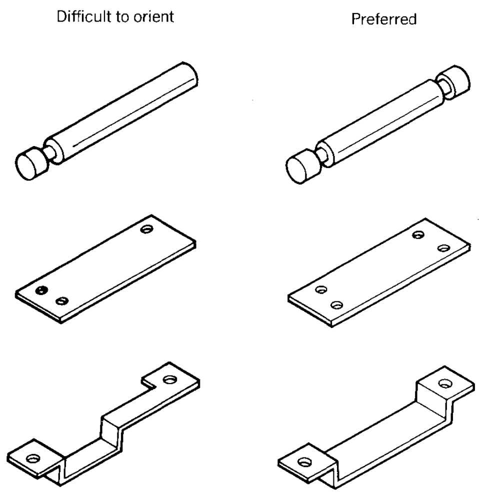
50% (?) of manufacturing cost: Assembly

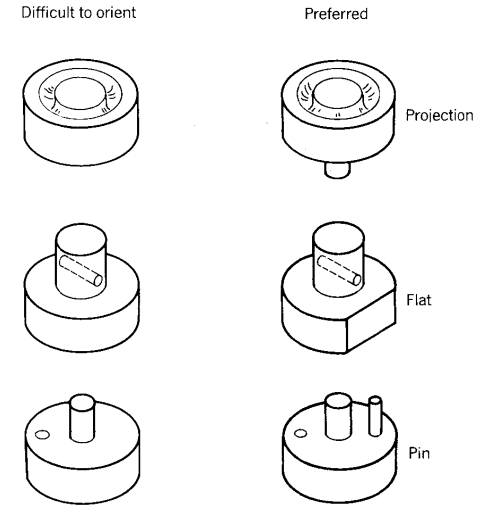
- Use Standard Component
- Reduce number of parts
- Increase Interchangeability
- Modular design (Subassembly)
- Minimize part variation
- Minimize assembly directions
- Maximize compliance

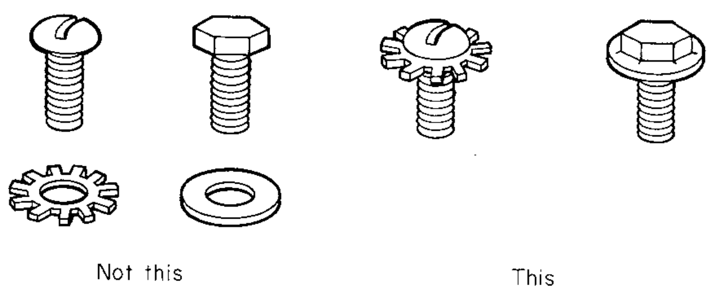
Examples:

- Use pointed screws to reduce alignment effort
- Plastic parts or metal stamping parts to reduce number of parts
- Eliminate screws by snap joints
- Easy part handling (Spring, rectangular shape, symmetry)

