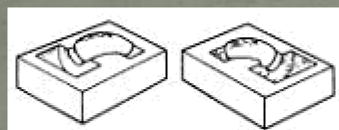
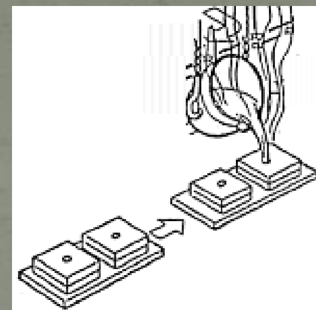
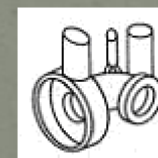
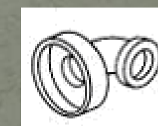
Manufacturing Processes

UNIT I

Metal Casting Process

Casting

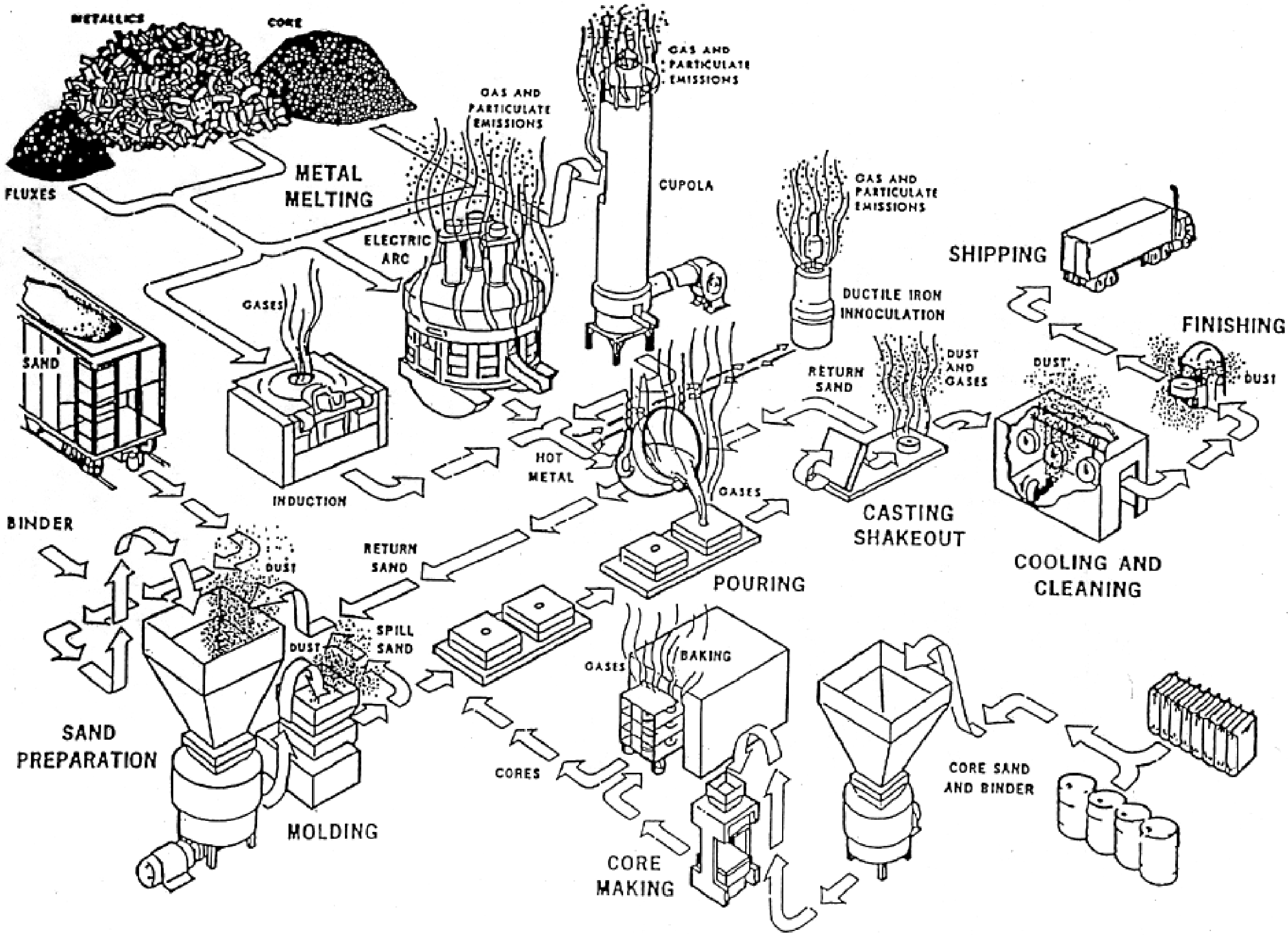
Refractory mold → pour liquid metal → solidify, remove → finish

- VERSATILE: complex geometry, internal cavities, hollow sections
- VERSATILE: small (~10 grams) → very large parts (~1000 Kg)
- ECONOMICAL: little wastage (extra metal is re-used)
- ISOTROPIC: cast parts have same properties along all directions

Different Casting Processes

Process	Advantages	Disadvantages	Examples
Sand	many metals, sizes, shapes, cheap	poor finish & tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, few shapes	pipes, boilers, flywheels

Sand Casting



Sand Casting

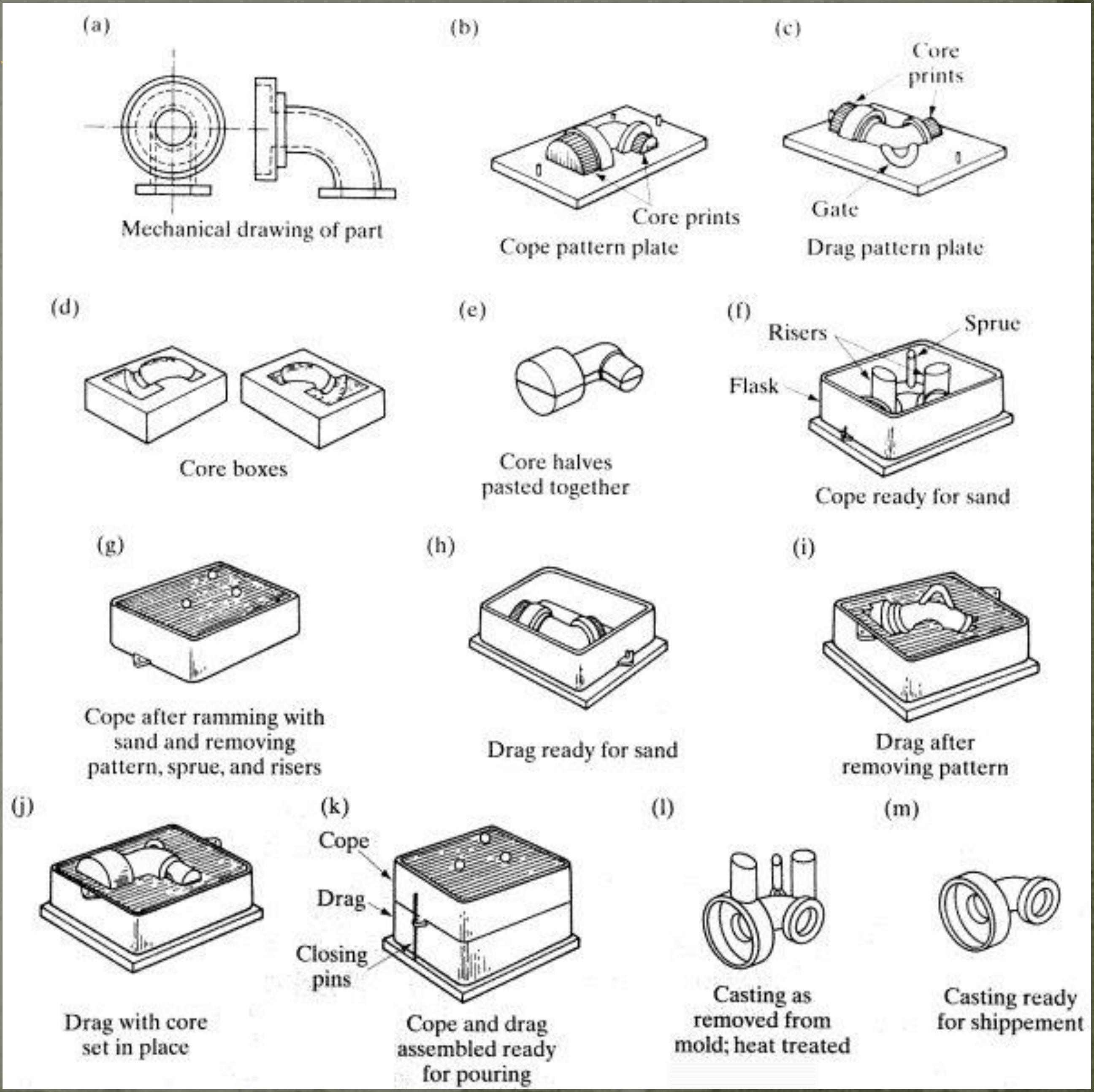
cope: top half

drag: bottom half

core: for internal cavities

pattern: positive

funnel → sprue →
→ runners → gate →
→ cavity →
→ {risers, vents}



Sand Casting Considerations

(a) How do we make the **pattern**?

[cut, carve, machine]

(b) Why is the pattern not exactly identical to the part shape?

- pattern → outer surfaces; (inner surfaces: core)
- shrinkage, post-processing

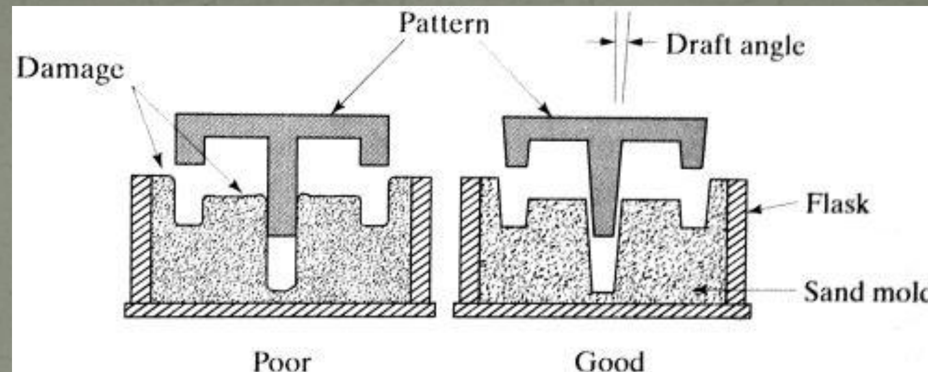
(c) **parting line**

- how to determine?

Sand Casting Considerations..

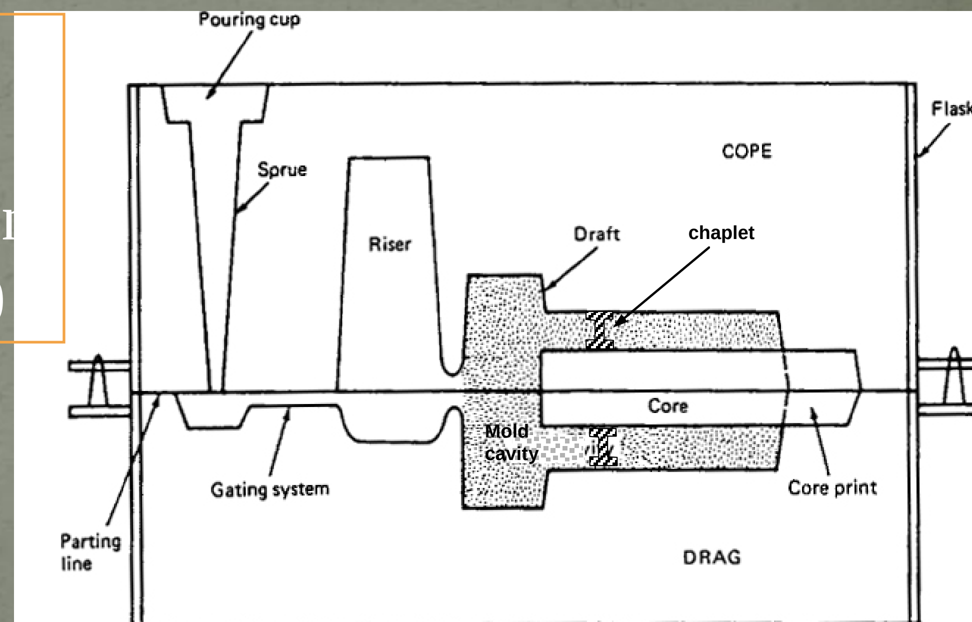
(d) **taper**

- do we need it ?



(e) **core prints, chaplets**

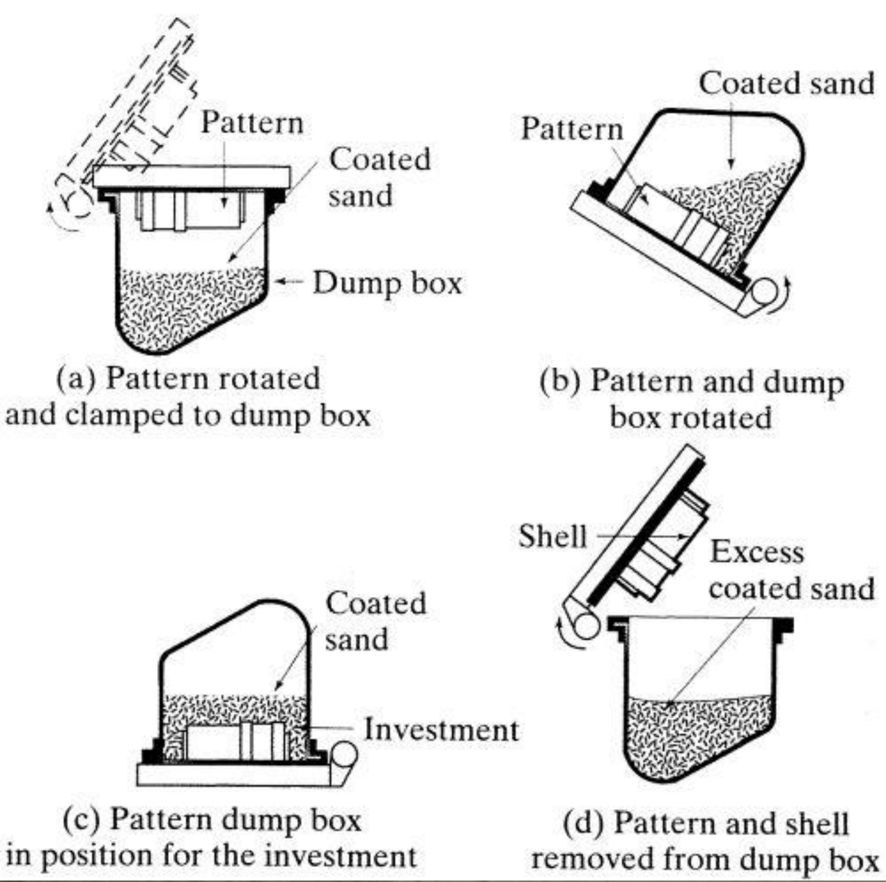
- hold the core in positio
- chaplet is metal (why?)

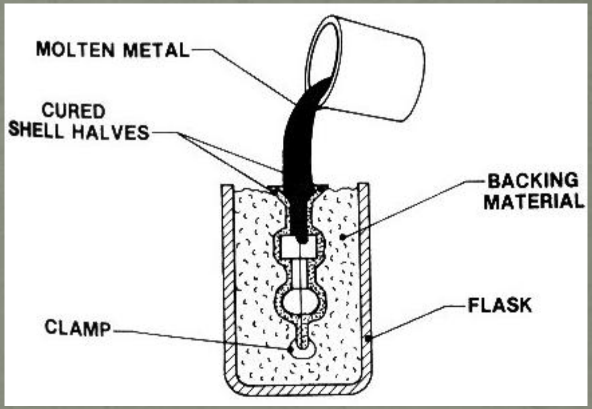


(f) **cut-off, finishing**

Shell mold casting

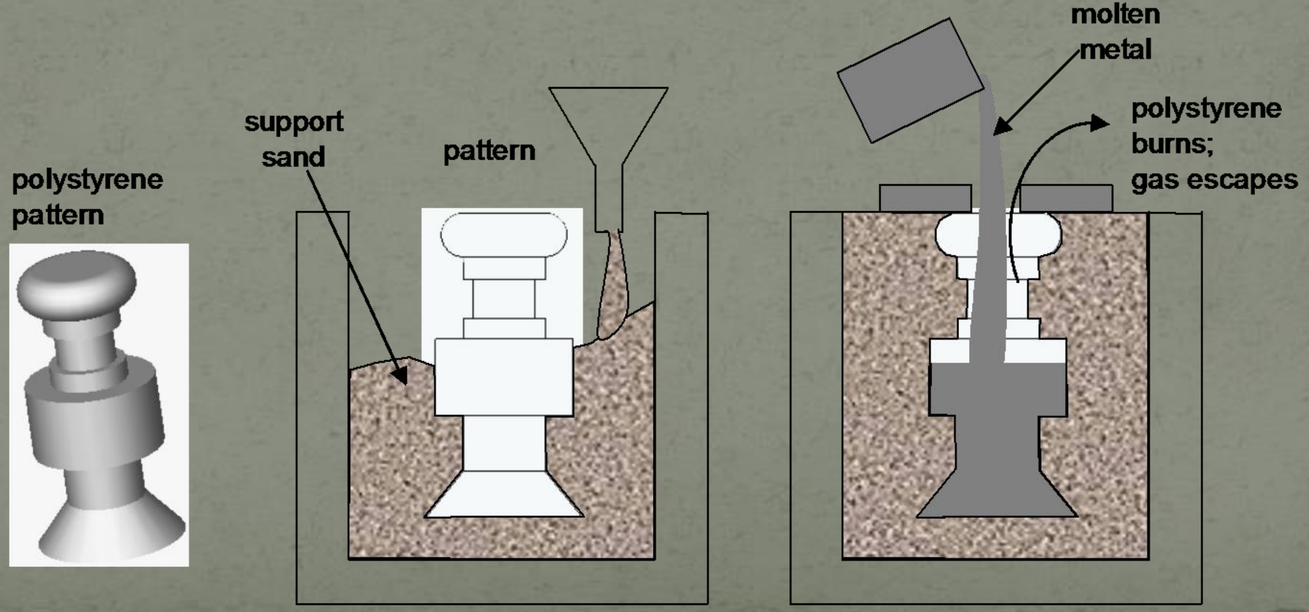
- metal, 2-piece *pattern*, 175°C-370°C
- coated with a lubricant (silicone)
- mixture of sand, thermoset resin/epoxy
- cure (baking)
- remove patterns, join half-shells → mold
- pour metal
- solidify (cooling)
- break shell → part





Expendable Mold Casting

- Styrofoam pattern
- dipped in refractory slurry → dried
- sand (support)
- pour liquid metal
- foam evaporates, metal fills the shell
- cool, solidify
- break shell → part



Plaster-mold, Ceramic-mold casting

Plaster-mold slurry: *plaster of paris* ($CaSO_4$), talc, silica flour

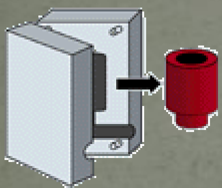
Ceramic-mold slurry: silica, powdered Zircon ($ZrSiO_4$)

- The slurry forms a shell over the pattern
- Dried in a low temperature oven
- Remove pattern
- Backed by clay (strength), baked (burn-off volatiles)
- cast the metal
- break mold → part

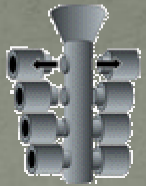
Plaster-mold: *good finish (Why ?)*
plaster: low conductivity => low warpage, residual stress
low mp metal (Zn, Al, Cu, Mg)

Ceramic-mold: good finish
high mp metals (steel, …) => impeller blades, turbines, …

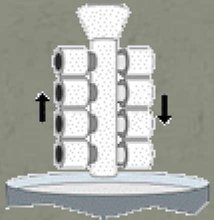
Investment casting (lost wax casting)



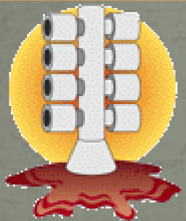
(a) Wax pattern
(injection molding)



(b) Multiple patterns
assembled to wax sprue

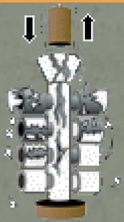


(c) Shell built →
immerse into ceramic slurry
→ immerse into fine sand
(few layers)



(d) dry ceramic
melt out the wax
fire ceramic (burn wax)

(e) Pour molten metal (gravity)
→ cool, solidify
[Hollow casting:
pouring excess metal before solidification



(f) Break ceramic shell
(vibration or water blasting)

(g) Cut off parts
(high-speed friction saw)
→ finishing (polish)

Permanent mold casting

MOLD: made of metal (cast iron, steel, refractory alloys)

CORE: (hollow parts)
- metal: core can be extracted from the part
- sand-bonded: core must be destroyed to remove

Mold-surface: coated with refractory material

- Spray with lubricant (graphite, silica)
  - improve flow, increase life

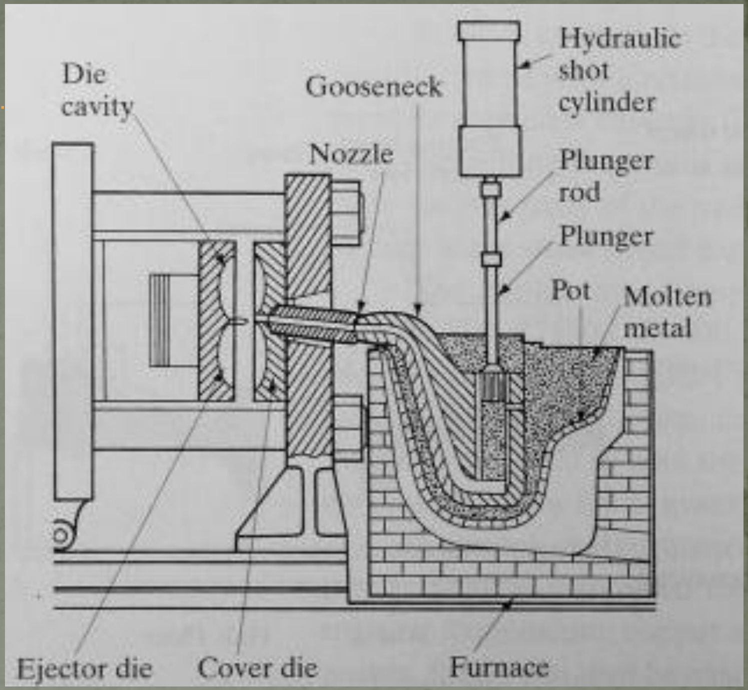
- good tolerance, good surface finish

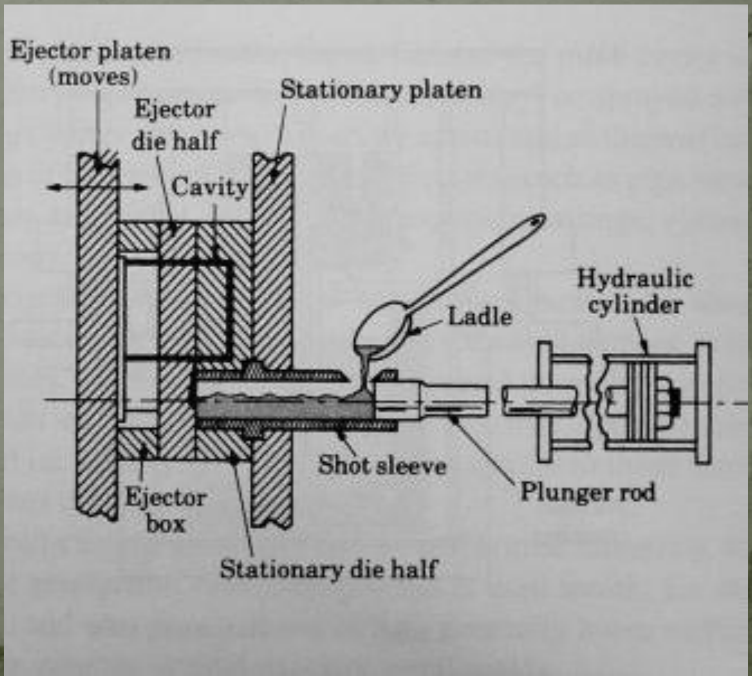
- low mp metals (Cu, Bronze, Al, Mg)

Die casting

- a type of permanent mold casting
- common uses: components for
  rice cookers, stoves, fans, washing-, drying machines, fridges, motors, toys, hand-tools, car wheels, …

HOT CHAMBER: (low mp e.g. Zn, Pb; non-alloying)
(i) die is closed, gooseneck cylinder is filled with molten metal
(ii) plunger pushes molten metal through gooseneck into cavity
(iii) metal is held under pressure until it solidifies
(iv) die opens, cores retracted; plunger returns
(v) ejector pins push casting out of ejector die

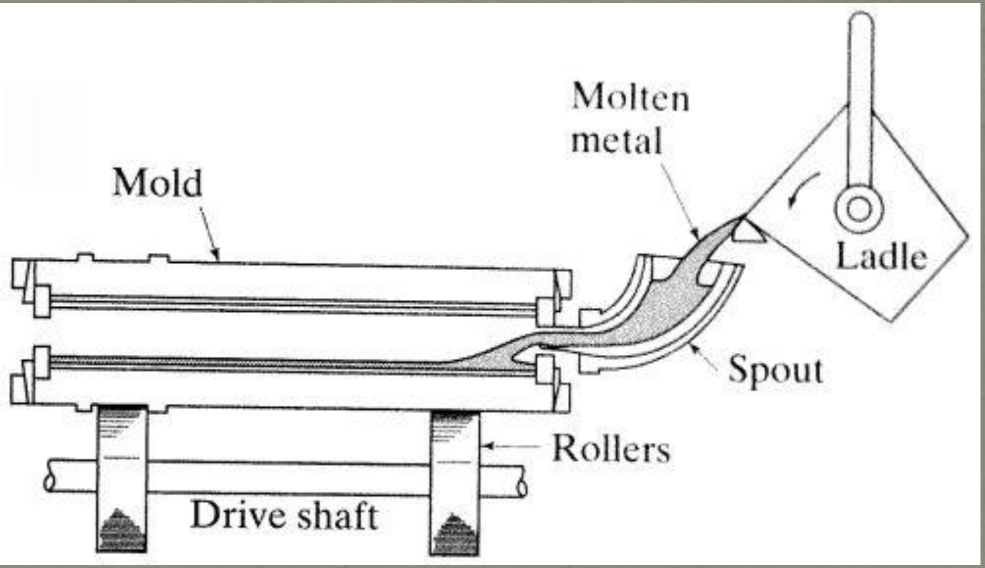




COLD CHAMBER: (high mp e.g. Cu, Al)
(i) die closed, molten metal is ladled into cylinder
(ii) plunger pushes molten metal into die cavity
(iii) metal is held under high pressure until it solidifies
(iv) die opens, plunger pushes solidified slug from the cylinder
(v) cores retracted
(iv) ejector pins push casting off ejector die

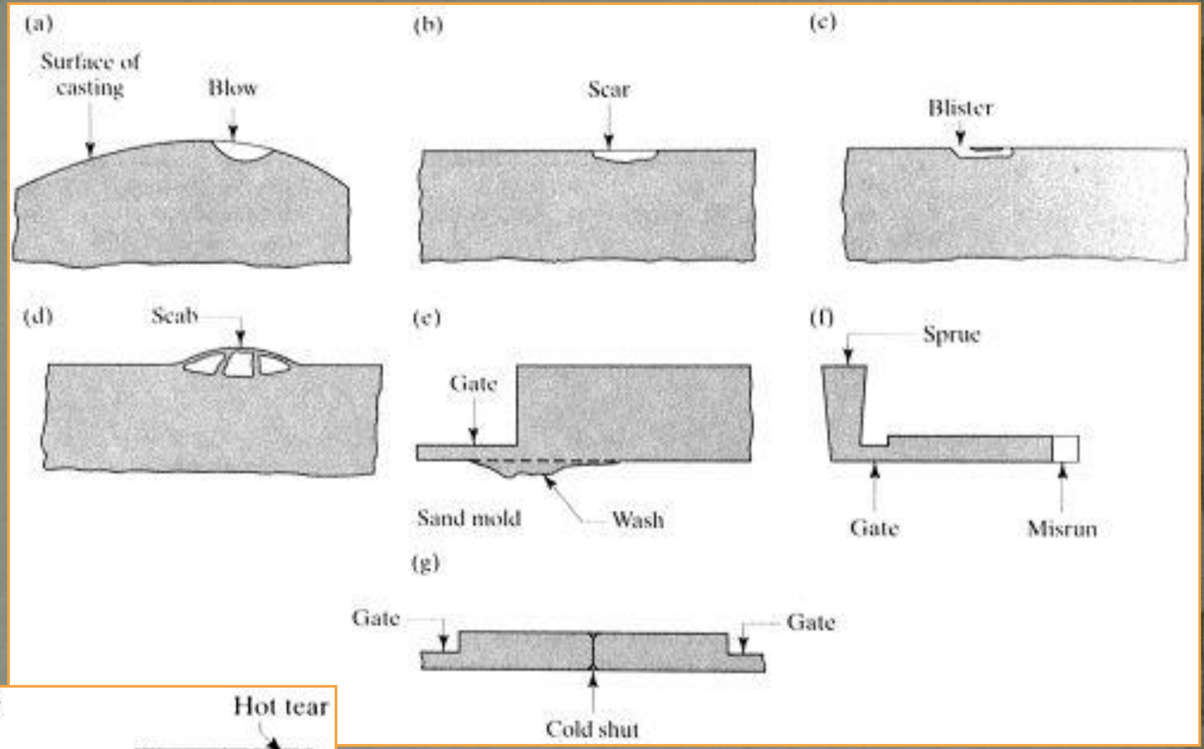
Centrifugal casting

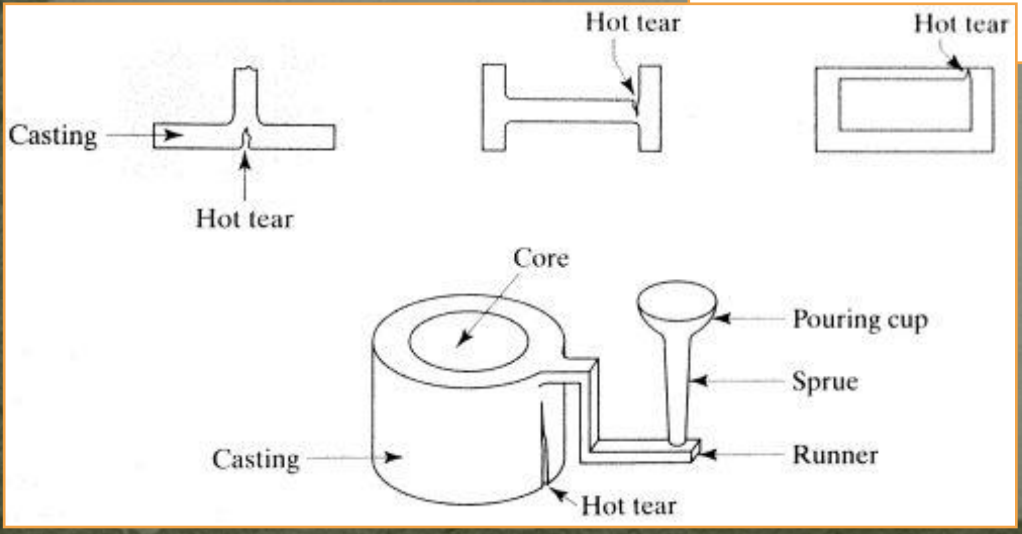
- permanent mold
- rotated about its axis at 300 ~ 3000 rpm
- molten metal is poured



- Surface finish: better along outer diameter than inner,
- Impurities, inclusions, closer to the inner diameter (why ?)

Casting Design: Typical casting defects





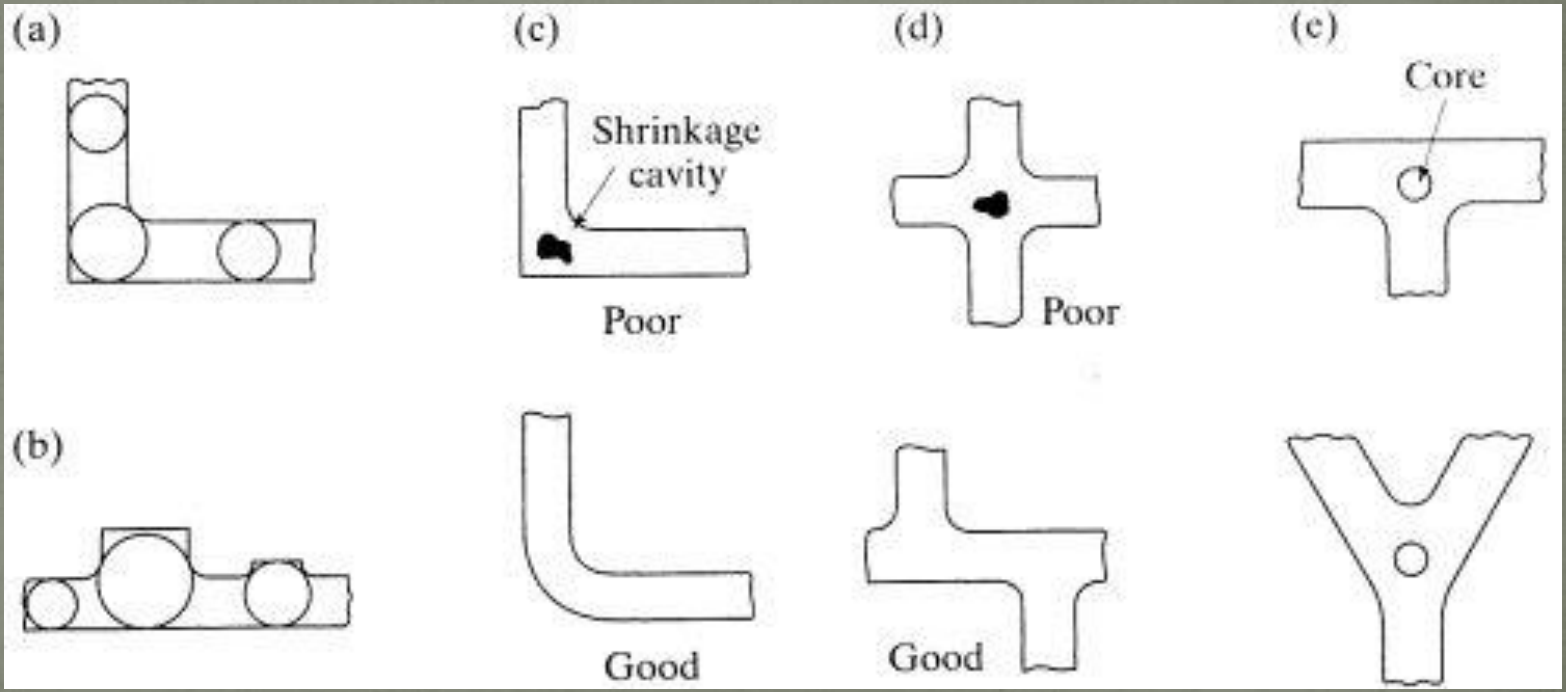
Casting Design: Defects and Associated Problems

- Surface defects: finish, stress concentration

- Interior holes, inclusions: stress concentrations

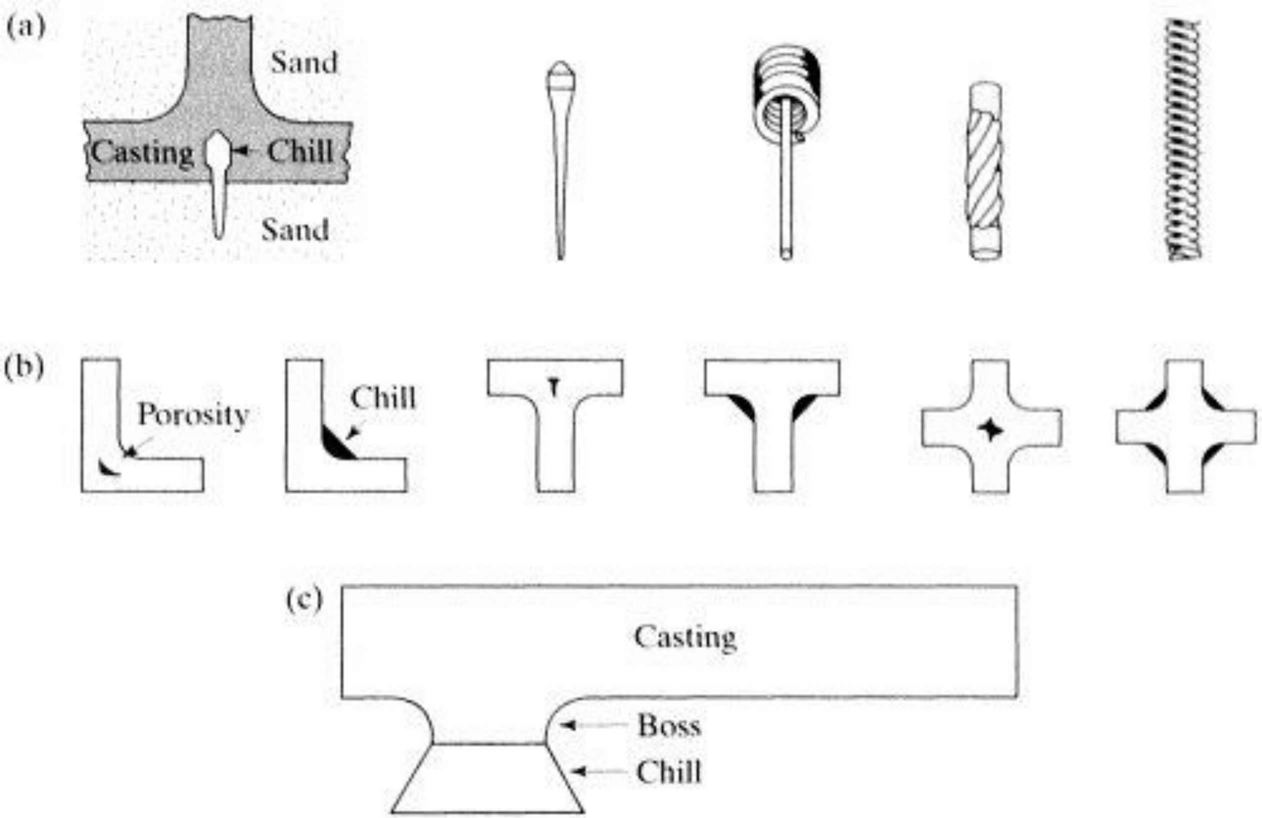
Casting Design: guidelines

(a) avoid sharp corners
(b) use fillets to blend section changes smoothly
(c1) avoid rapid changes in cross-section areas



Casting Design: guidelines

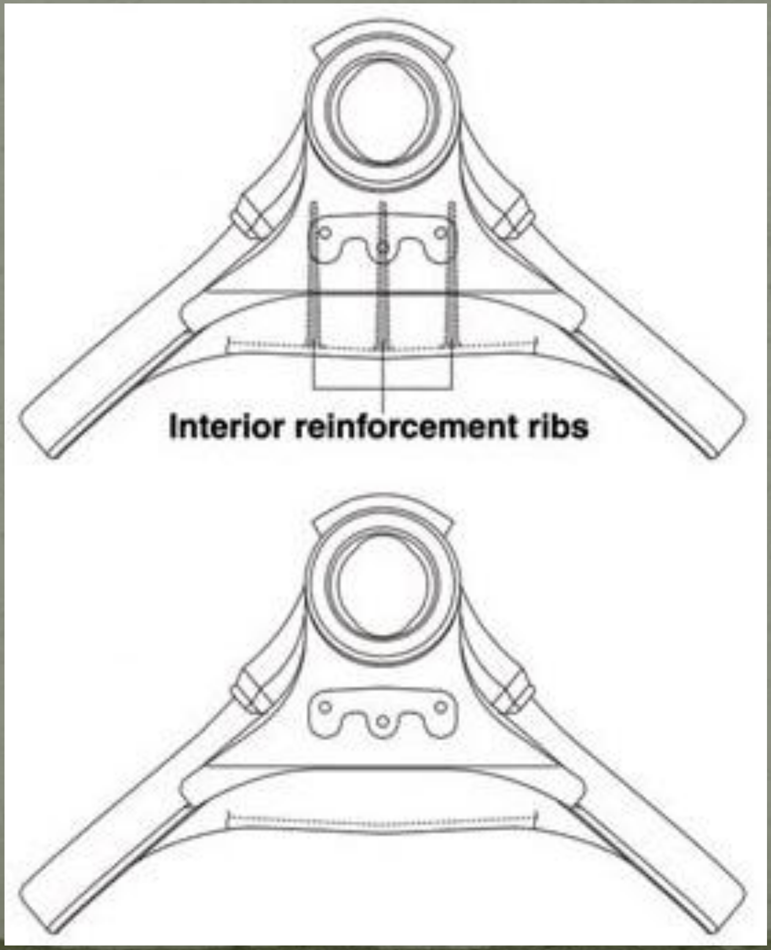
(c1) avoid rapid changes in cross-section areas
(c2) if unavoidable, design mold to ensure
- easy metal flow
- uniform, rapid cooling (use chills, fluid-cooled tubes)



Casting Design: guidelines

(d) avoid large, flat areas

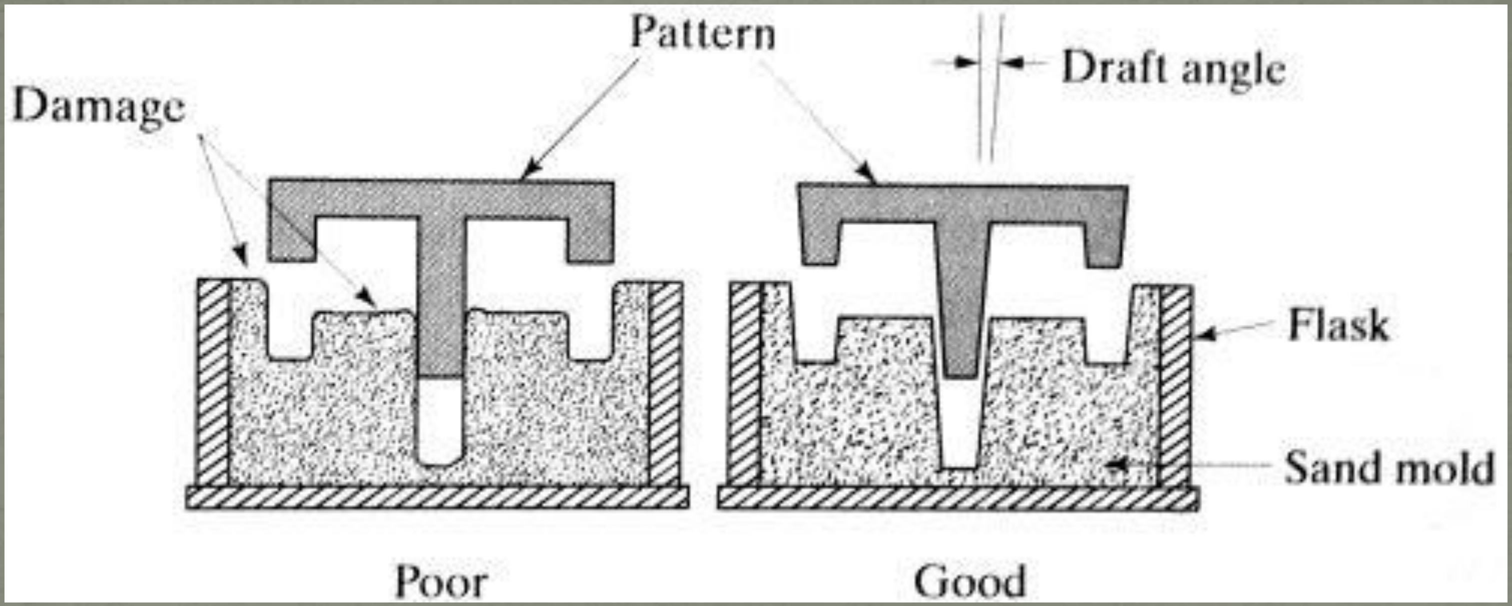
- warpage due to residual stresses (why?)



Casting Design: guidelines

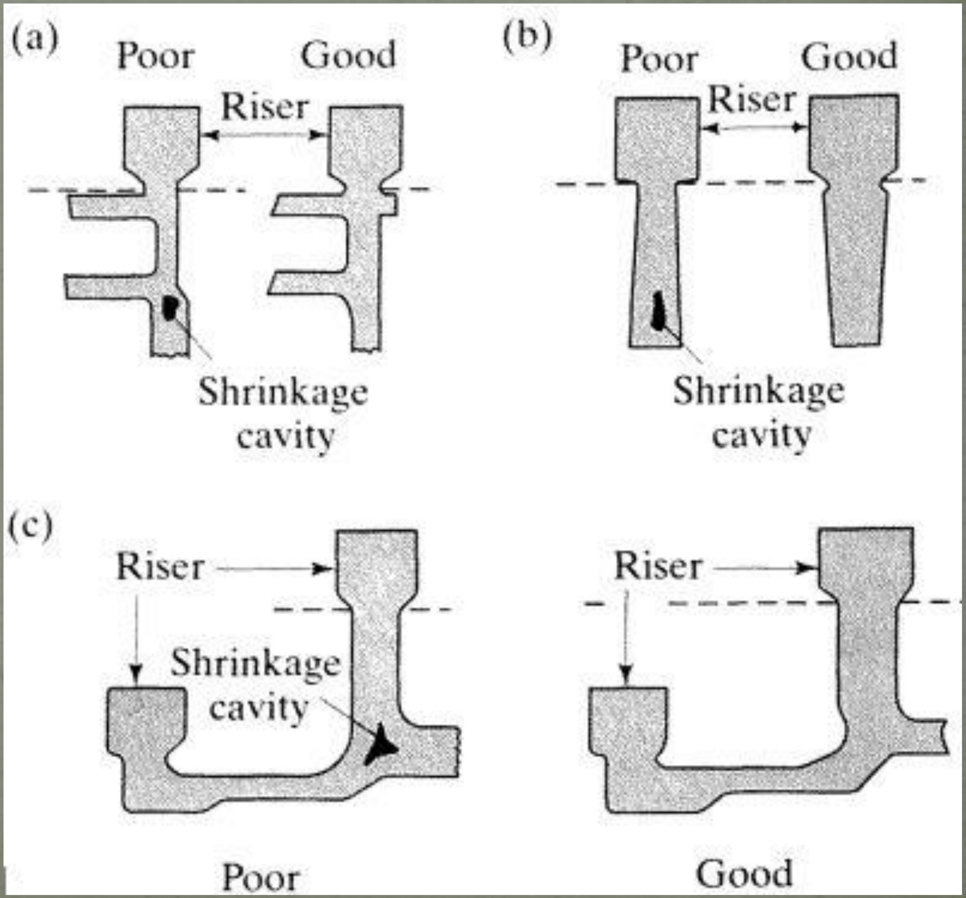
(e) provide drafts and tapers

- easy removal, avoid damage
- along what direction should we taper ?



Casting Design: guidelines

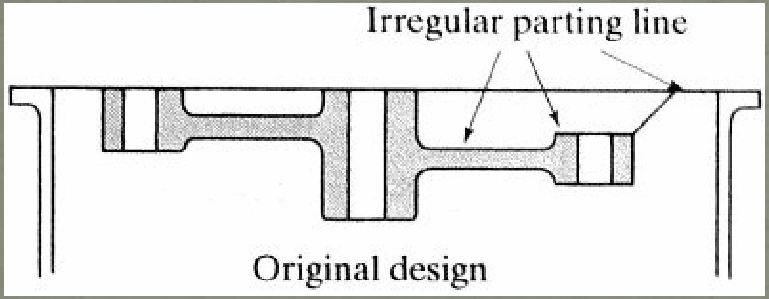
(f) account for shrinkage
- geometry
- shrinkage cavities

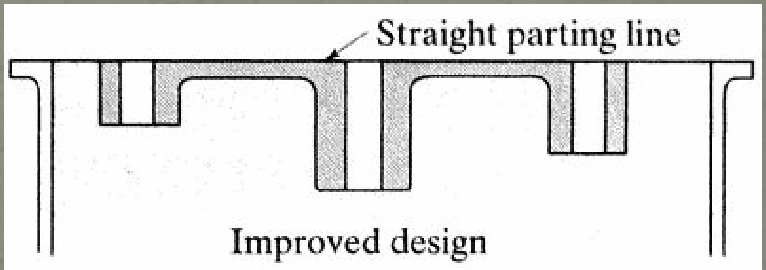


Casting Design: guidelines

(g) proper design of parting line

- “flattest” parting line is best





UNIT II

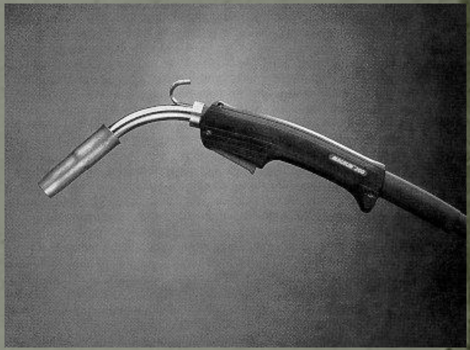
Joining Processes

Consumable Electrode

SMAW – Shielded Metal Arc Welding

GMAW – Gas Metal Arc Welding

SAW – Submerged Arc Welding



Non-Consumable Electrode

GTAW – Gas Tungsten Arc Welding

PAW – Plasma Arc Welding

High Energy Beam

Electron Beam Welding

Laser Beam Welding

- Consumable electrode
- Flux coated rod
- Flux produces protective gas around weld pool
- Slag keeps oxygen off weld bead during cooling

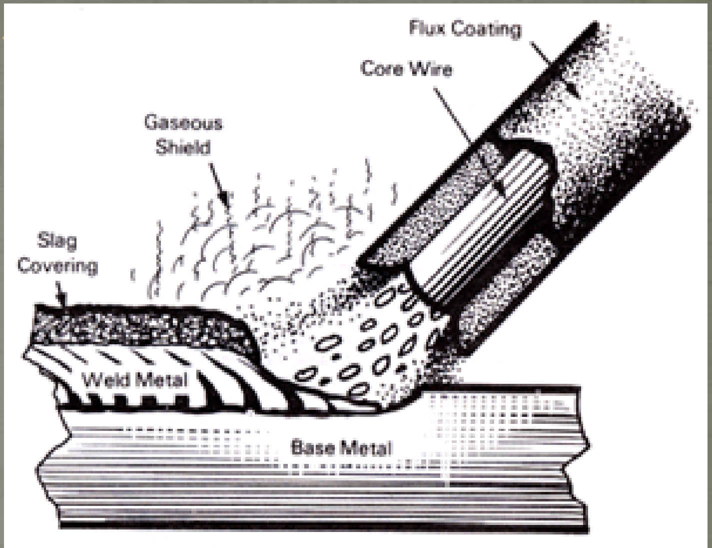


Fig. 6

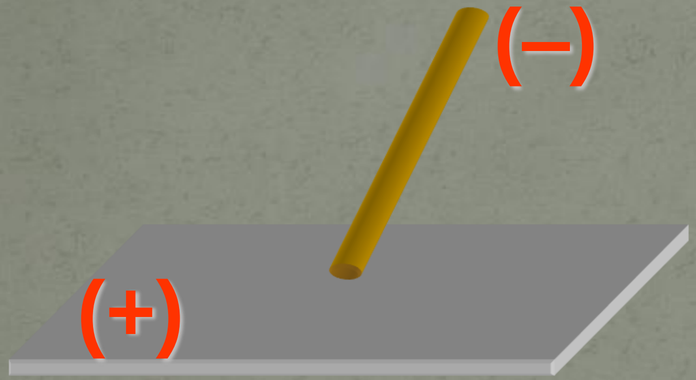
- General purpose welding—widely used
- Thicknesses 1/8” – 3/4”
- Portable