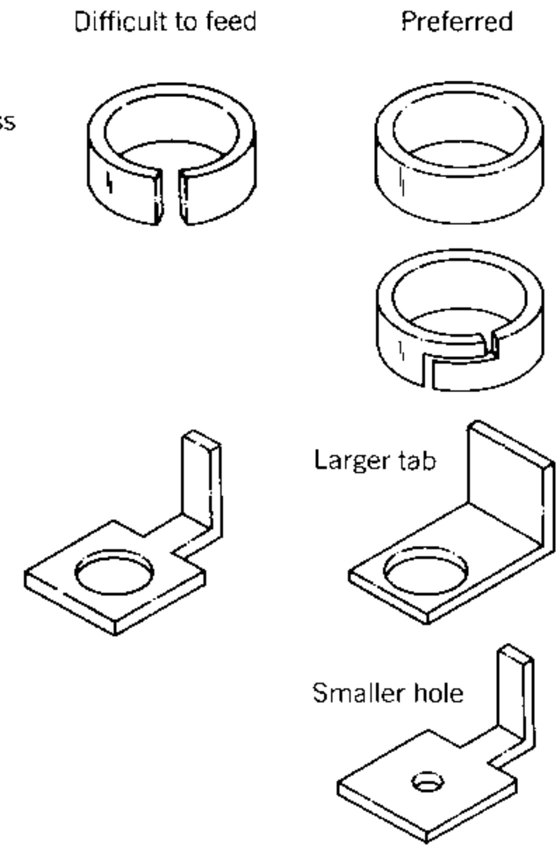
Design for Assembly



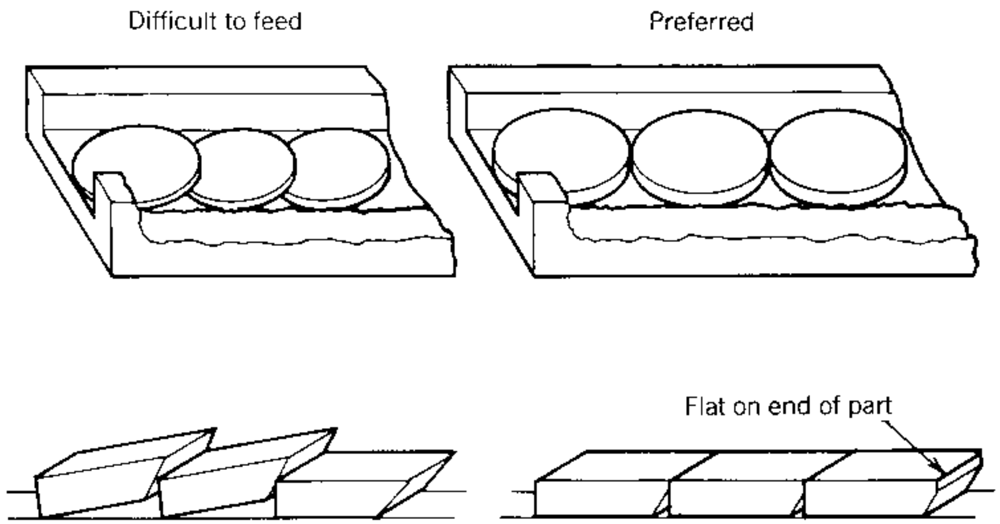




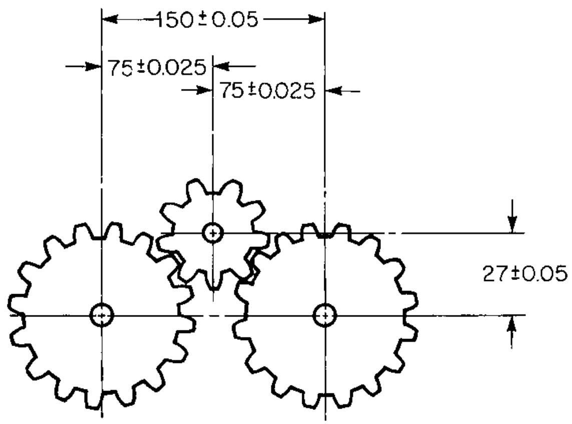
Design for Assembly



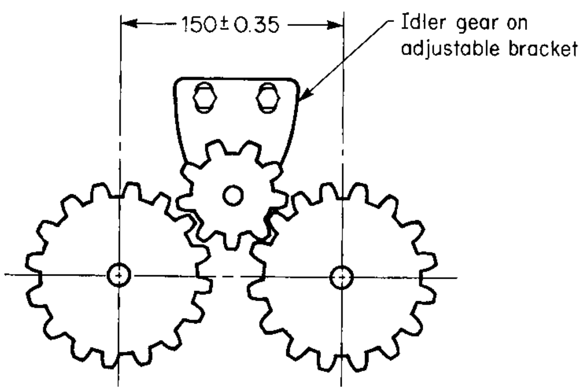
Design for Assembly



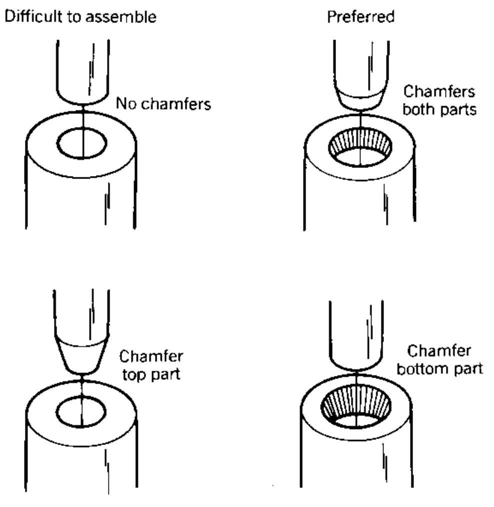
Design for Assembly



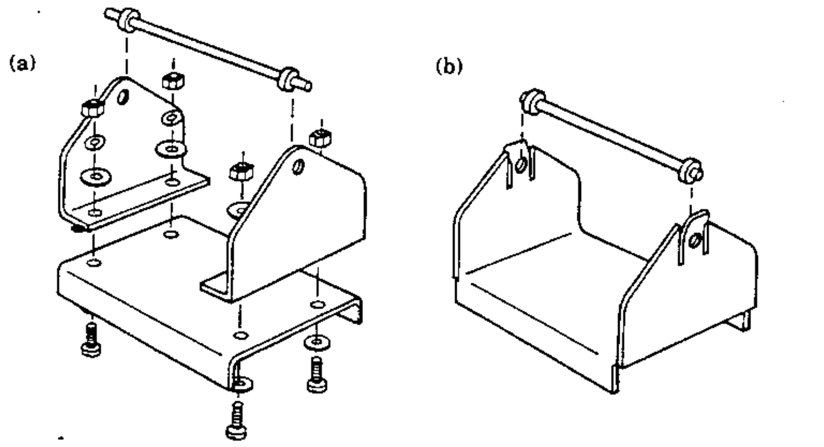
Feasible