Power... Current I (50 - 300 amps)
Voltage V (15 - 45 volts)

Power = VI ≈ 10 kW

SMAW - DC Polarity

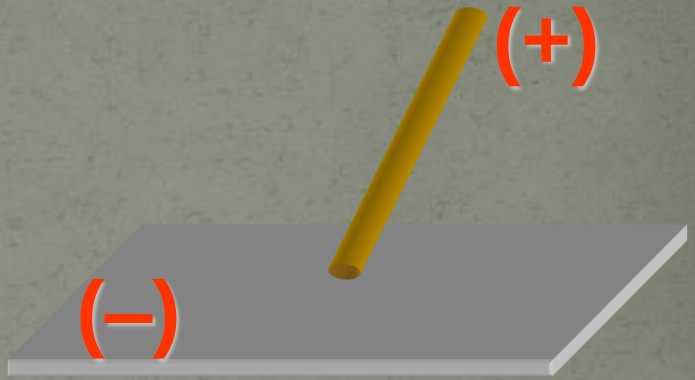
Straight Polarity



Shallow penetration

(thin metal)

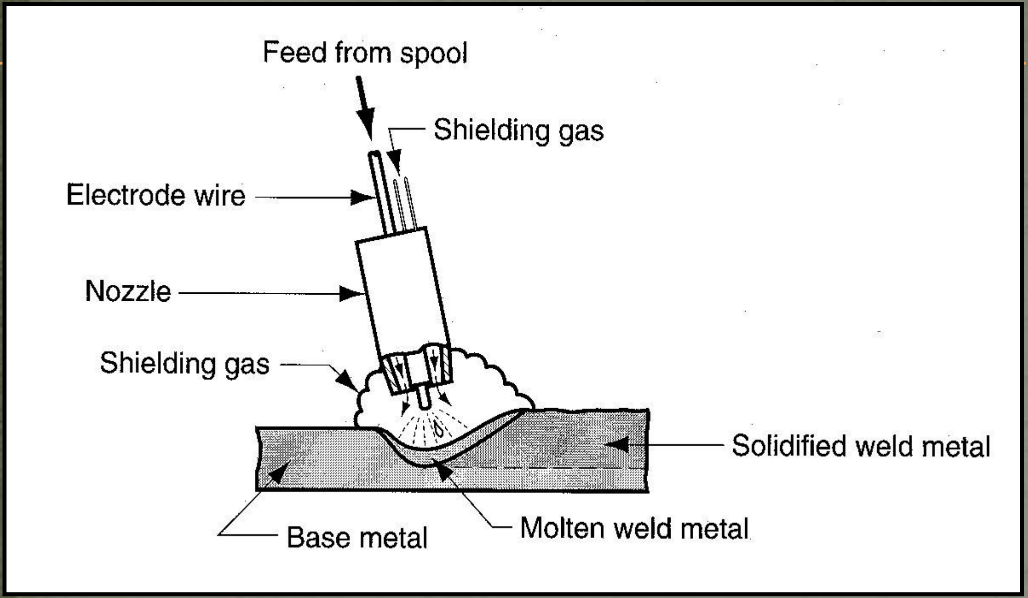
Reverse Polarity



Deeper weld penetration

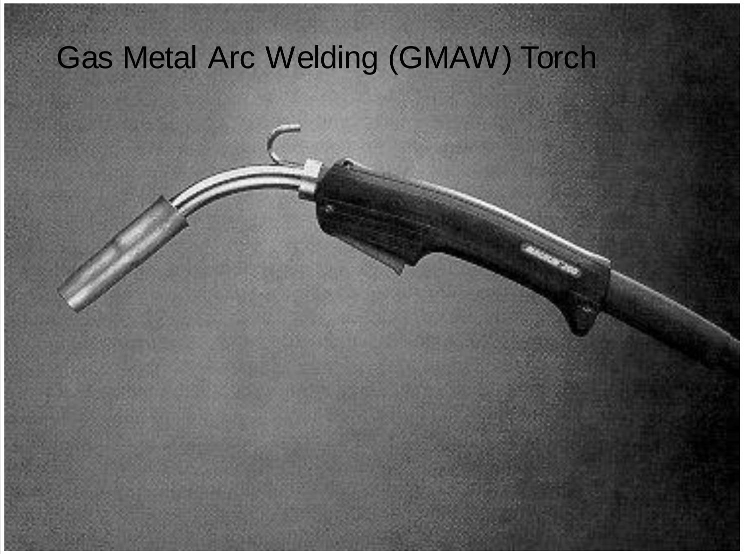
AC - Gives pulsing arc

- used for welding thick sections

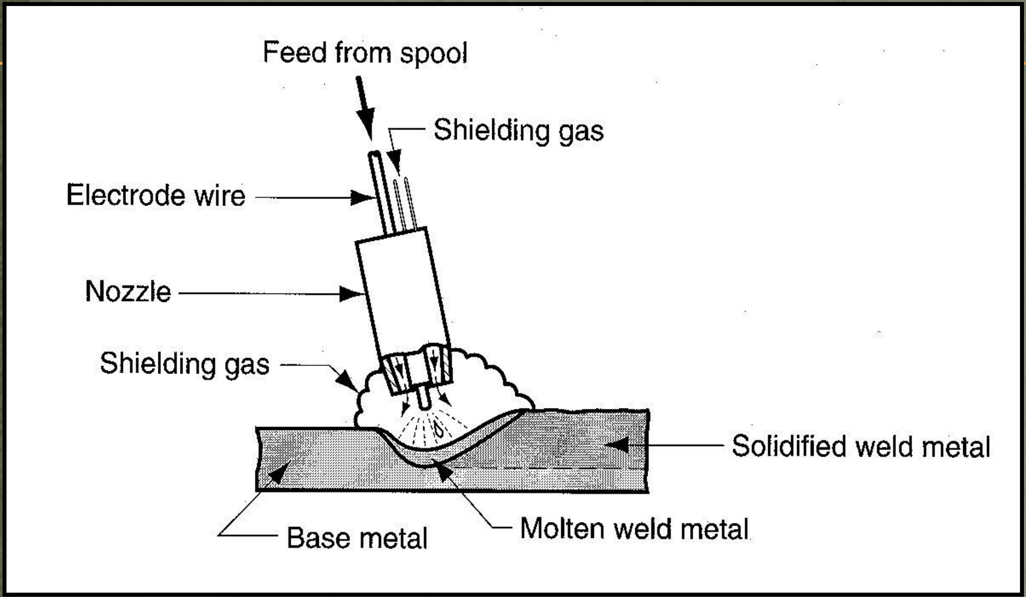


- DC reverse polarity - hottest arc
- AC - unstable arc

- MIG - Metal Inert Gas
- Consumable wire electrode
- Shielding provided by gas
- Double productivity of SMAW
- Easily automated



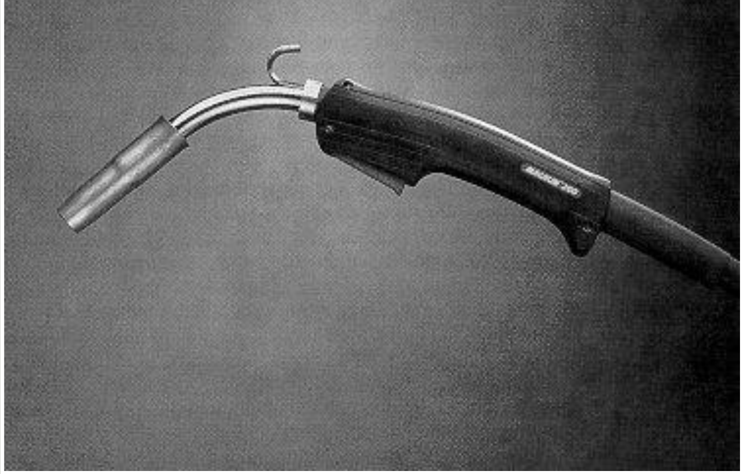
Groover, M., *Fundamentals of Modern Manufacturing*,, p. 734, 1996



- DC reverse polarity - hottest arc
- AC - unstable arc

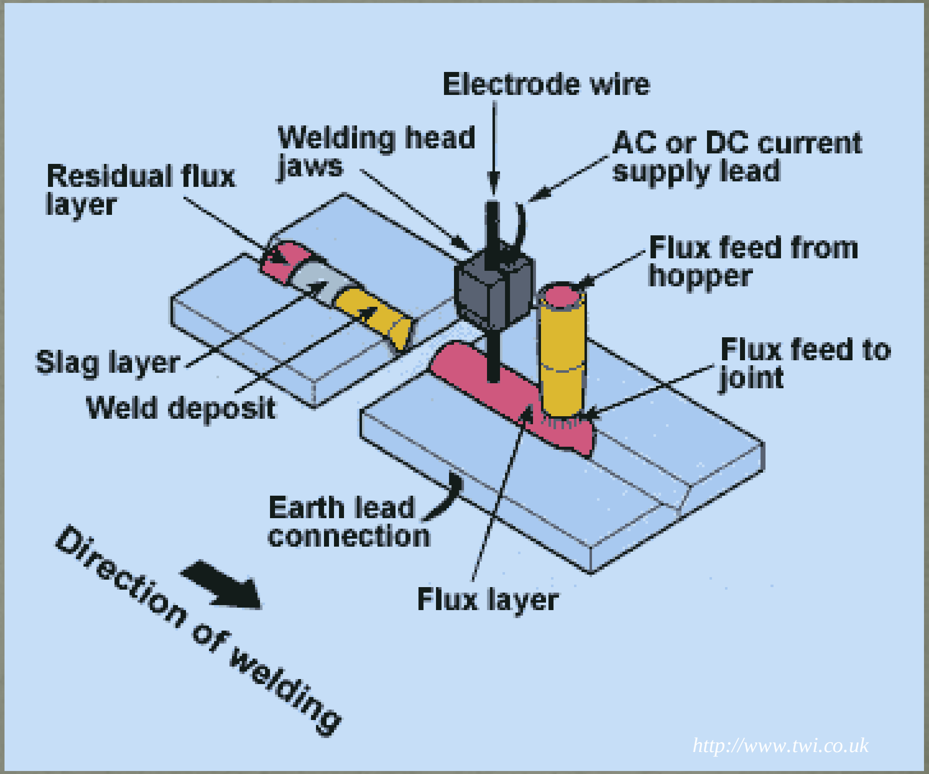
- MIG - Metal Inert Gas
- Consumable wire electrode
- Shielding provided by gas
- Double productivity of SMAW
- Easily automated

Gas Metal Arc Welding (GMAW) Torch

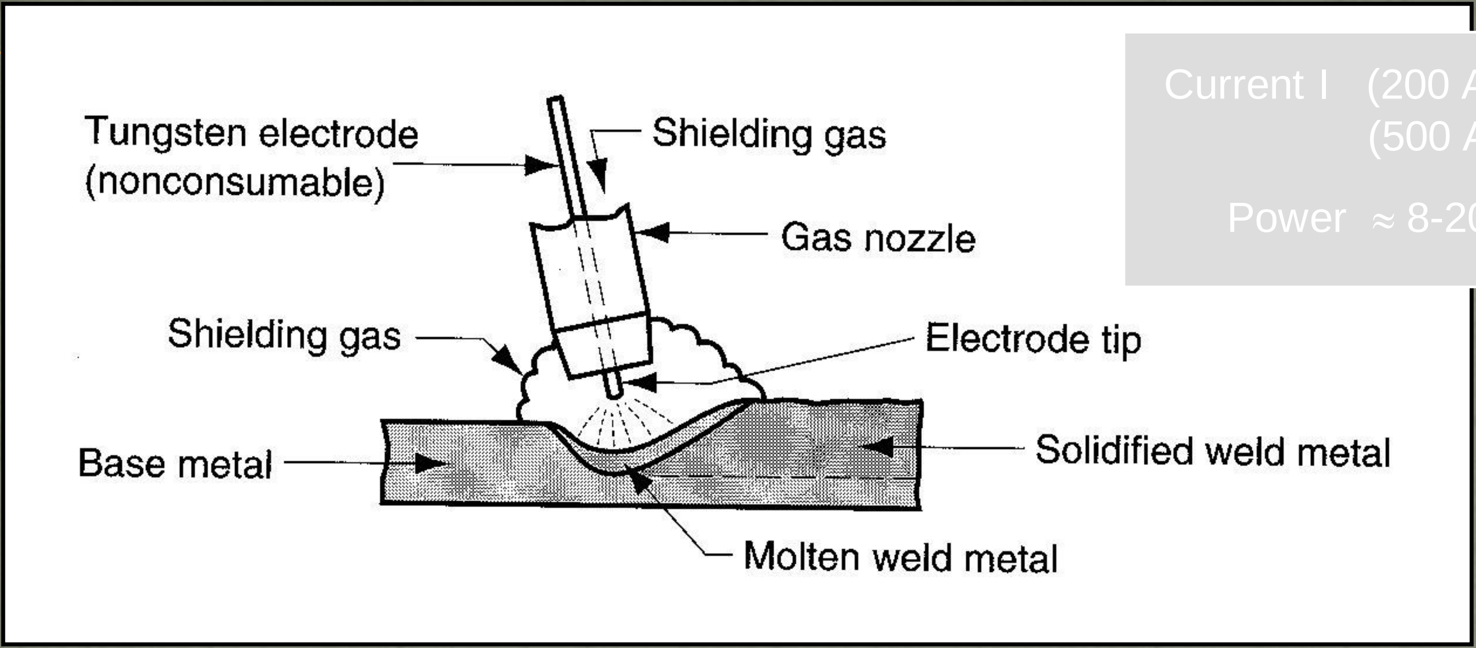


Groover, M., *Fundamentals of Modern Manufacturing*,, p. 734, 1996

- 300 – 2000 amps (440 V)



- Consumable wire electrode
- Shielding provided by flux granules
- Low UV radiation & fumes
- Flux acts as thermal insulator
- Automated process (limited to flats)
- High speed & quality (4 – 10x SMAW)
- Suitable for thick plates

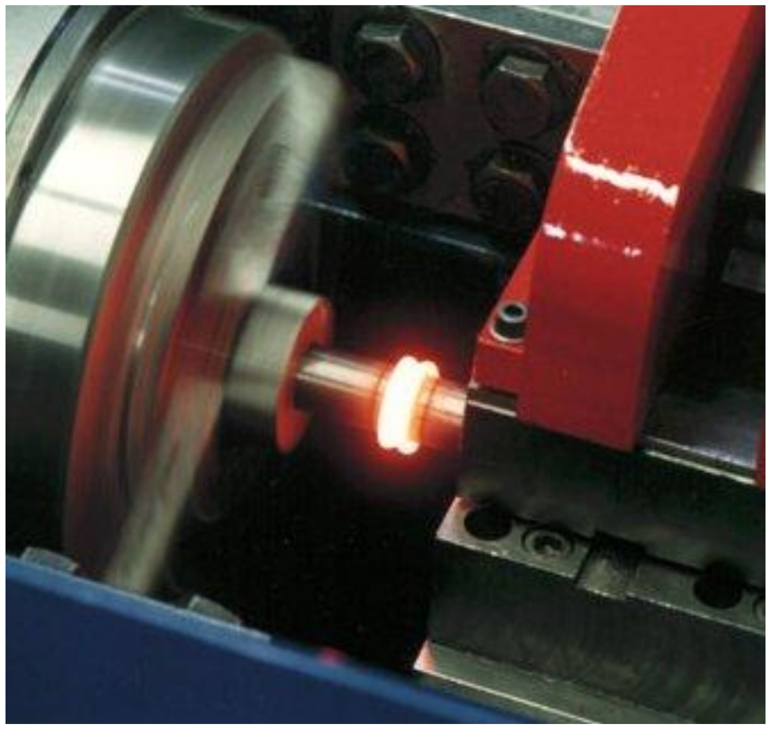


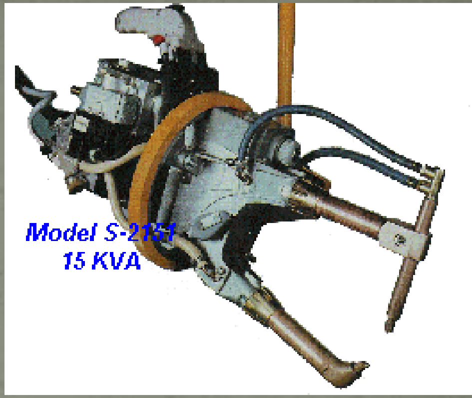
Current I (200 A DC)
(500 A AC)

Power ≈ 8-20 kW

- a.k.a. TIG - Tungsten Inert Gas
- Non-consumable electrode
- With or without filler metal
- Shield gas usually argon
- Used for thin sections of Al, Mg, Ti.
- Most expensive, highest quality

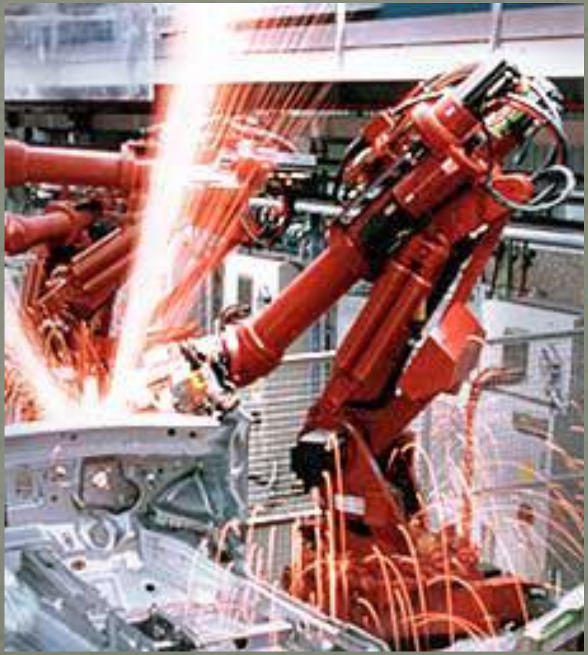
- One part rotated, one stationary
- Stationary part forced against rotating part
- Friction converts kinetic energy to thermal energy
- Metal at interface melts and is joined
- When sufficiently hot, rotation is stopped & axial force increased



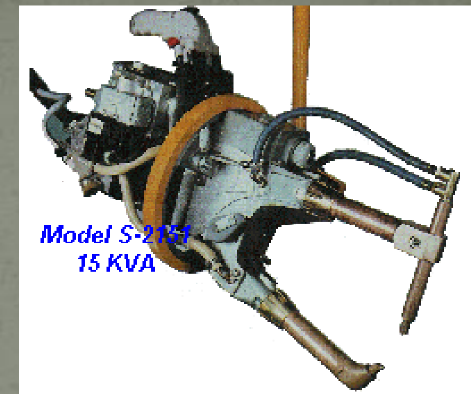


Resistance Welding is the coordinated application of electric current and mechanical pressure in the proper magnitudes and for a precise period of time to create a coalescent bond between two base metals.

- Heat provided by resistance to electrical current ($Q=I^2Rt$)
- Typical 0.5 – 10 V but up to 100,000 amps!
- Force applied by pneumatic cylinder
- Often fully or partially automated
    - Spot welding
    - Seam welding



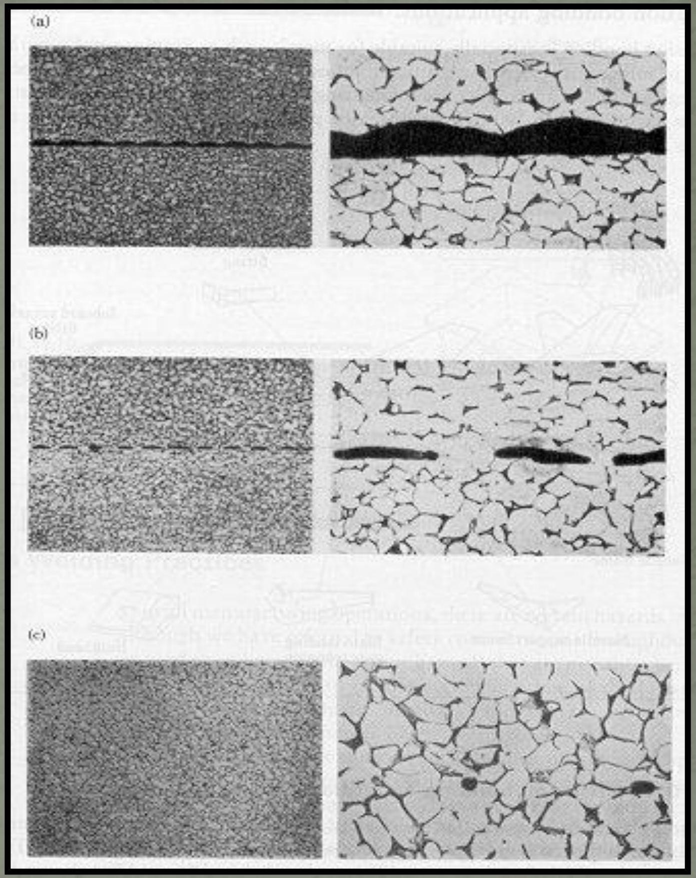
Resistance Welding



- Heat provided by resistance to
- Typical 0.5 – 10 V but up to 10
- Force applied by pneumatic cy
- Often fully or partially automat

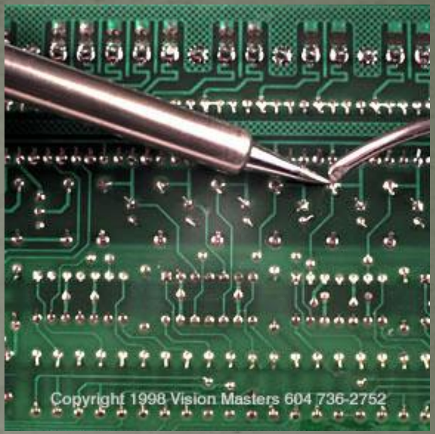
  - Spot welding
  - Seam welding

- Parts forced together at high temperature (< 0.5Tm absolute) and pressure
- Heated in furnace or by resistance heating
- Atoms diffuse across interface
- After sufficient time the interface disappears
- Good for dissimilar metals
- Bond can be weakened by surface impurities



Kalpakjian, S., *Manufacturing Engineering & Technology*, p. 889, 1992

Soldering & Brazing



- Only filler metal is melted, not base metal
- Lower temperatures than welding
- Filler metal distributed by capillary action
- Metallurgical bond formed between filler & base metals
- Strength of joint typically
  - stronger than filler metal itself
  - weaker than base metal
  - gap at joint important (0.001 – 0.010”)
- Pros & Cons
  - Can join dissimilar metals
  - Less heat - can join thinner sections (relative to welding)
  - Excessive heat during service can weaken joint

Soldering

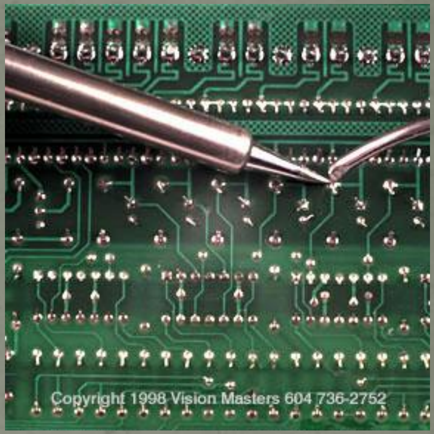
Solder = Filler metal

- Alloys of Tin (silver, bismuth, lead)
- Melt point typically below 840 F

Flux used to clean joint & prevent oxidation

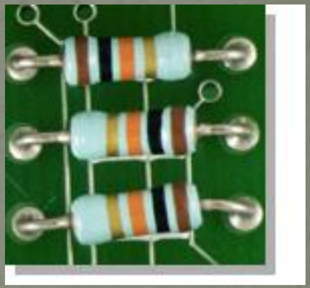
- separate or in core of wire (rosin-core)

Tinning = pre-coating with thin layer of solder



Applications:

- Printed Circuit Board (PCB) manufacture
- Pipe joining (copper pipe)
- Jewelry manufacture
- Typically non-load bearing



Easy to solder: copper, silver, gold

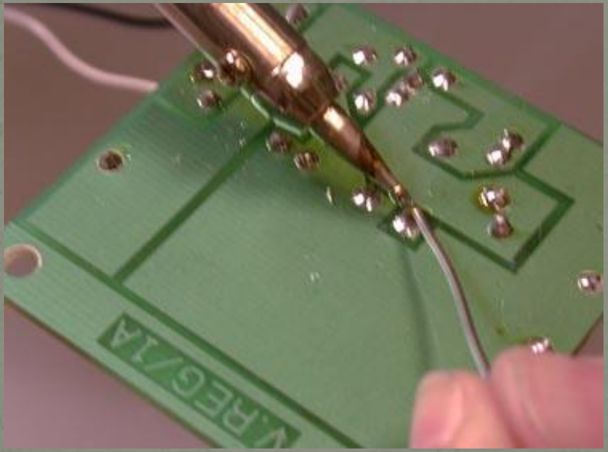
Difficult to solder: aluminum, stainless steels

(can pre-plate difficult to solder metals to aid process)

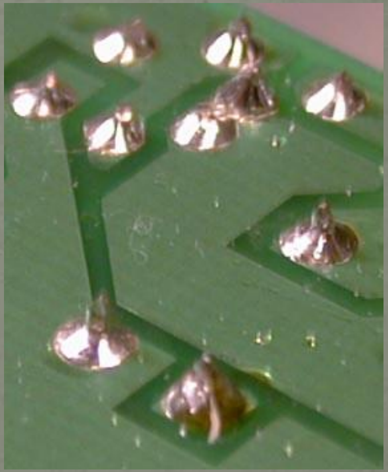
Manual PCB Soldering

• Soldering Iron & Solder Wire

• Heating lead & placing solder



• Heat for 2-3 sec. & place wire opposite iron



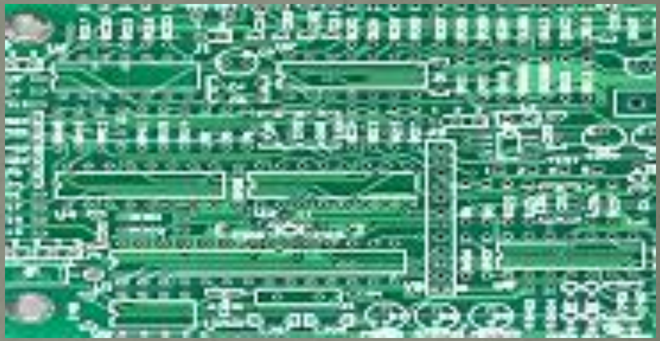
• Trim excess lead

Automated Reflow Soldering

SMT = Surface Mount Technology

- Solder/Flux paste mixture applied to PCB using screen print or similar transfer method

- Solder Paste serves the following functions:
  - supply solder material to the soldering spot,
  - hold the components in place prior to soldering,
  - clean the solder lands and component leads
  - prevent further oxidation of the solder lands.



Printed solder paste on a printed circuit board (PCB)

- PCB assembly then heated in “Reflow” oven to melt solder and secure connection

Brazing

Use of low melt point filler metal to fill thin gap between mating surfaces to be joined utilizing capillary action

- Filler metals include Al, Mg & Cu alloys (melt point typically above 840 F)
- Flux also used
- Types of brazing classified by heating method:
  - Torch, Furnace, Resistance

Applications:

- Automotive - joining tubes
- Pipe/Tubing joining (HVAC)
- Electrical equipment - joining wires
- Jewelry Making
- Joint can possess significant strength

Figure 7. Typical brazed pipe/tube applications. (Photo courtesy of Handy & Harman)

Figure 11. Typical brazing filler metal preforms. (Photo courtesy of Handy & Harman)

Brazing

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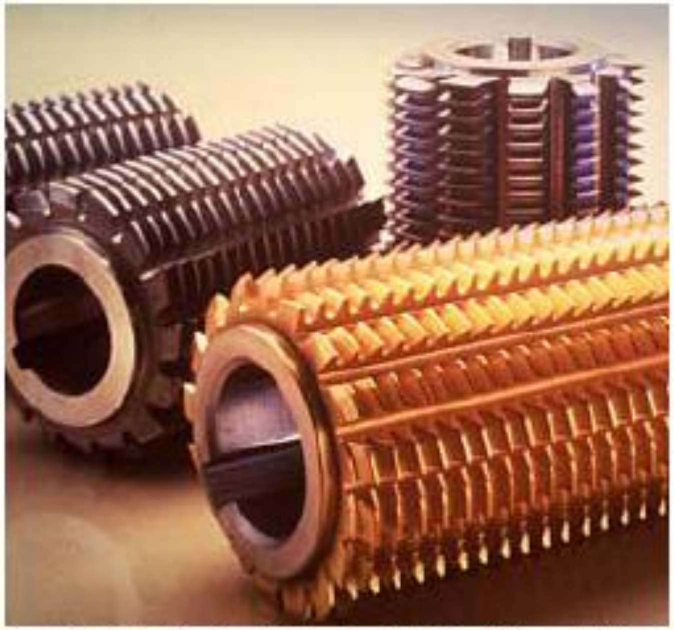


Figure 9. Typical carbide cutting tools brazed to metal in a brazing furnace. (Photo courtesy of Handy & Harman)

UNIT III

Deformation Processes

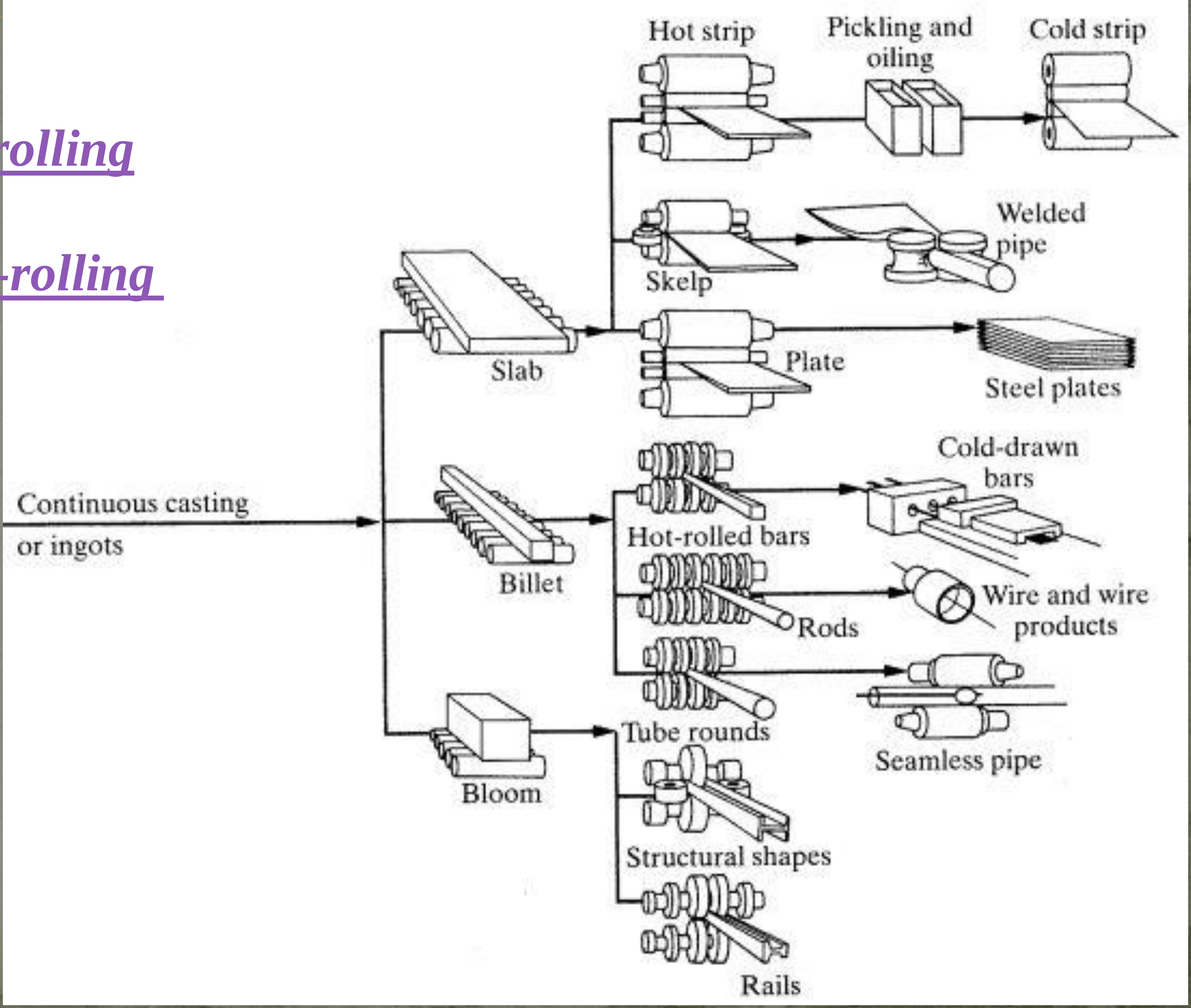
Forming

Any process that changes the shape of a raw stock without changing its phase

Example products:
Al/Steel frame of doors and windows, coins, springs,
Elevator doors, cables and wires, sheet-metal, sheet-metal parts…

Rolling

- → ***Hot-rolling***
- → ***Cold-rolling***



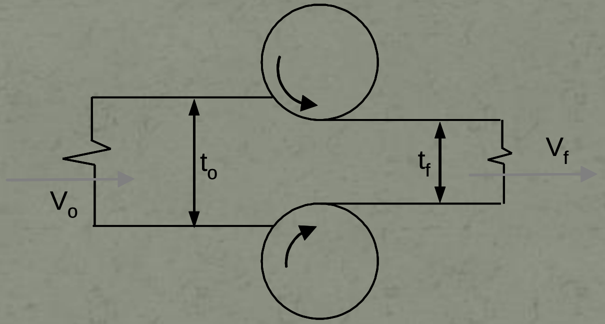
Rolling

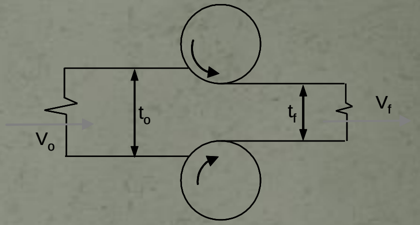
Important Applications:

Steel Plants,
Raw stock production (sheets, tubes, Rods, etc.)
Screw manufacture

Rolling Basics

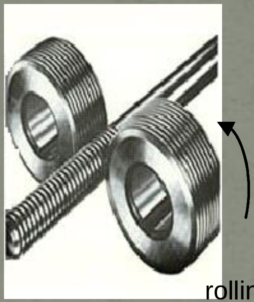
Sheets are rolled in multiple stages (why ?)





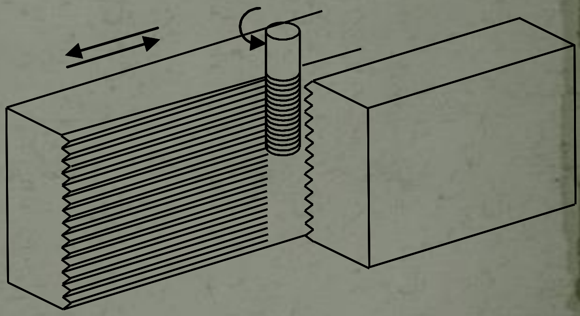
Screw manufacture:

stationary die



rolling die

thread rolling machine



Reciprocating flat thread-rolling dies

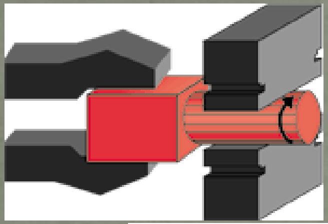
Forging

[Heated] metal is beaten with a heavy hammer to give it the required shape

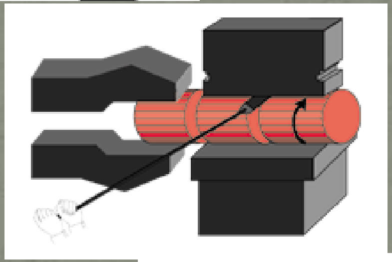
Hot forging,

open-die

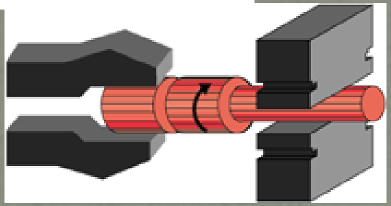
Stages in Open-Die Forging



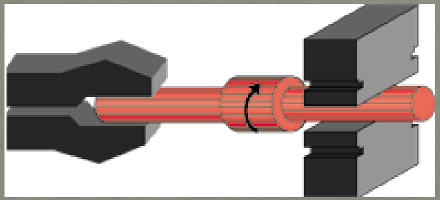
(a) forge hot billet to max diameter



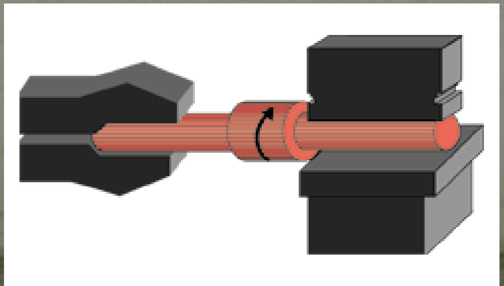
(b) “fuller: tool to mark step-locations



(c) forge right side



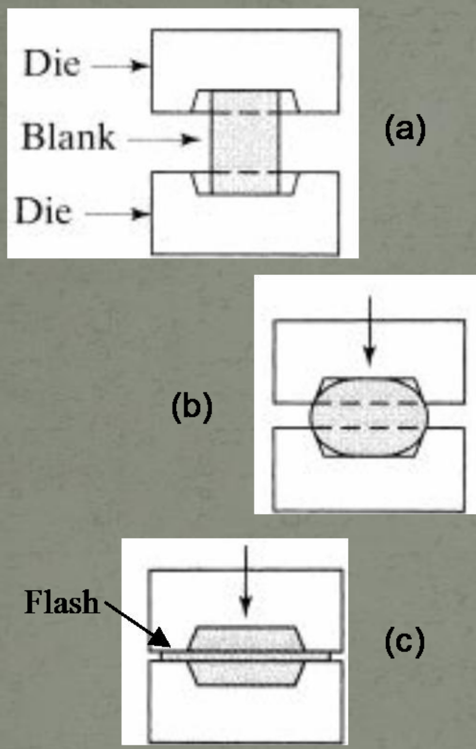
(d) reverse part, forge left side

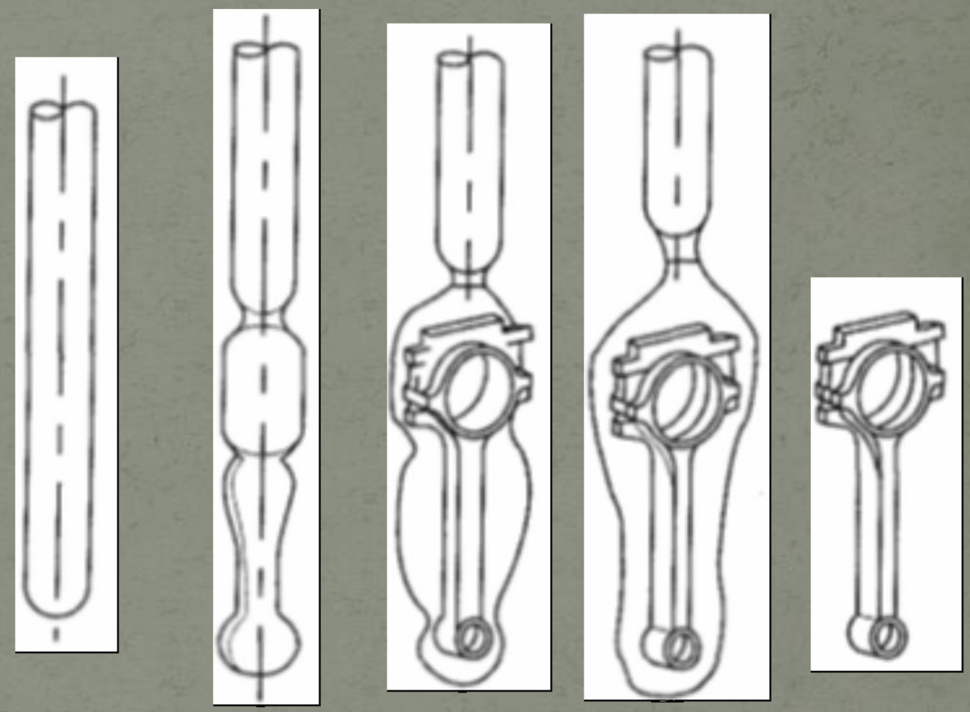


(e) finish (dimension control)

[source:www.scotforge.com]

Stages in Closed-Die Forging





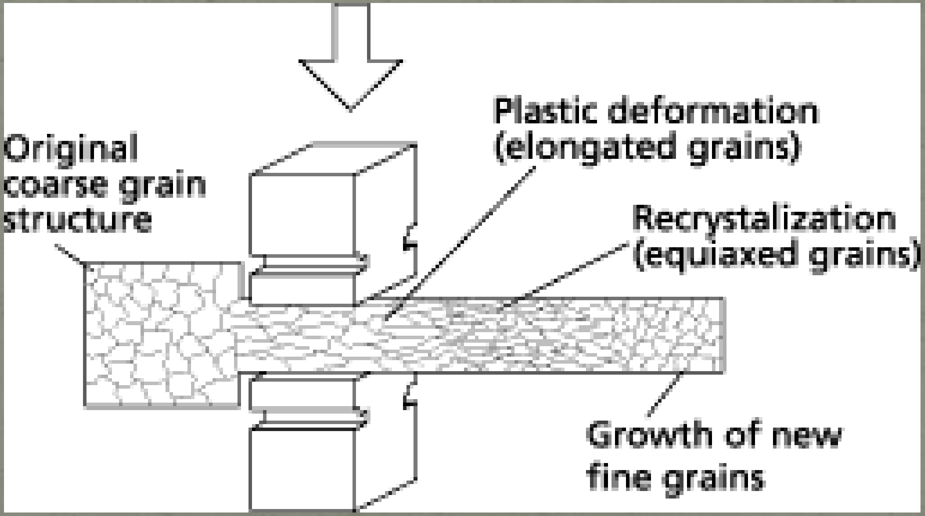
1. Blank (bar) 2. Edging 3.Blocking 4. Finishing 5. Trimming

[source:Kalpakjian & Schmid]

Quality of forged parts

Surface finish/Dimensional control:
Better than casting (typically)

Stronger/tougher than cast/machined parts of same material



[source:www.scotforge.com]

Extrusion

Metal forced/squeezed out through a hole (die)

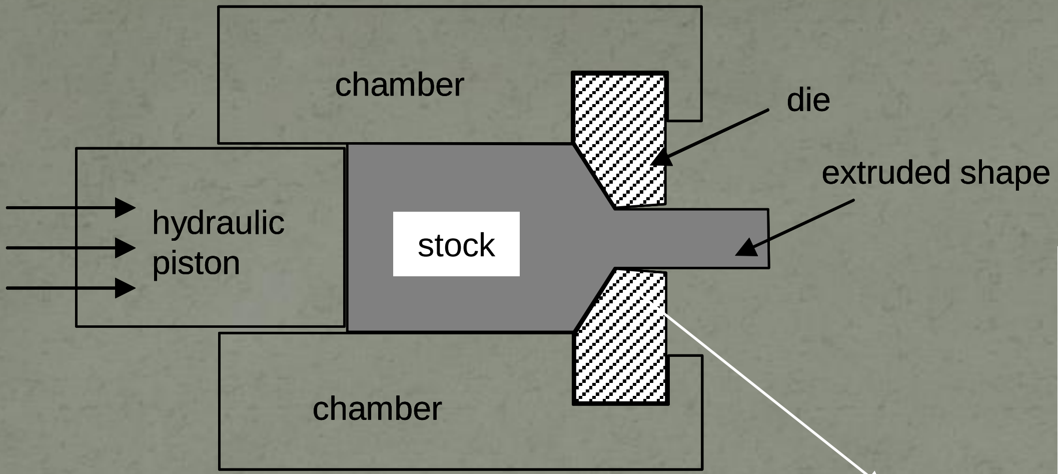
[source:www.magnode.com]

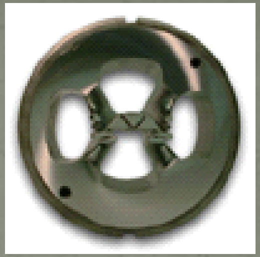
Typical use: ductile metals (Cu, Steel, Al, Mg), Plastics, Rubbers

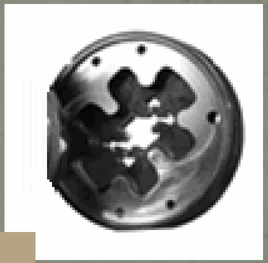
Common products:

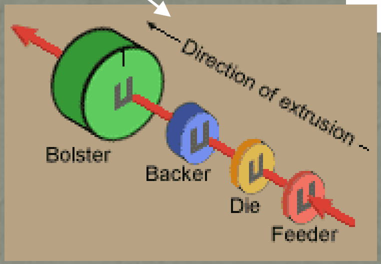
Al frames of white-boards, doors, windows, …

Extrusion: Schematic, Dies





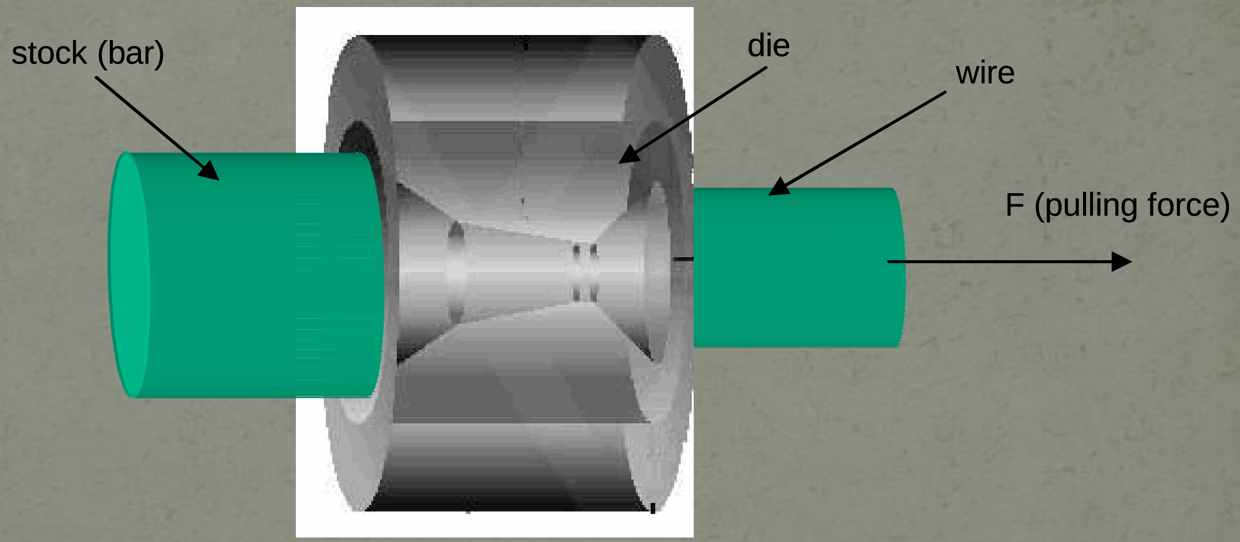




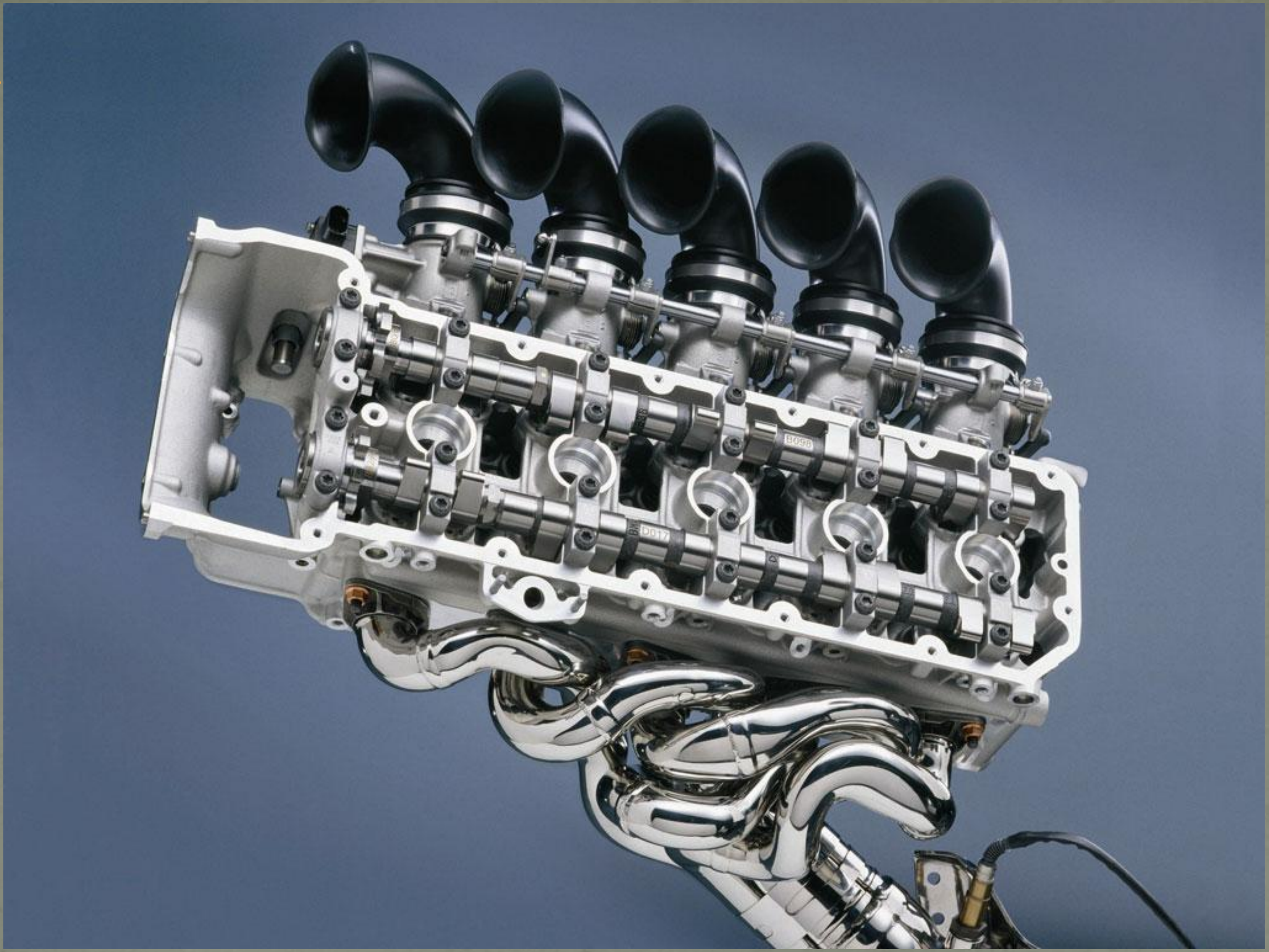
Exercise: how can we get hollow parts?