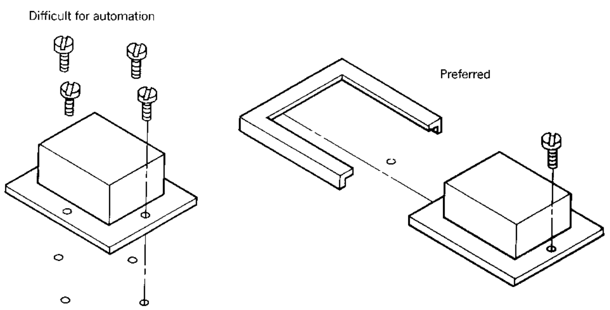


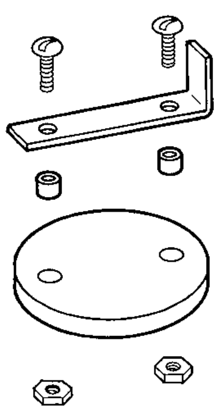
Sometimes better



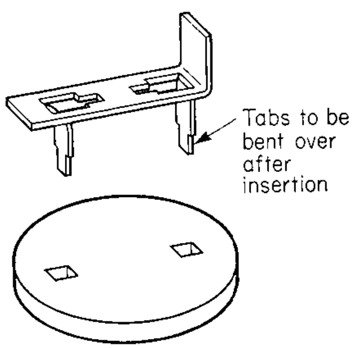
Design for Assembly



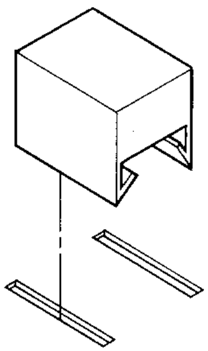




Feasible



Better



Quiz 2

1. Explain about the difference between precision and accuracy.

2. List metal forming processes and briefly explain about them