Drawing

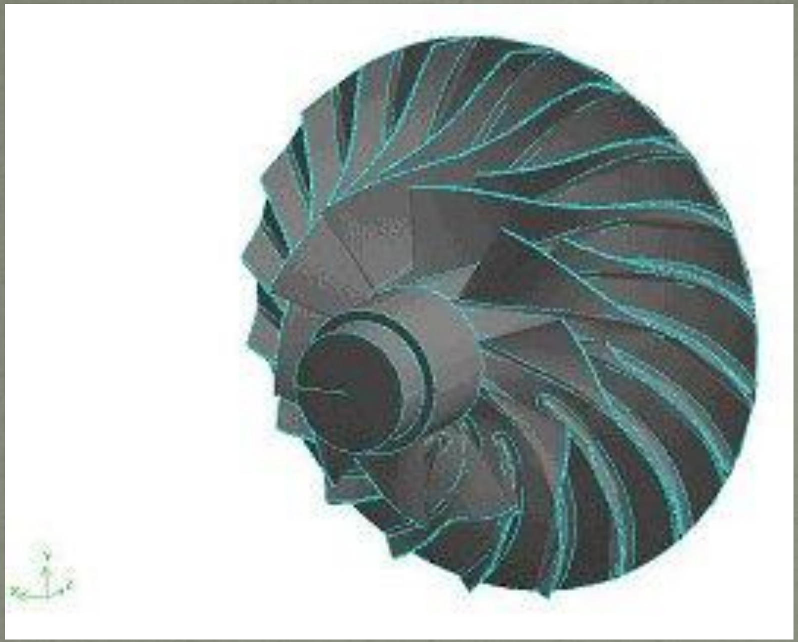
Similar to extrusion, except: ***pulling force*** is applied



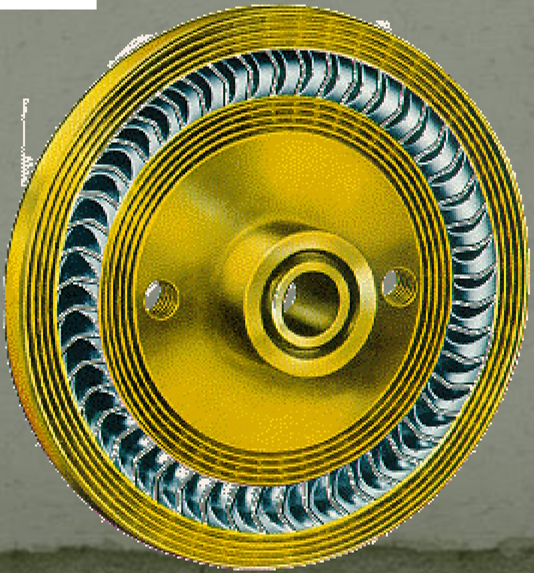
Commonly used to make wires from round bars



BMW cylinder head



Impellers



Sheet Metal Processes

Raw material: sheets of metal, rectangular, large

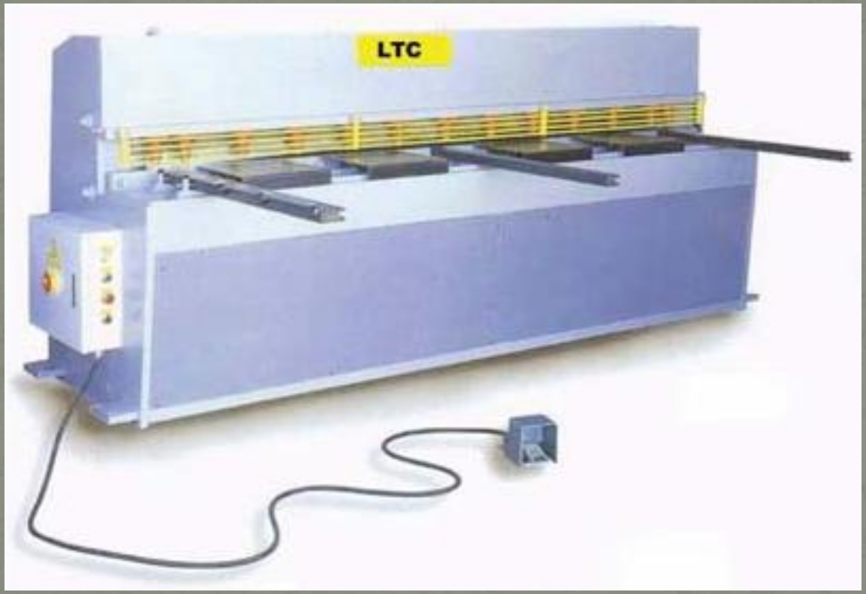
Raw material Processing: Rolling (anisotropic properties)

Processes:

- Shearing
- Punching
- Bending
- Deep drawing

Shearing

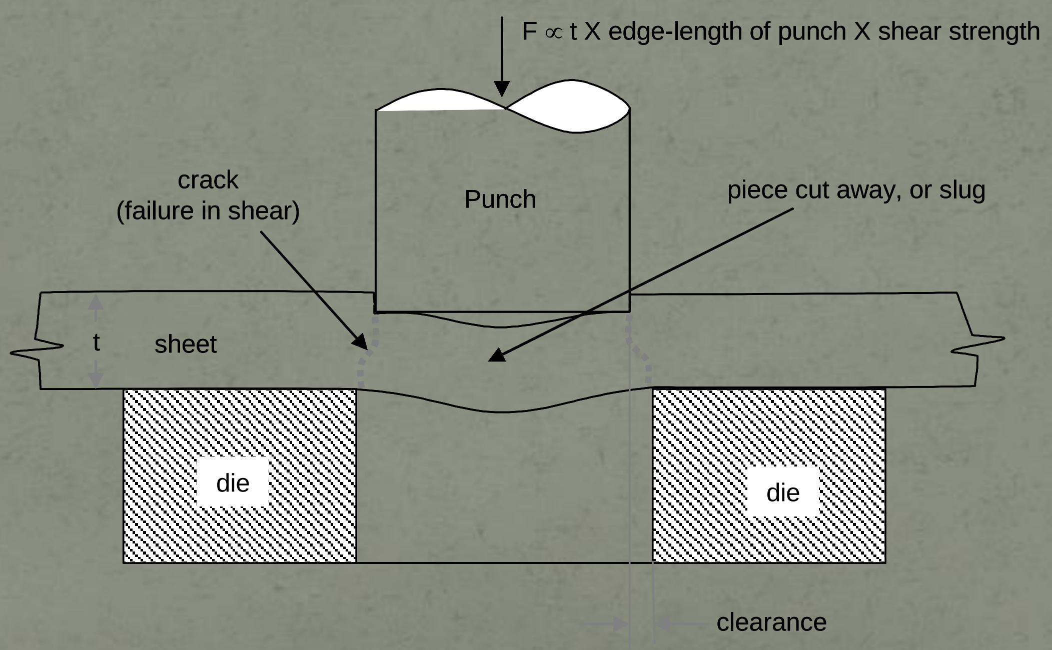
A large scissors action, cutting the sheet along a straight line



Main use: to cut large sheet into smaller sizes for making parts.

Punching

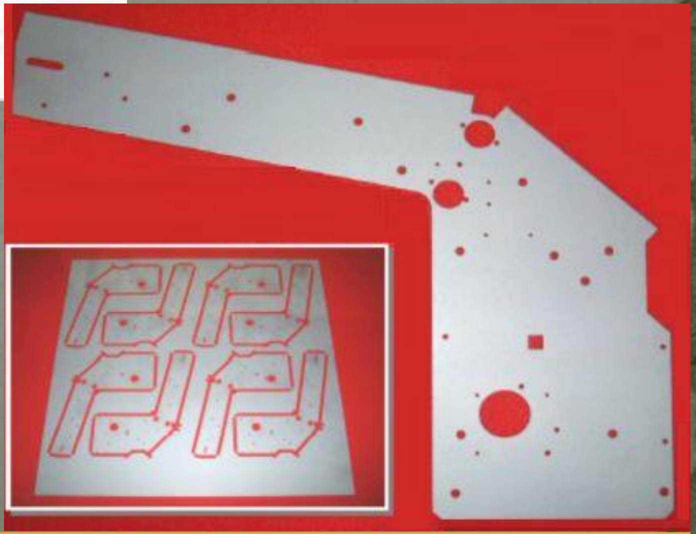
Cutting tool is a round/rectangular punch, that goes through a hole, or die of same shape



Punching

Main uses: cutting holes in sheets; cutting sheet to required shape

nesting of parts

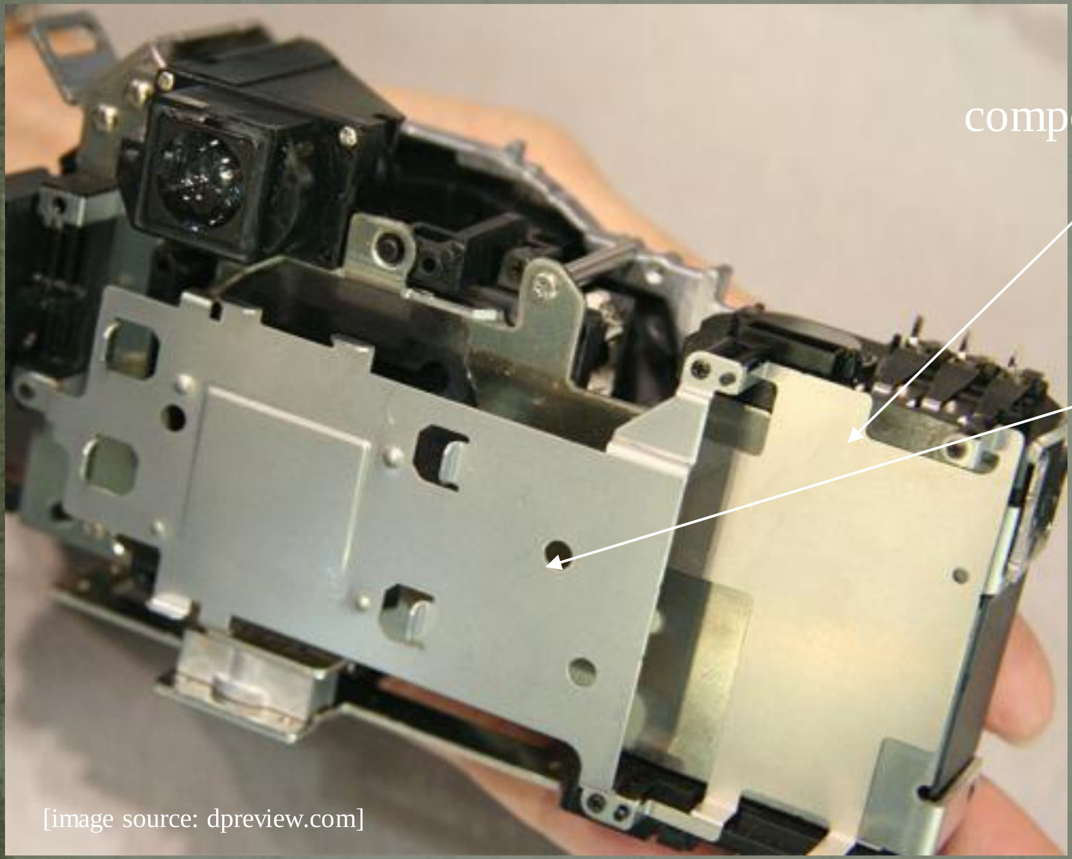


typical punched part

Exercise: how to determine optimal nesting?

Bending

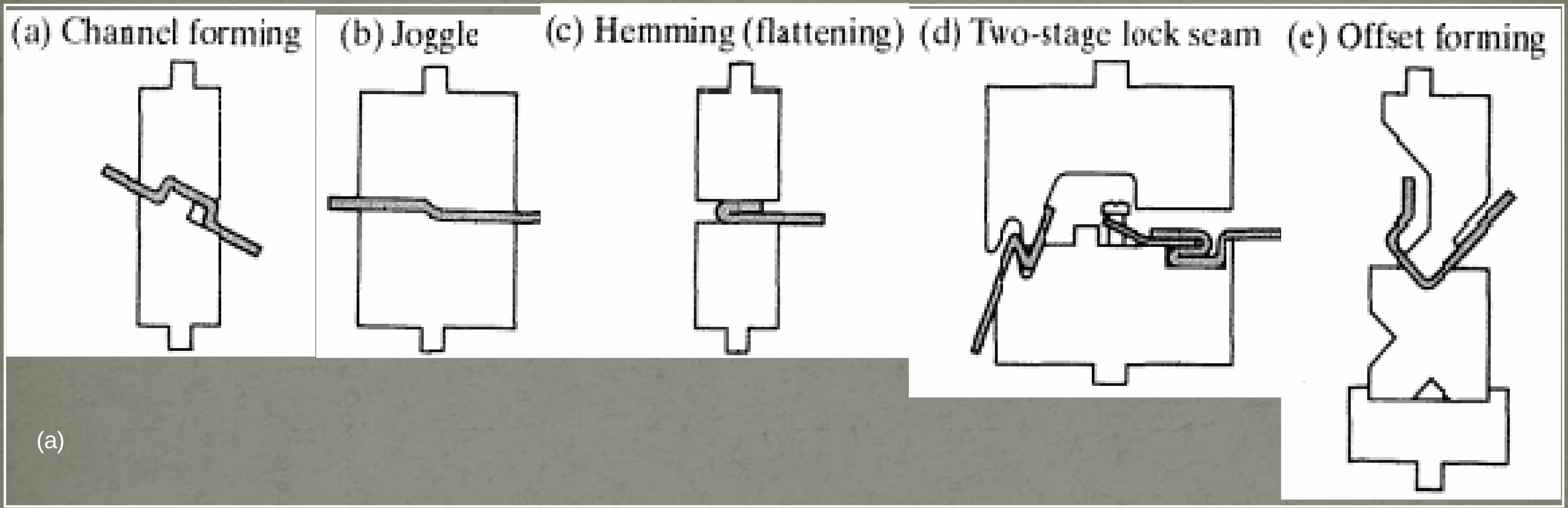
Body of Olympus E-300 camera



component with multiple bending operations

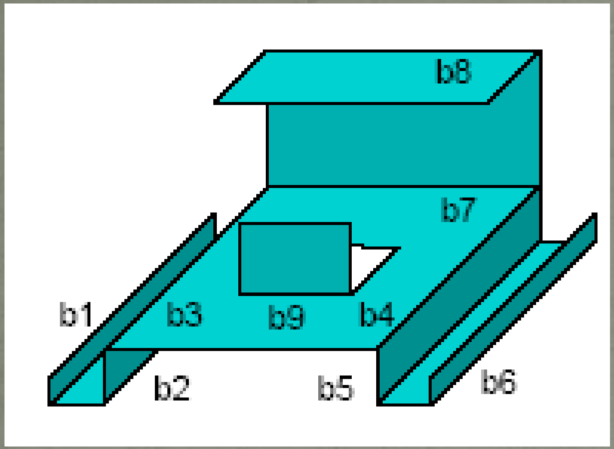
component with punching, bending, drawing operations

Typical bending operations and shapes

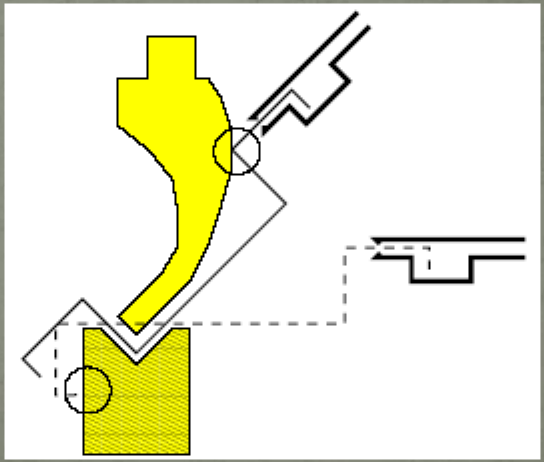


Sheet metal bending

Planning problem: what is the sequence in which we do the bending operations?

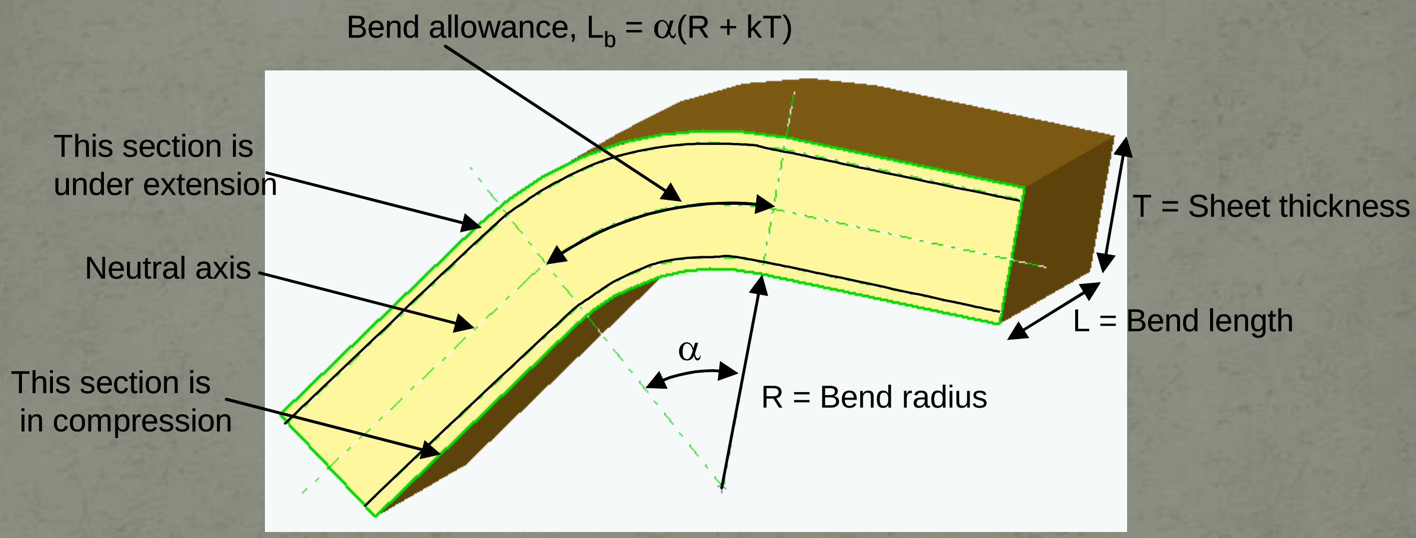


Avoid: part-tool, part-part, part-machine interference



Bending mechanics

Bending Planning ➔ what is the length of blank we must use?



Ideal case: $k = 0.5$

Real cases: $k = 0.33$ ($R < 2T$) ~~ $k = 0.5$ ($R > 2T$)

Bending: cracking, anisotropic effects, Poisson effect

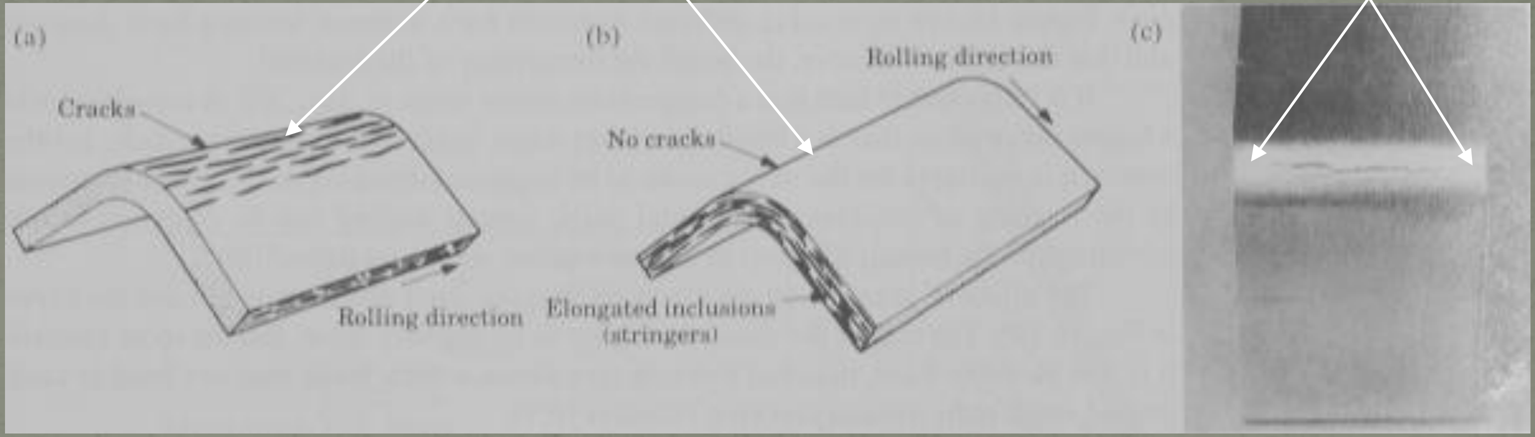
Bending ➔ plastic deformation

Engineering strain in bending = e = 1/(1 + 2R/T)

Bending ➔ disallow failure (cracking) ➔ limits on corner radius: bend radius ≥ 3T

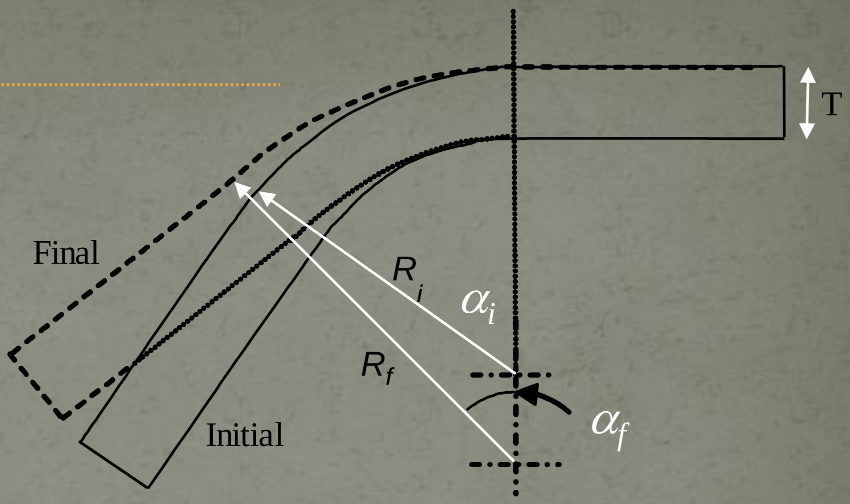
effect of anisotropic stock

Poisson effect



Exercise: how does anisotropic behavior affect planning?

Bending: springback



How to handle springback:

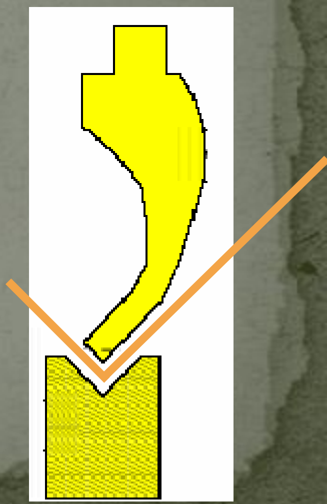
(a) Compensation: the metal is bent by a larger angle

$$\frac{R_i}{R_f} = 4\left(\frac{R_i Y}{ET}\right)^3 - 3\left(\frac{R_i Y}{ET}\right) + 1$$

(b) Coining the bend:

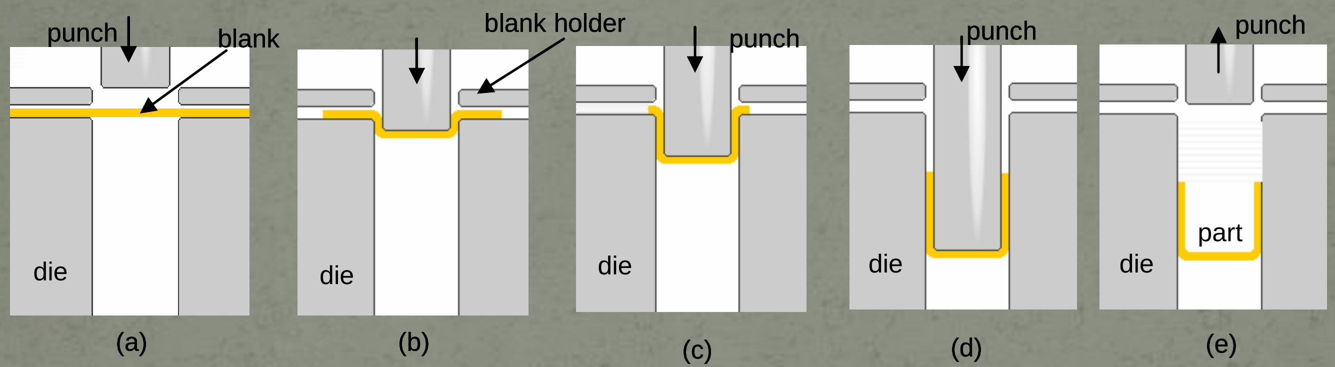
at end of bend cycle, tool exerts large force, dwells

coining: press down hard, wait, release



Deep Drawing

Tooling: similar to punching operation,
Mechanics: similar to bending operation

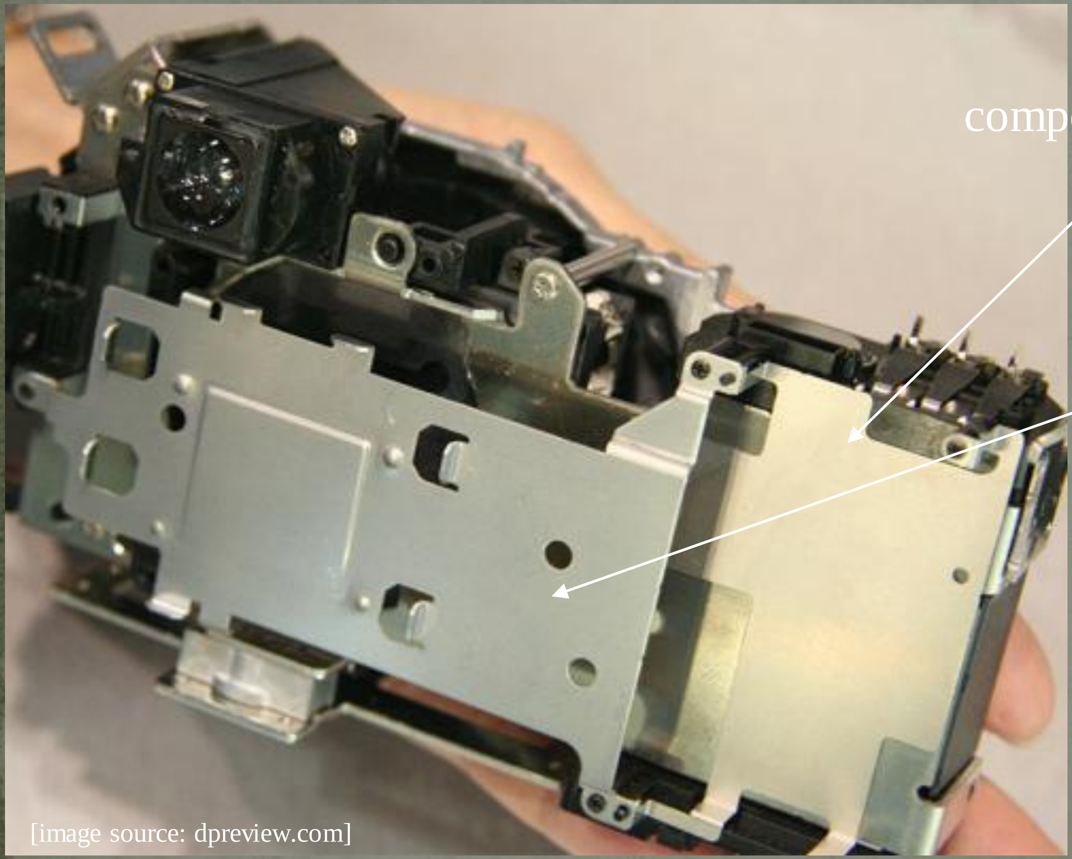


Examples of deep drawn parts

Common applications: cooking pots, containers, …

Sheet metal parts with combination of operations

Body of Olympus E-300 camera



component with multiple bending operations

component with punching, bending, drawing operations

UNIT IV
SPECIAL WELDING AND FORMING PROCESS

THERMIT WELDING

Thermit welding is a mixture of aluminium powder and metal oxide which when ignited results in a non explosive exothermic reaction. The heat so generated melts and reduces the metal oxide to metallic form at high temperature. This molten metal is used for joining metal parts by pouring it between them resulting in cast weld joint.

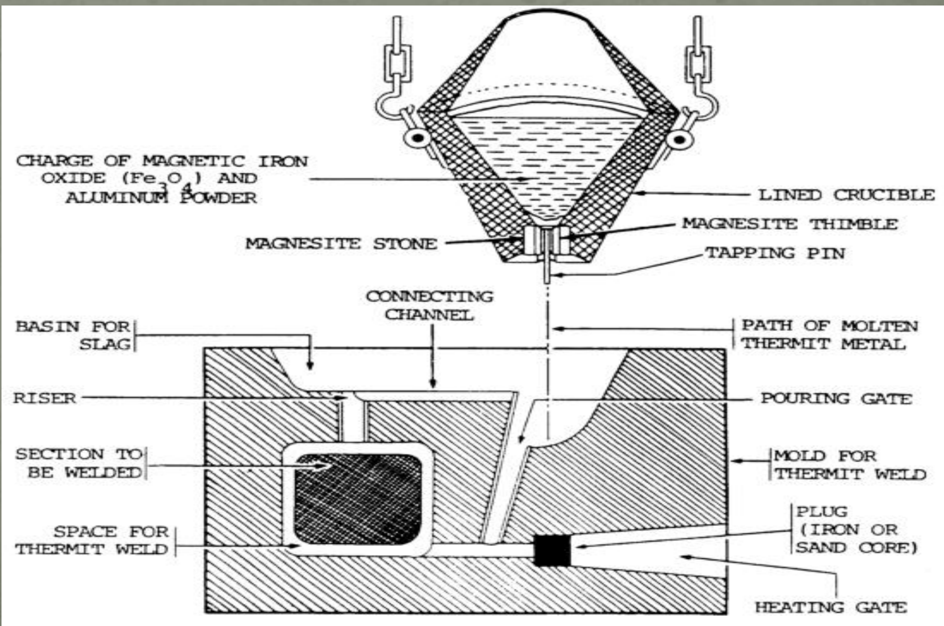


Figure 5-41. Thermit welding crucible and mold.

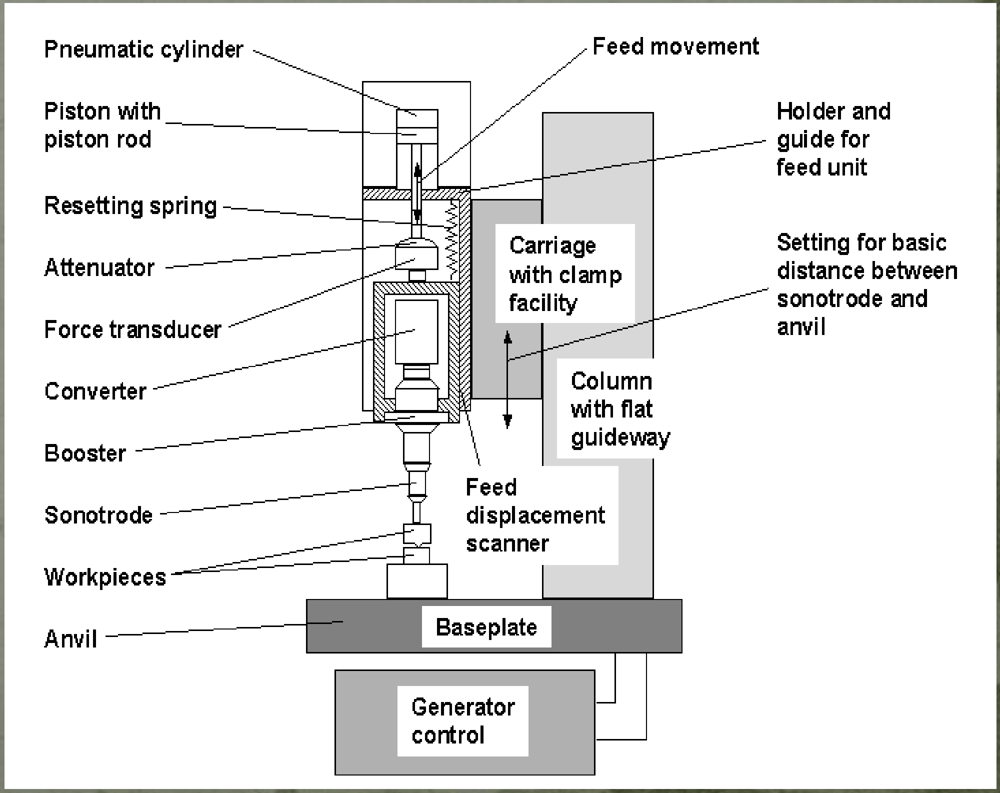
- Laser beam produced by a CO_2 or YAG Laser
- High penetration, high-speed process
- Concentrated heat = low distortion
- Laser can be shaped/focused & pulsed on/off
- Typically automated & high speed (up to 250 fpm)
- Workpieces up to 1” thick

Typical laser welding applications :

- Catheters & Other Medical Devices
- Small Parts and Components
- Fine Wires
- Jewelry
- Small Sensors
- Thin Sheet Materials Down To 0.001" Thick

ULTRASONIC WELDING

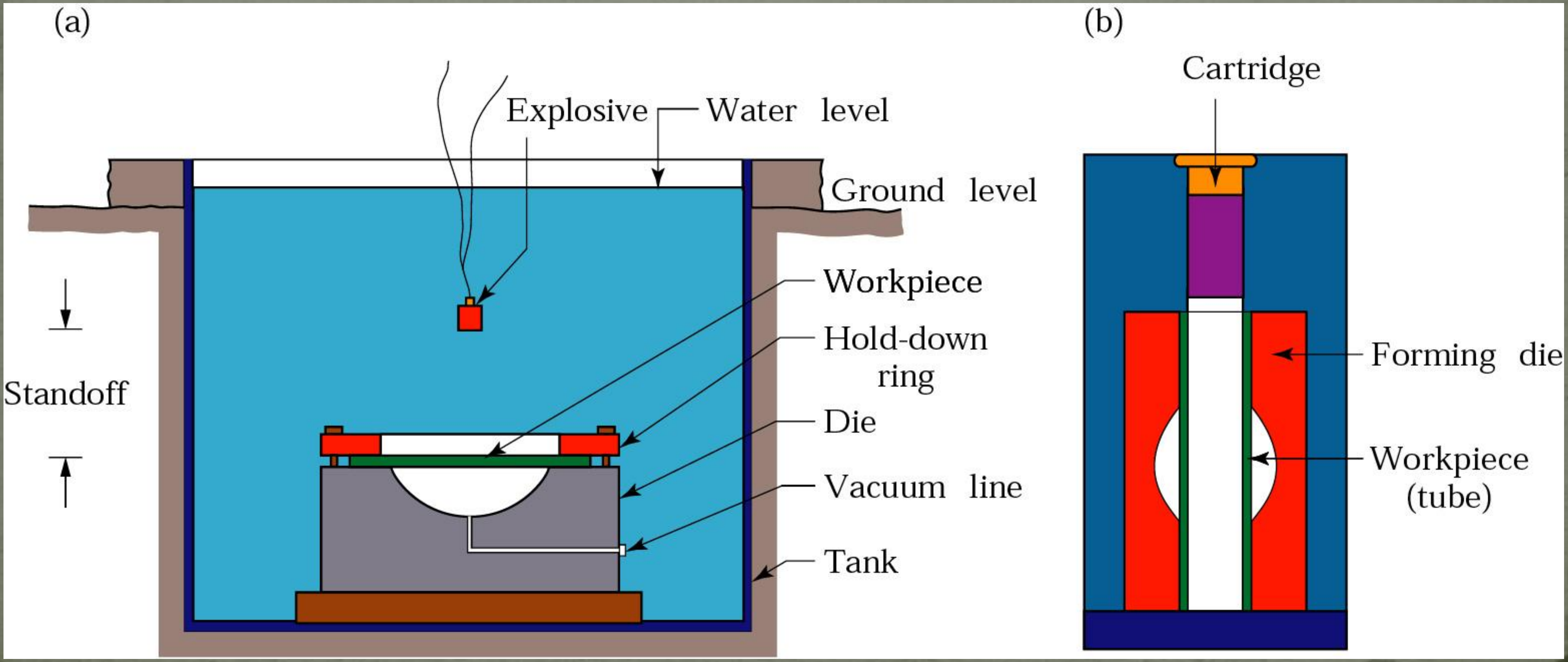
In ultrasonic welding a metallic tip vibrating at ultrasonic frequency is made to join a thin piece to a thicker piece supported on anvil. Frequency used is from 20khz to 60khz. Ultrasonic welding equipment consists of mainly two parts, one is power source and other is transducer.



Explosive forming

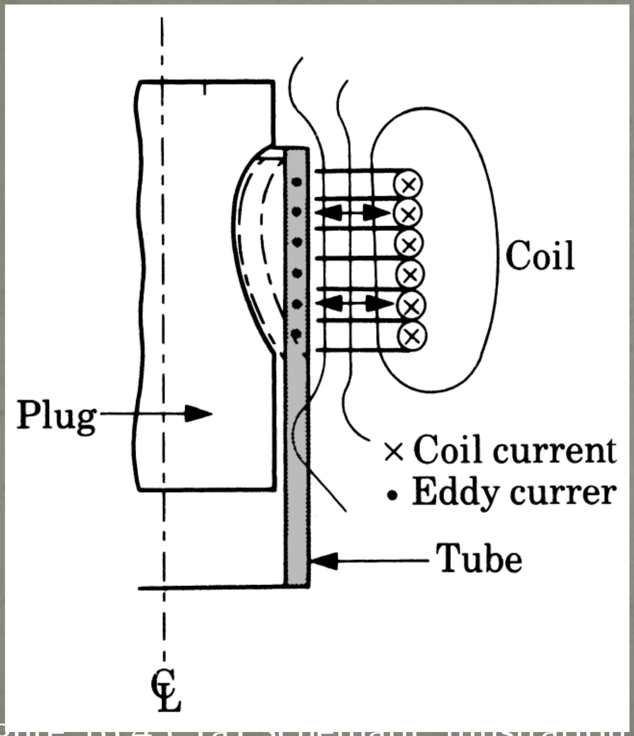
EXPLOSIVE FORMING

- First used to form metals in the 1900’s. A sheet metal blank is clamped over a die, and the entire assembly is lowered into a tank filled with water. The air in the cavity is evacuated, and an explosive is detonated at a certain height above.



MAGNETIC PULSE FORMING

- Also called electromagnetic forming. Energy stored in a capacitor bank is discharged rapidly through a magnetic coil. Magnetic field crosses metal tube (conductor) creating eddy currents which have an opposing magnetic field.



(b)

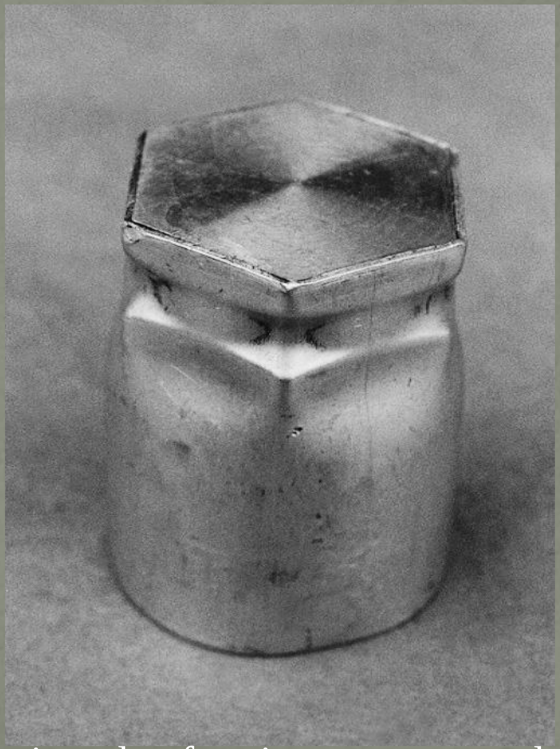
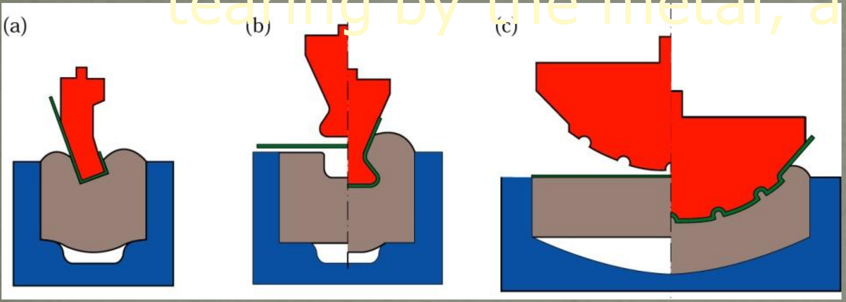


Figure 16.45 (a) Schematic illustration of the magnetic-pulse forming process used to form a tube over a plug. (b) Aluminum tube collapsed over a hexagonal plug by the magnetic-pulse forming process.

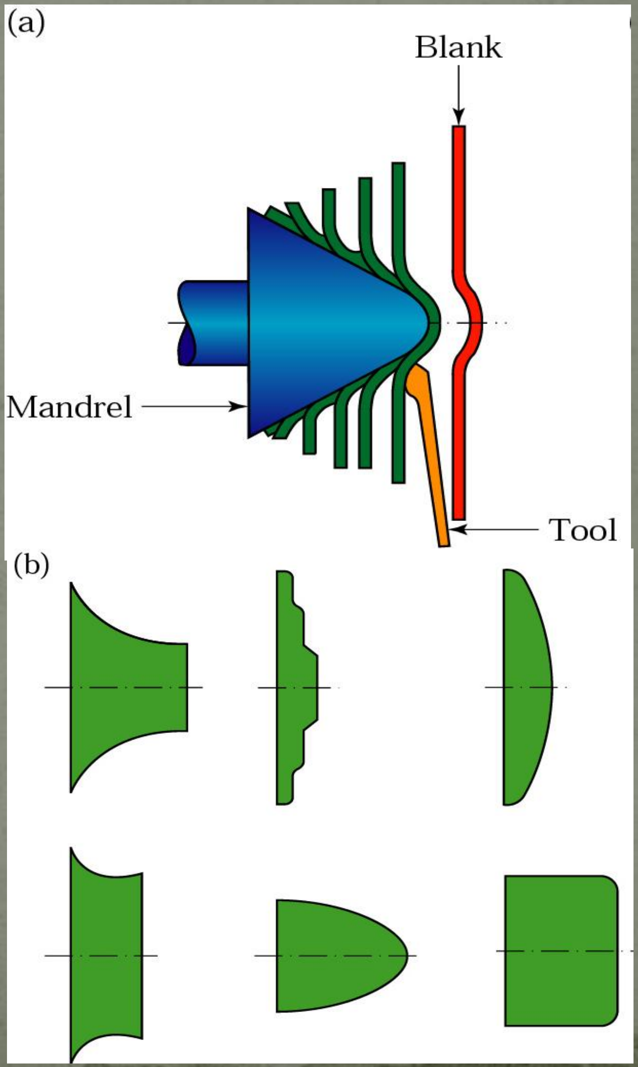
16.8 Rubber Forming

- Rubber Forming
  - One of the dies in the set is made of polyurethane membrane, which is a type of flexible material.
  - Polyurethane is resistant to abrasion, cutting or tearing by the metal, and has a long fatigue life.



16.9 Spinning

- Conventional Spinning
  - Process where a circular piece of sheet metal is placed and held against a mandrel and rotated while a rigid tool deforms and shapes the material over the mandrel.
  - May be performed at room temperature or at higher temperature for thicker metal.



Powder Metallurgy

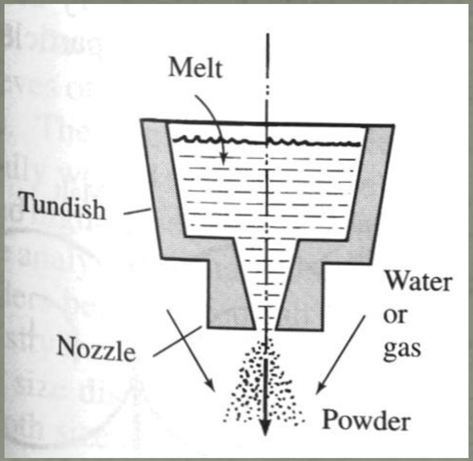
Example Parts

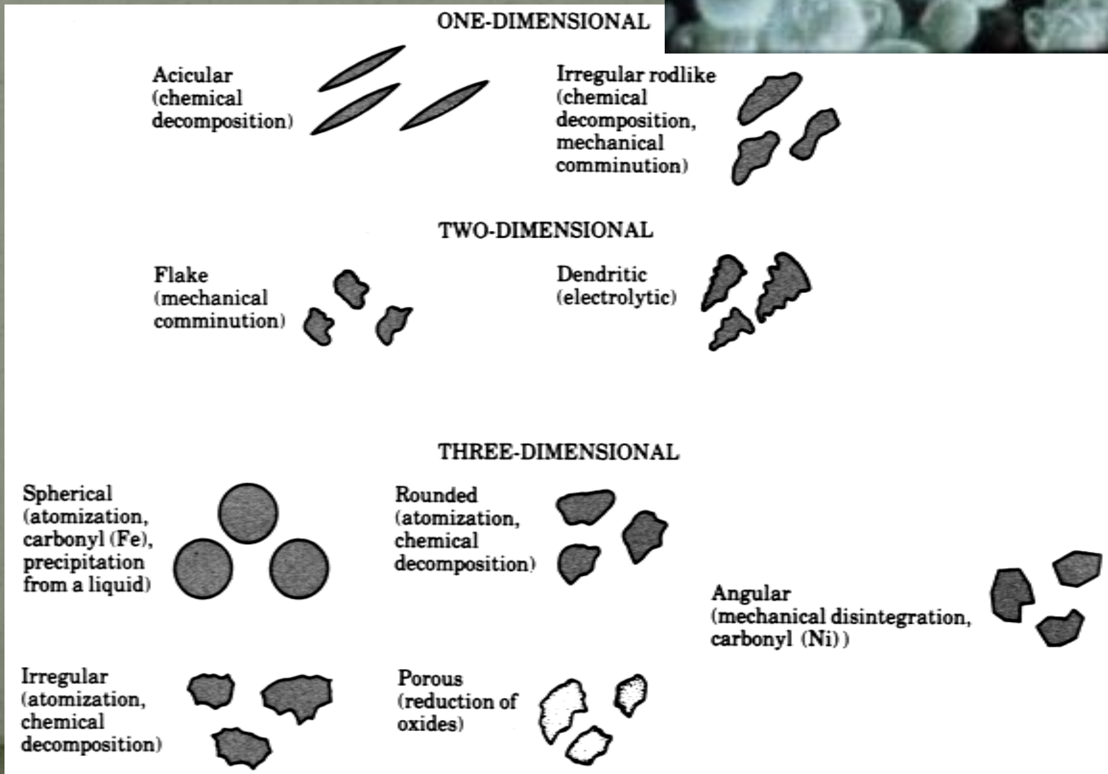
Basic Steps In Powder Metallurgy (P/M)

- Powder Production
- Blending or Mixing
- Compaction
- Sintering
- Finishing

Powder Production

- Atomization the most common
- Others
  - Chemical reduction of oxides
  - Electrolytic deposition
- Different shapes produced
  - Will affect compaction process significantly



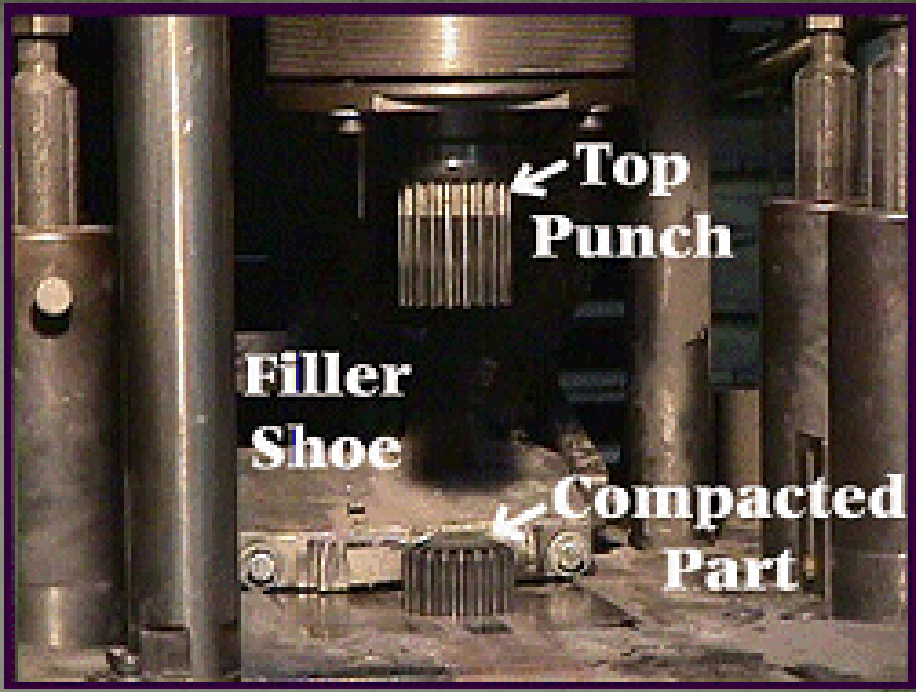


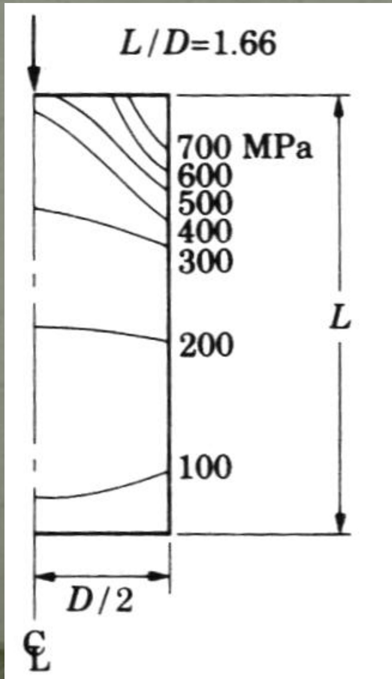
Blending or Mixing

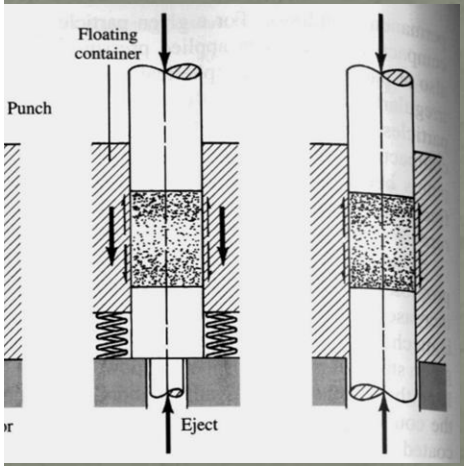
- Can use master alloys, (most commonly) or elemental powders that are used to build up the alloys
  - Master alloys are with the normal alloy ingredients
- Elemental or pre-alloyed metal powders are first mixed with lubricants or other alloy additions to produce a homogeneous mixture of ingredients
- The initial mixing may be done by either the metal powder producer or the P/M parts manufacturer
- When the particles are blended:
  - Desire to produce a homogenous blend
  - Over-mixing will work-harden the particles and produce variability in the sintering process

action

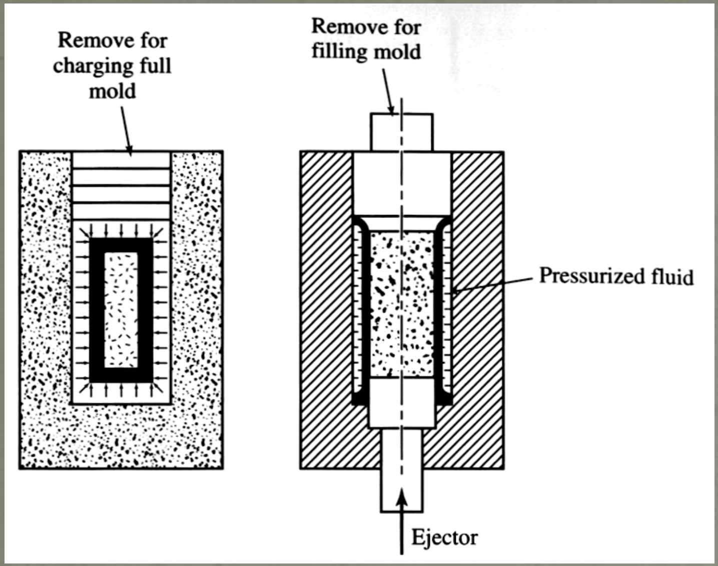
- Usually gravity filled cavity at room temperature
- Pressed at 60-100 ksi
- Produces a "Green" compact
  - Size and shape of finished part (almost)
  - Not as strong as finished part – handling concern
- Friction between particles is a major factor







Isostatic Pressing



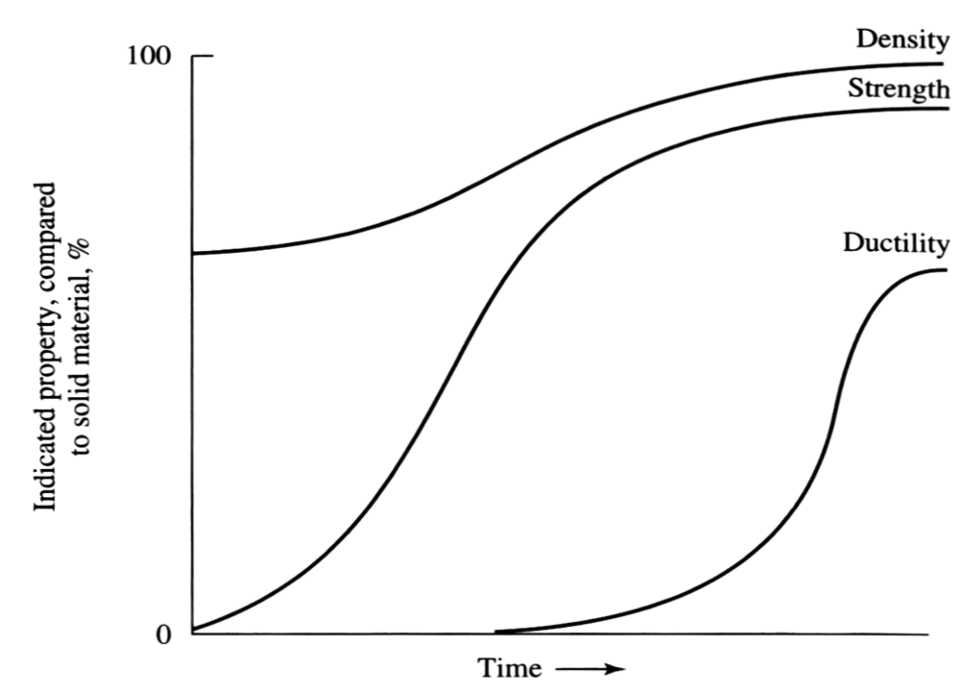
- Because of friction between particles
  - Apply pressure uniformly from all directions (in theory)
- Wet bag (left)
- Dry bag (right)

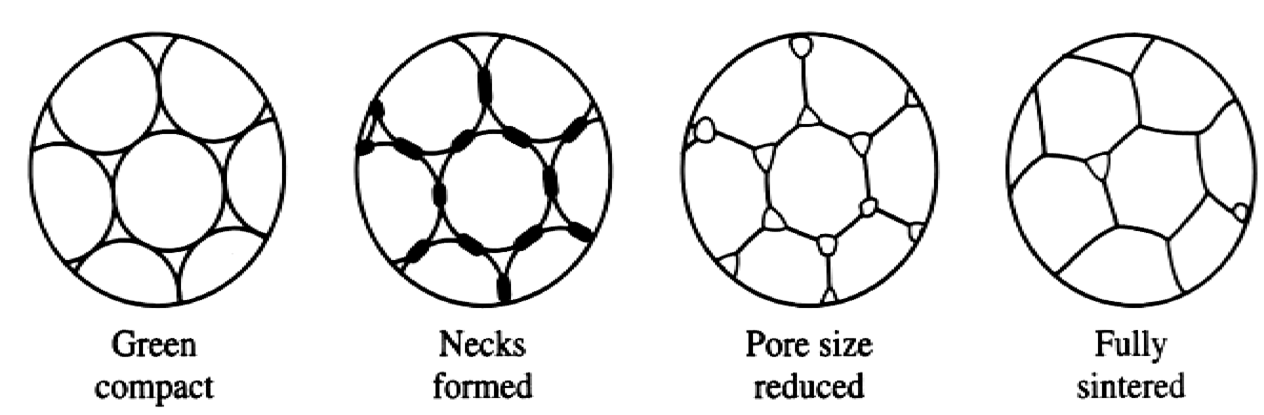
Sintering

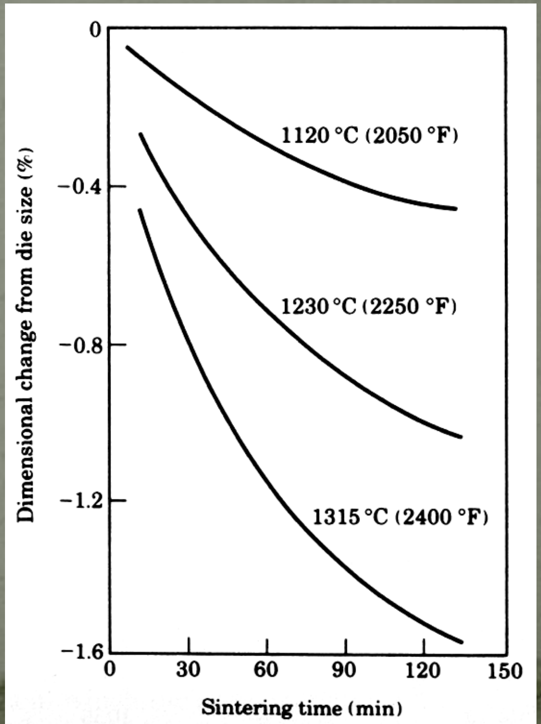
- Parts are heated to ~80% of melting temperature
- Transforms compacted mechanical bonds to much stronger metal bonds
- Many parts are done at this stage. Some will require additional processing

Sintering ctd

- Final part properties drastically affected
- Fully sintered is not always the goal
  - Ie. Self lubricated bushings
- Dimensions of part are affected





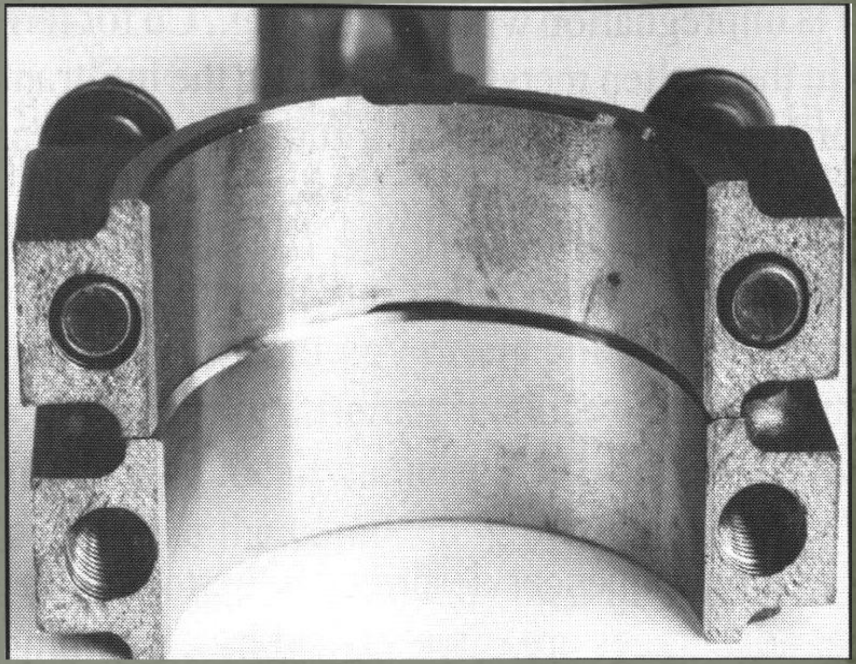


Die Design for P/M

- Thin walls and projections create fragile tooling.
- Holes in pressing direction can be round, square, D-shaped, keyed, splined or any straight-through shape.
- Draft is generally not required.
- Generous radii and fillets are desirable to extend tool life.
- Chamfers, rather the radii, are necessary on part edges to prevent burring.
- Flats are necessary on chamfers to eliminate feather-edges on tools, which break easily.

Advantages of P/M

- Virtually unlimited choice of alloys, composites, and associated properties
  - Refractory materials are popular by this process
- Controlled porosity for self lubrication or filtration uses
- Can be very economical at large run sizes (100,000 parts)
- Long term reliability through close control of dimensions and physical properties
- Wide latitude of shape and design
- Very good material utilization



Disadvantages of P/M

- Limited in size capability due to large forces
- Specialty machines
- Need to control the environment – corrosion concern
- Will not typically produce part as strong as wrought product. (Can repress items to overcome that)
- Cost of die – typical to that of forging, except that design can be more – specialty
- Less well known process

Financial Considerations

- Die design – must withstand 100 ksi, requiring specialty designs
- Can be very automated
  - 1500 parts per hour not uncommon for average size part
  - 60,000 parts per hour achievable for small, low complexity parts in a rolling press
- Typical size part for automation is 1" cube
  - Larger parts may require special machines (larger surface area, same pressure equals larger forces involved)

UNIT V
Manufacturing of Plastic Components

Extrusion

- Raw materials in the form if thermoplastic pallets,granules,or powder, placed into a hopper and fed into extruder barrel.
- The barrel is equipped with a screw that blends the pallets and conveys them down the barrel
- Heaters around the extruder's barrels heats the pellets and liquefies them

Screw has 3-sections

- Feed section
- Melt or transition section
- Pumping section.

- Complex shapes with constant cross-section

- Solid rods, channels, tubing, pipe, window frames, architectural components can be extruded due to continuous supply and flow.

- Plastic coated electrical wire, cable, and strips are also extruded

Pellets :extruded product is a small-diameter rod which is chopped into small pellets

Sheet and film extrusion :

Extruded parts are rolled on water and on the rollers

Extruder

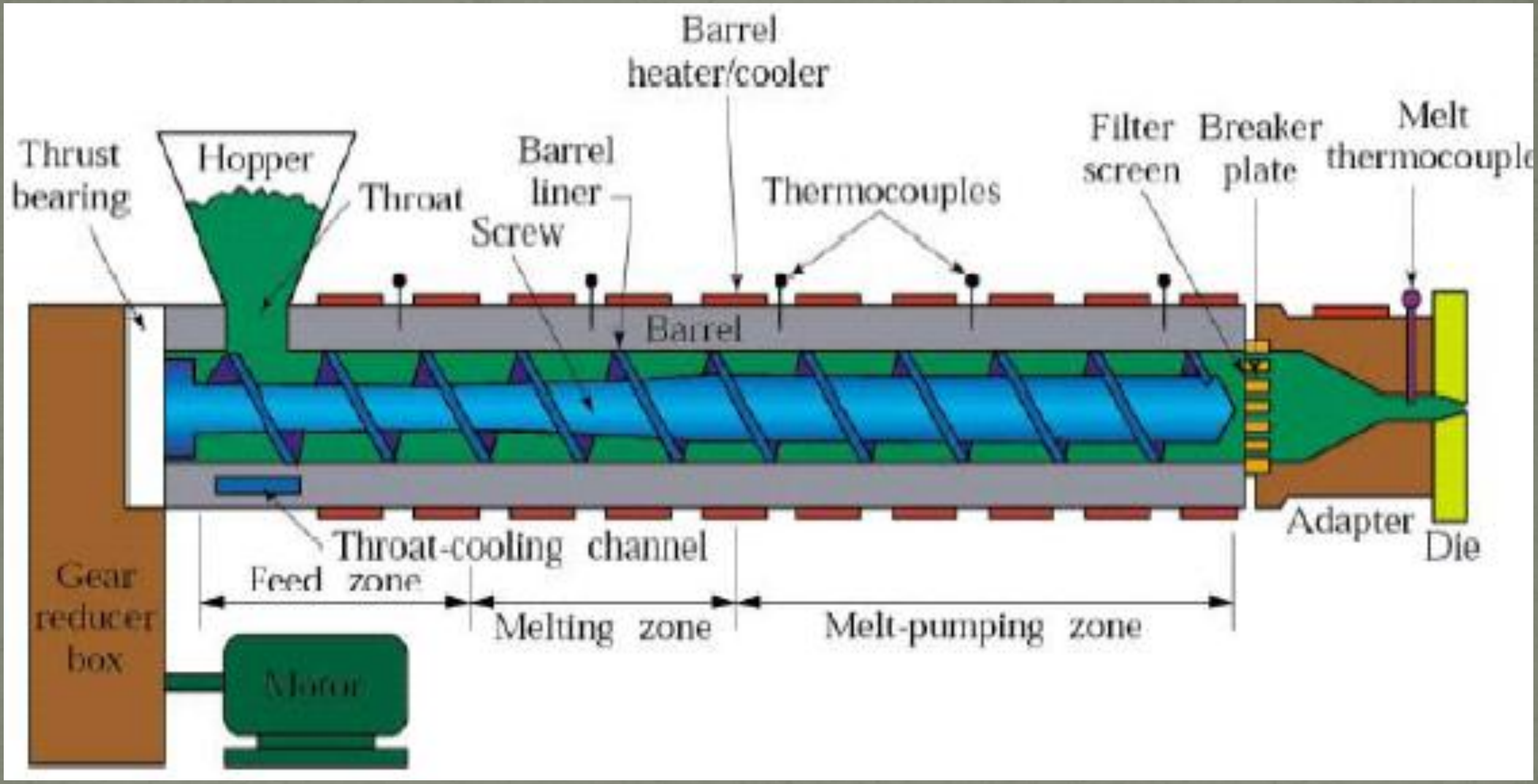


Fig : Schematic illustration of a typical extruder for plastics, elastomers, and composite materials.

Injection molding

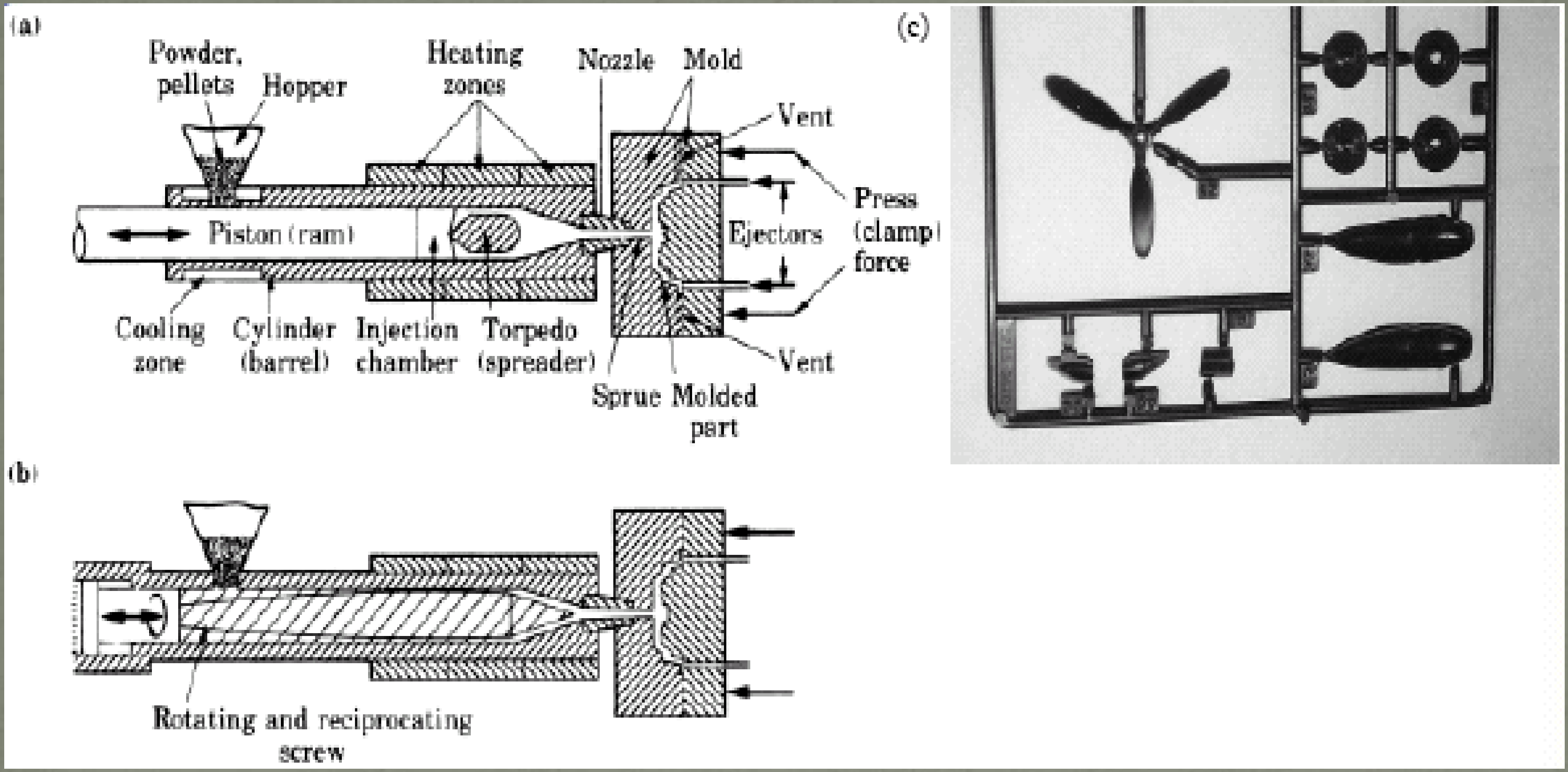


Fig : Injection molding with (a) plunger, (b) reciprocating rotating screw, (c) a typical part made from an injection molding machine cavity, showing a number of parts made from one shot, note also mold features such as sprues, runners and gates.

- Similar to extrusion barrel is heated
- Pellets or granules fed into heated cylinder
- Melt is forced into a split-die chamber
- Molten plastic pushed into mold cavity
- Pressure ranges from 70 Mpa – 200 Mpa
- Typical products : Cups, containers, housings, tool handles, knobs, electrical and communication components, toys etc.

Injection molding

- Injection molds have several components such as runners, cores, cavities, cooling channels, inserts, knock out pins and ejectors

3-basic types of molds

- Cold runner two plate mold
- Cold runner three plate mold
- Hot runner mold

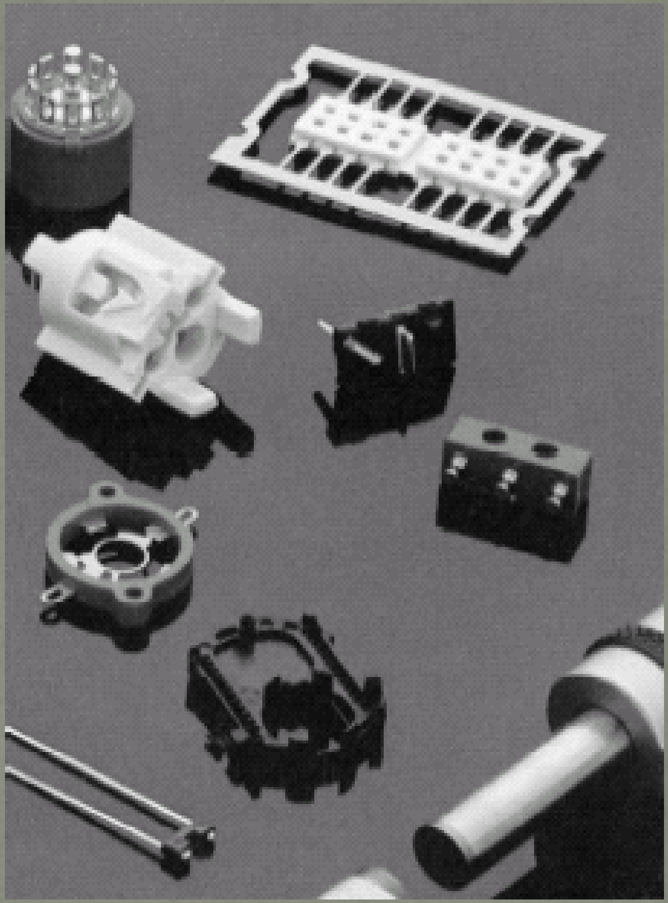


Fig : Examples of injection molding

Injection Molding Machine

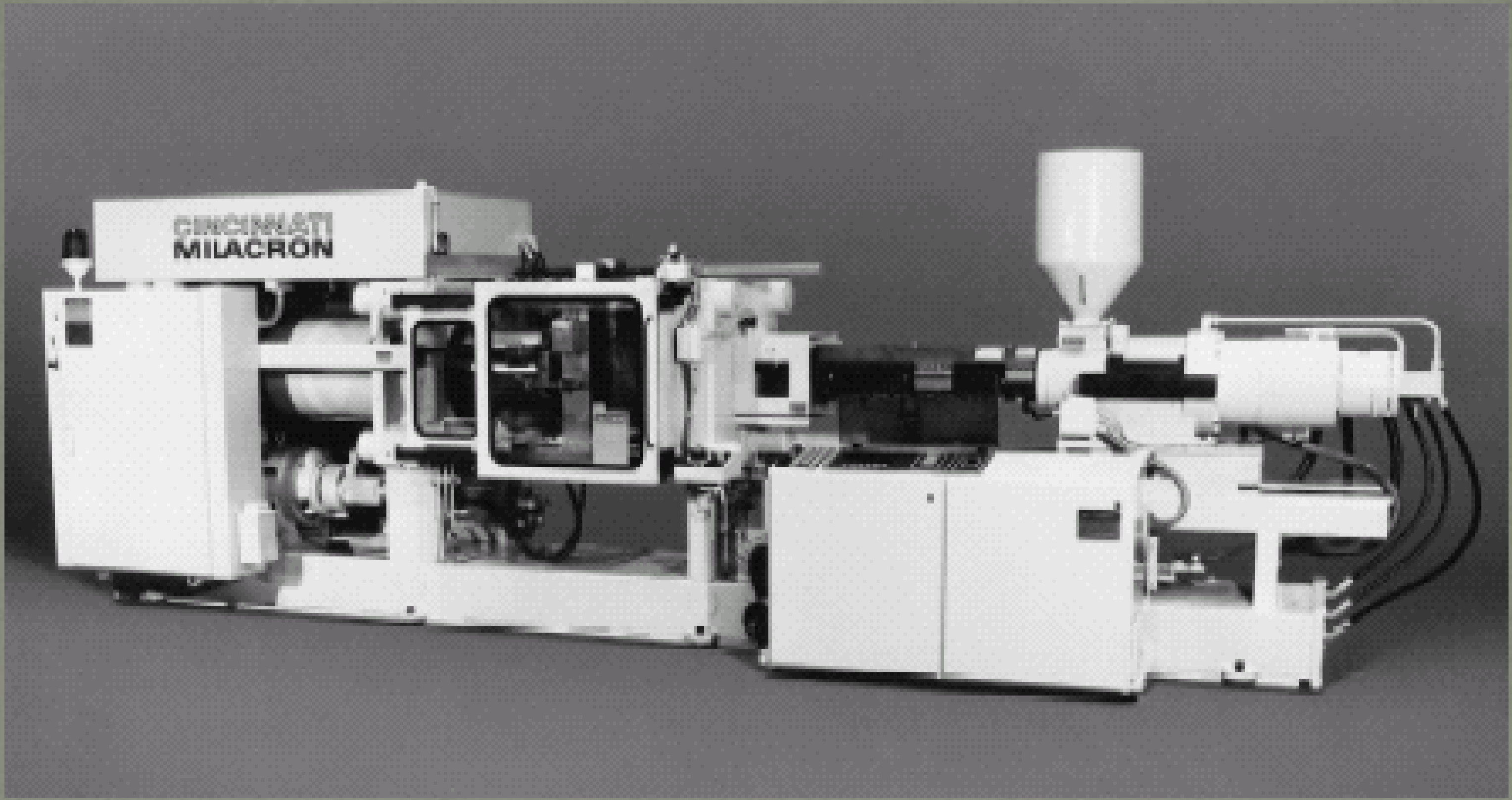


Fig : A 2.2-MN (250-ton) injection molding machine. The tonnage is the force applied to keep the dies closed during injection of molten plastic into the mold cavities.

Process capabilities :

- High production rates
- Good dimensional control
- Cycle time range 5 to 60 sec's
- Mold materials- tool steels, beryllium - Cu, Al
- Mold life- 2 million cycles (steel molds)
  10000 cycles (Al molds)

Machines :

- Horizontal or vertical machines
- Clamping – hydraulic or electric

Blow molding

- Modified extrusion and Injection Molding process.
- A tube extruded then clamped to mold with cavity larger than tube diameter.
- Finally blown outward to fill the cavity
- Pressure 350Kpa-700Kpa

Other Blow Molding processes

- Injection Blow molding
- Multi layer Blow molding

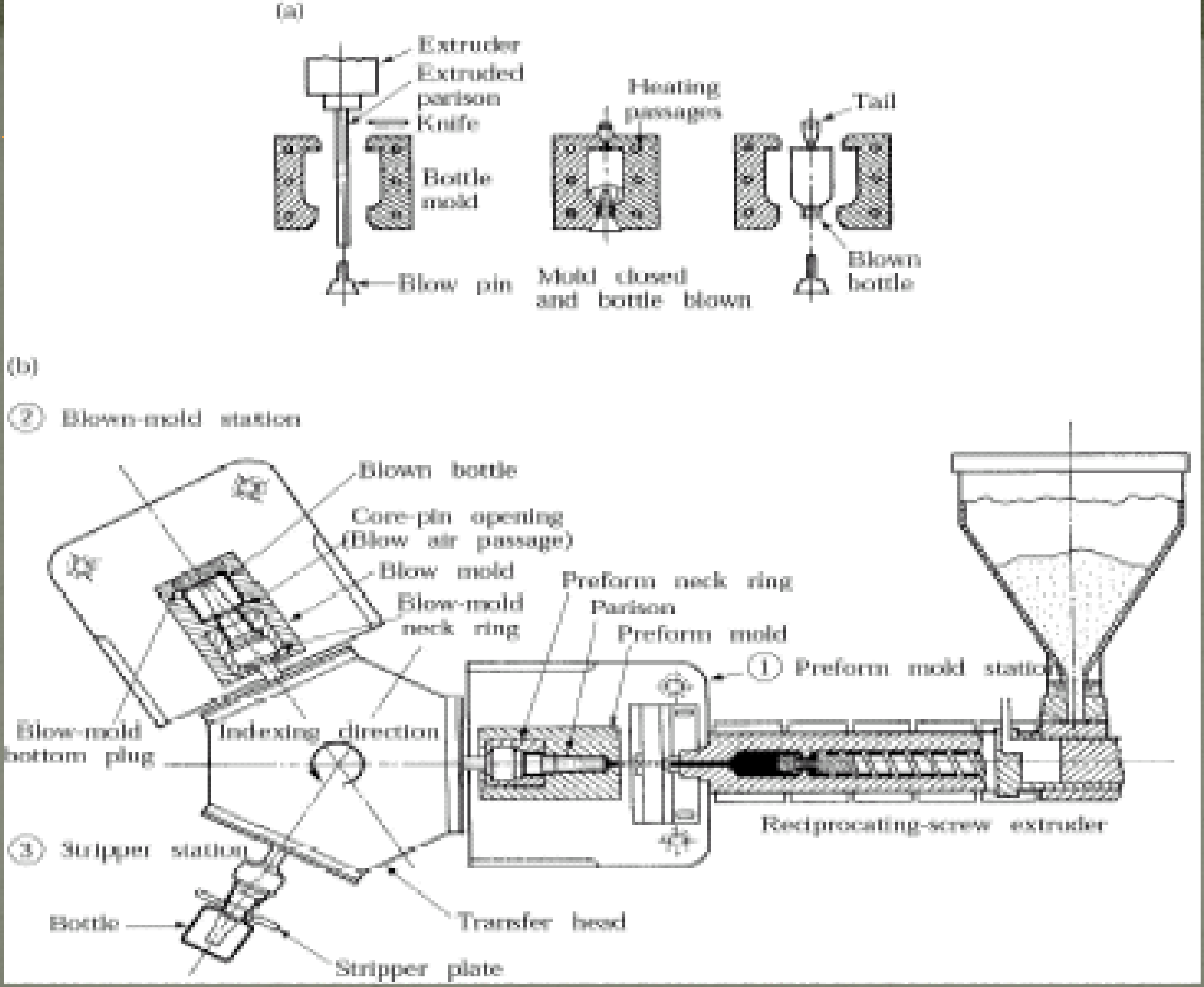


Fig : Schematic illustration of (a) the blow-molding process for making plastic beverage bottles, and (b) a three-station injection blow-molding machine.

Rotational Molding

- Thermo plastics are thermosets can be formed into large parts by rotational molding
- A thin walled metal mold is made of 2 pieces
- Rotated abut two perpendicular axes
- Pre-measured quantity of powdered plastic material is rotated about 2-axes
- Typical parts produced-Trash cans, boat hulls, buckets, housings, toys, carrying cases and foot balls.

Rotational Molding

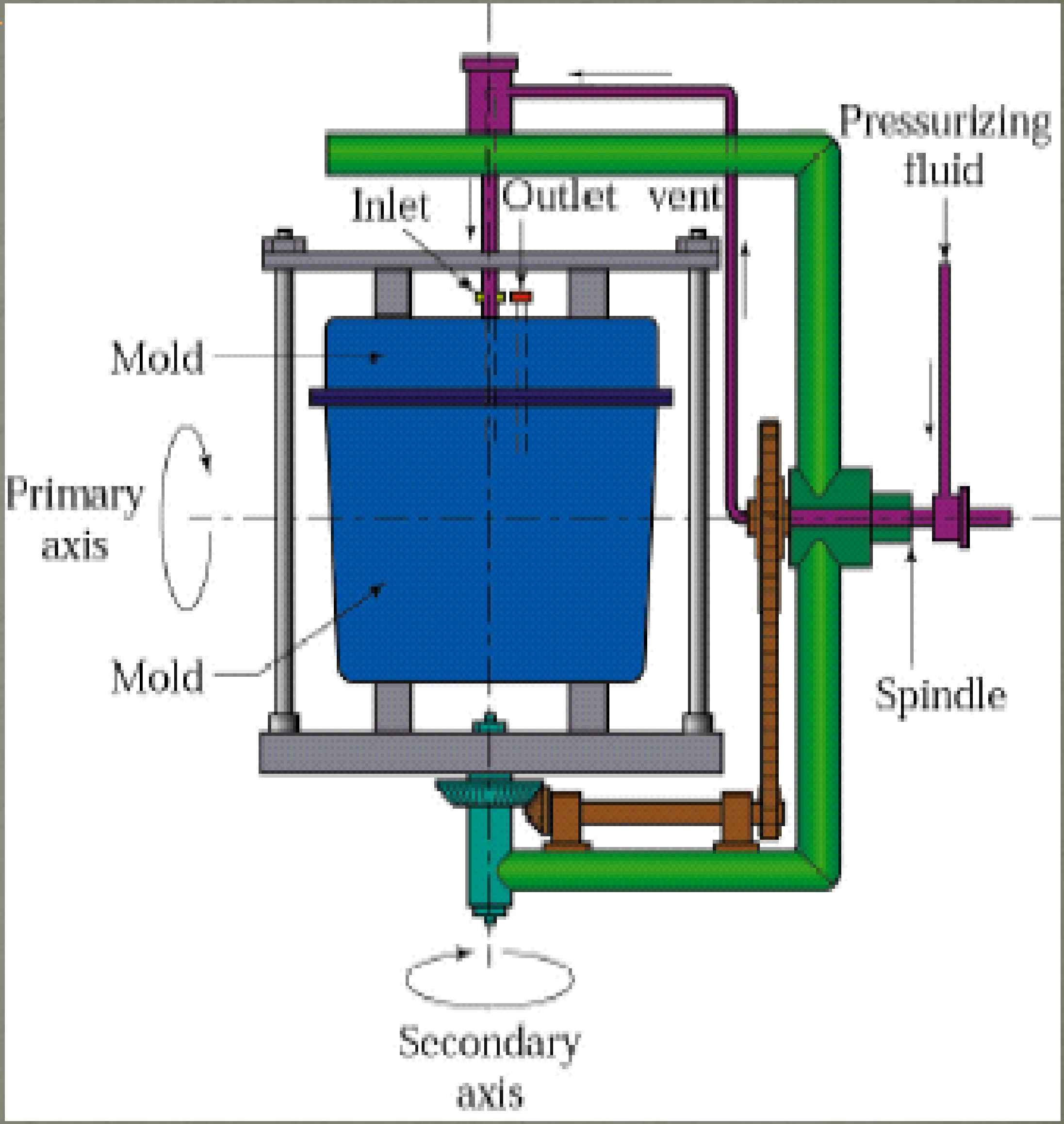


Fig: The rotational molding (rotomolding or rotocasting) process. Trash cans, buckets, and plastic footballs can be made by this process.

Thermoforming

- Series process for forming thermoplastic sheet or film over a mold by applying heat and pressure.
- Typical parts : advertising signs, refrigerator liner, packaging , appliance housing, and panels for shower stalls .

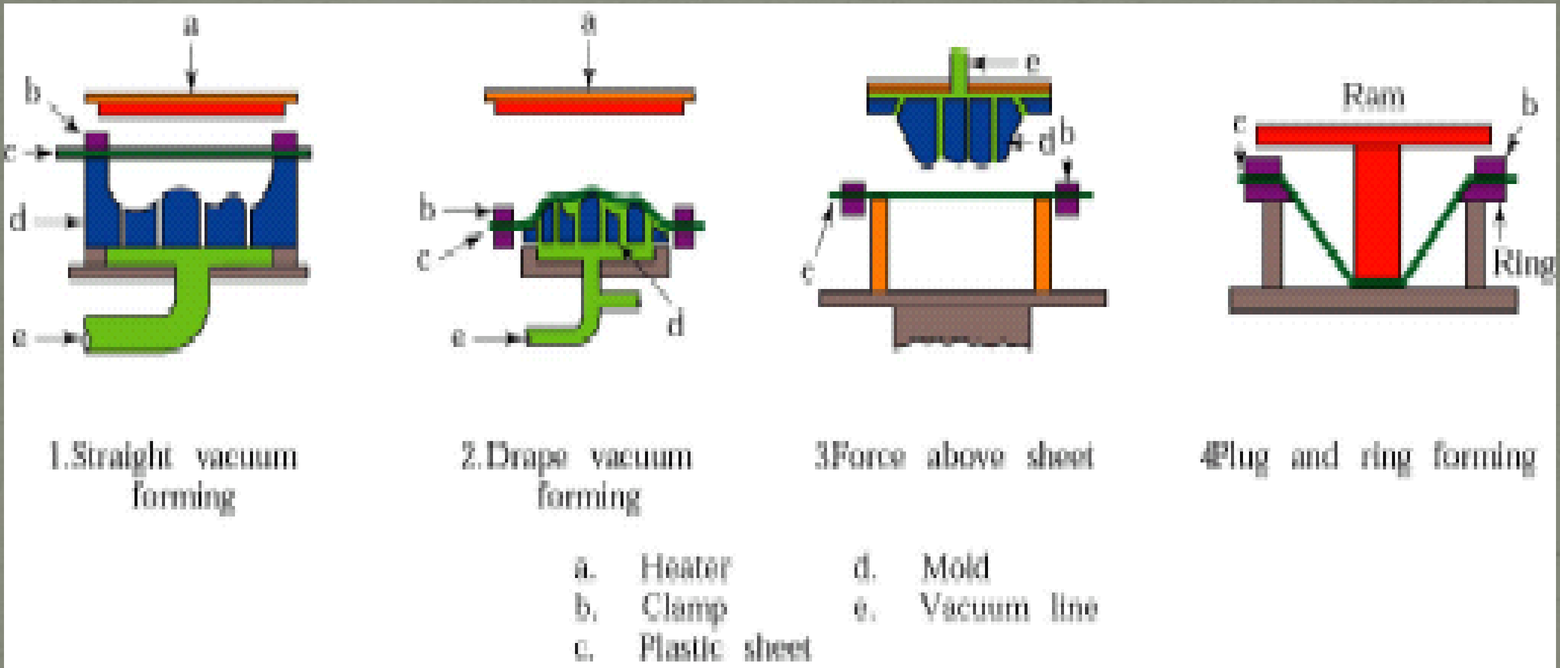


Fig : Various Thermoforming processes for thermoplastic sheet. These processes are commonly used in making advertising signs, cookie and candy trays, panels for shower stalls, and packaging.

Compression molding

- Pre-shaped charge ,pre-measured volume of powder and viscous mixture of liquid resin and filler material is placed directly into a heated mold cavity.
- Compression mold results in a flash formation which is a n excess material.
- Typical parts made are dishes, handles, container caps fittings, electrical and electronic components and housings
- Materials used in compression molding are thermosetting plastics & elastomers
- Curing times range from 0.5 to 5 mins

3- types of compression molds are

- Flash type
- Positive type
- Semi-positive

Compression Molding

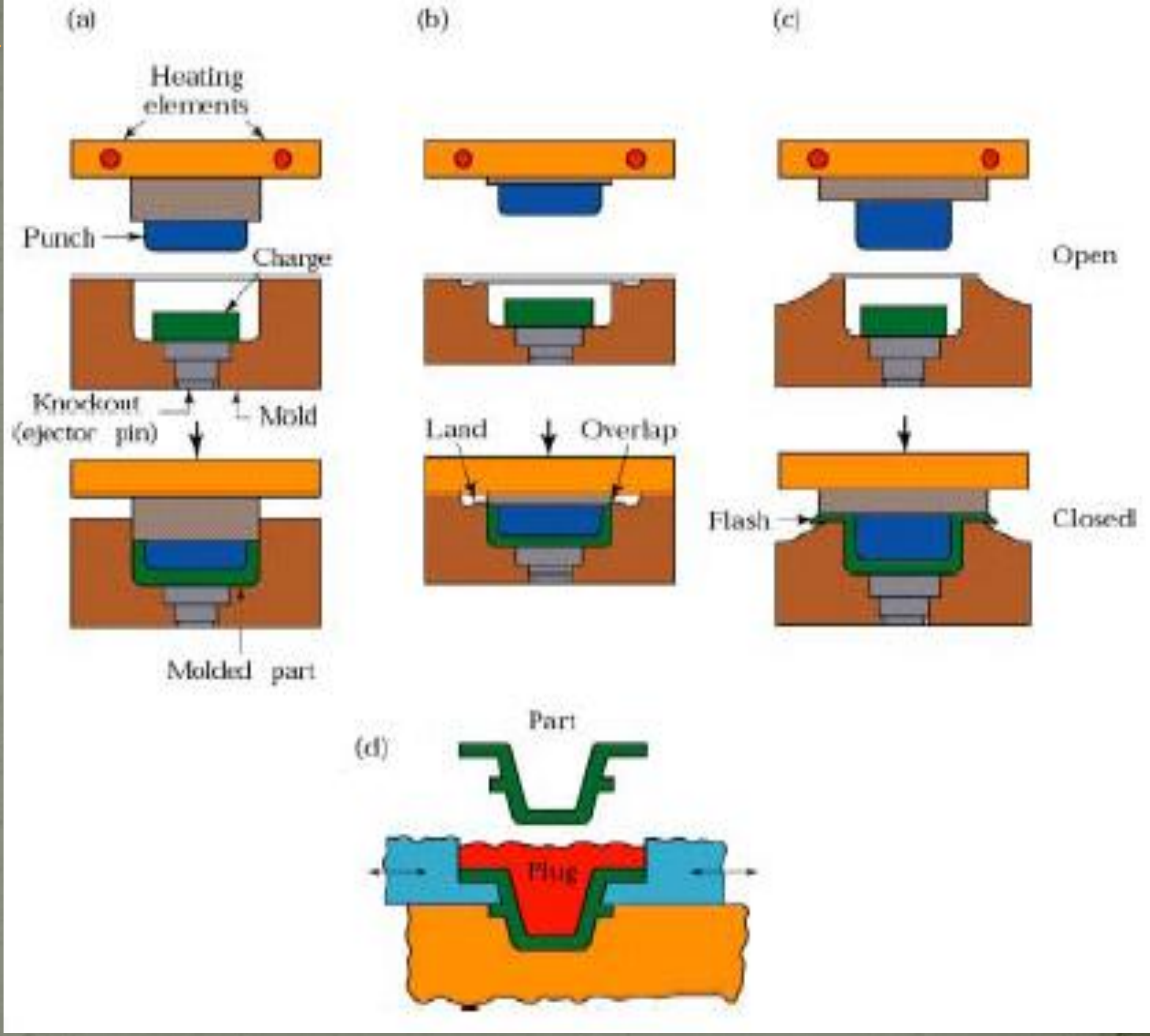


Fig : Types of compression molding, a process similar to forging; (a) positive, (b) semi positive, (c) flash (d) Die design for making compression-molded part with undercuts.

Transfer molding

- Transfer molding is an improvement if compression molding
- Uncured thermosetting material placed in a heated transfer pot or chamber, which is injected into heated closed molds
- Ram plunger or rotating screw feeder forces material into mold cavity through narrow channels
- This flow generates heat and resin is molten as it enters the mold

Typical parts : Electrical & electronic components, rubber and silicone parts

Transfer molding

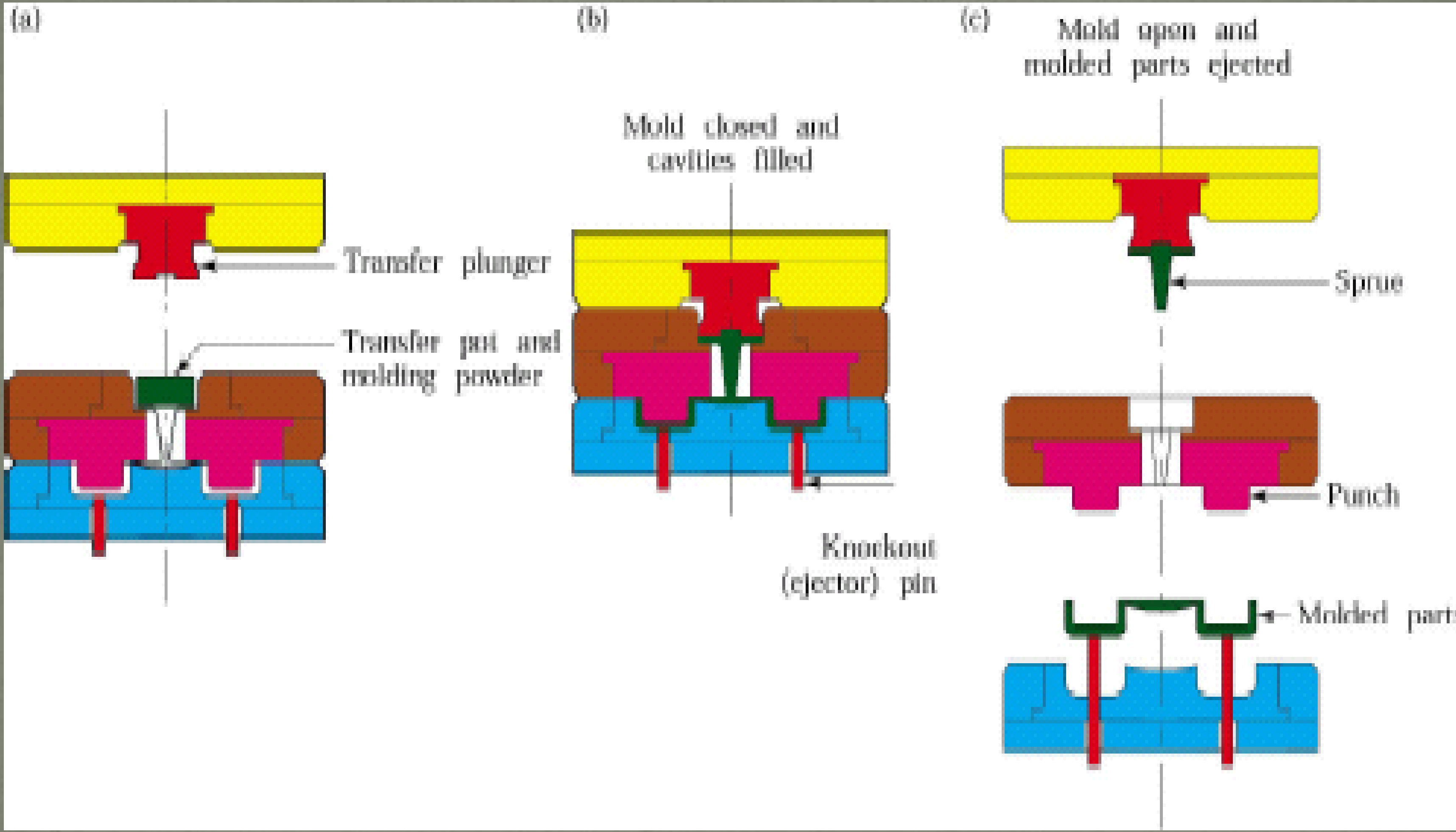


Fig : Sequence of operations in transfer molding for thermosetting plastics. This process is particularly suitable for intricate parts with varying wall thickness.

Casting

Conventional casting of thermo plastics :

- Mixture of monomer, catalyst and various additives are heated and poured into the mould
- The desired part is formed after polymerization takes place.

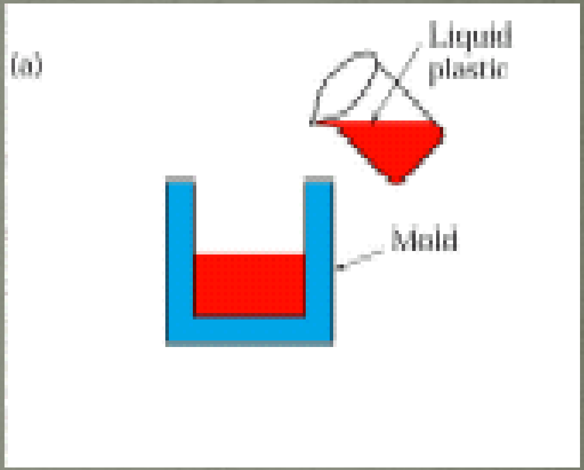


Fig : Casting

Centrifugal casting :

- Centrifugal force used to stack the material onto the mold
- Reinforced plastics with short fibers are used

Cold forming

- Processes such as rolling ,deep drawing extrusion closed die forging ,coining and rubber forming can be used for thermoplastics at room temperatures

- Typical materials used : Poly propylene, poly carbonate, Abs, and rigid PVC

Considerations :

- Sufficiently ductile material at room temperature
- Non recoverable material deformation

Solid Phase forming

- Temperatures from 10°c to 20°c are maintained, which is below melting point

Advantages :

- Spring-back is lower
- Dimensional accuracy can be maintained

Calendaring and Examples of Reinforced Plastics

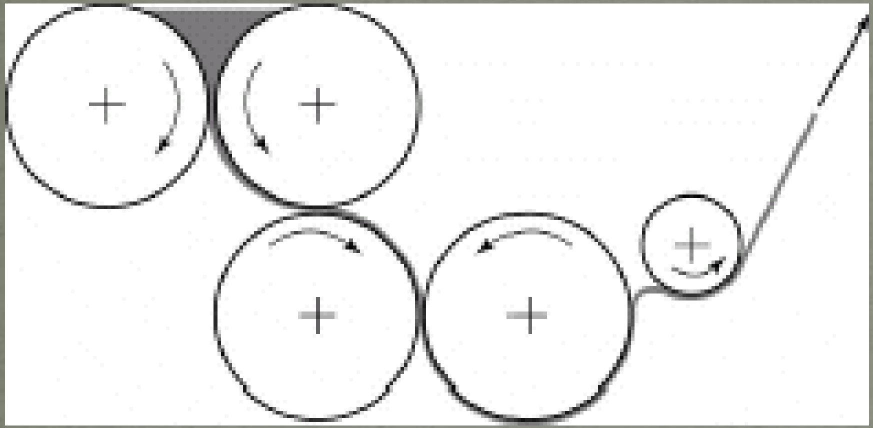


Fig : Schematic illustration of calendaring, Sheets produced by this process are subsequently used in thermoforming.

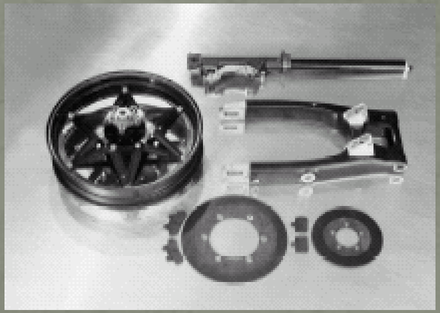


Fig : Reinforced-plastic components for a Honda motorcycle. The parts shown are front and rear forks, a rear swing arm, a wheel, and brake disks.

Sheet Molding

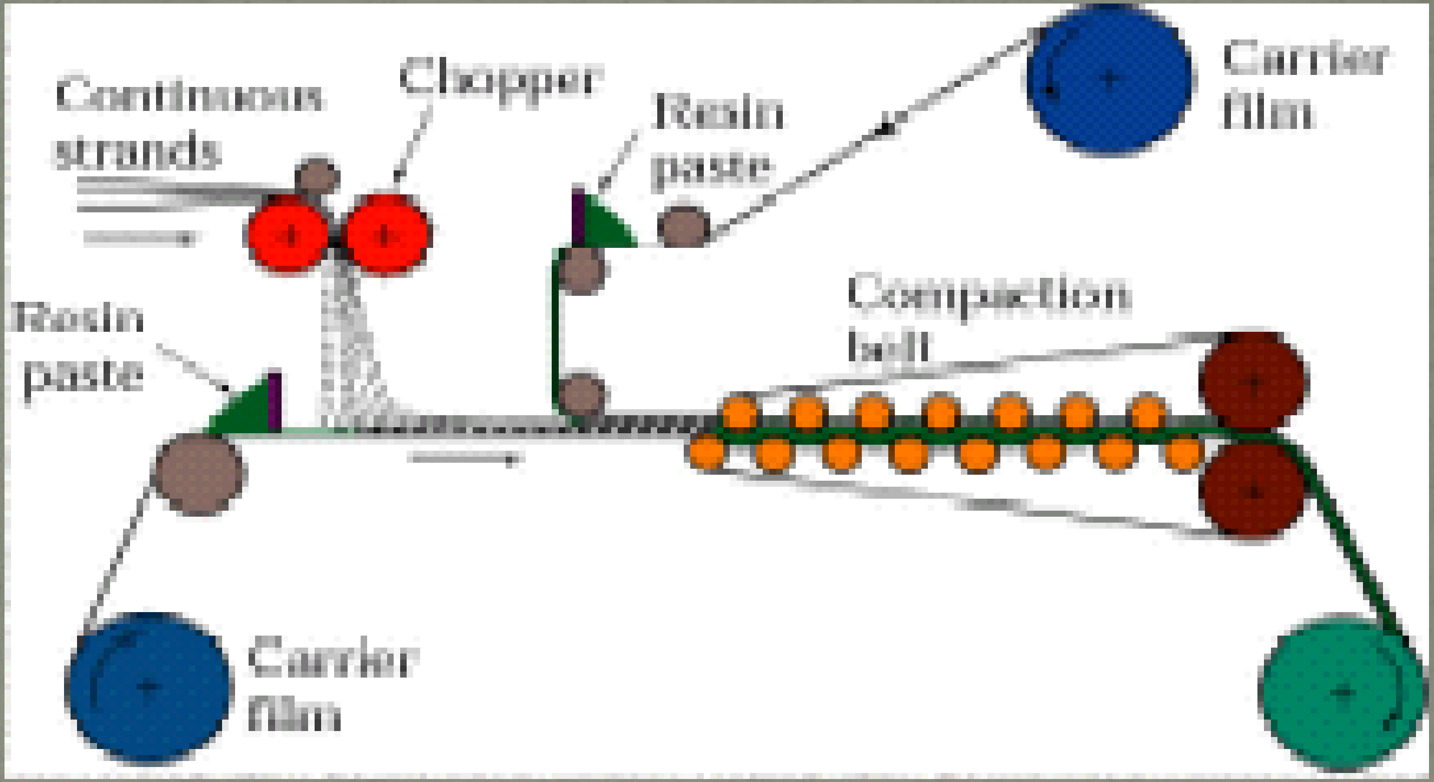


Fig : The manufacturing process for producing reinforced-plastic sheets. The sheet is still viscous at this stage; it can later be shaped into various products.

Examples of Molding processes

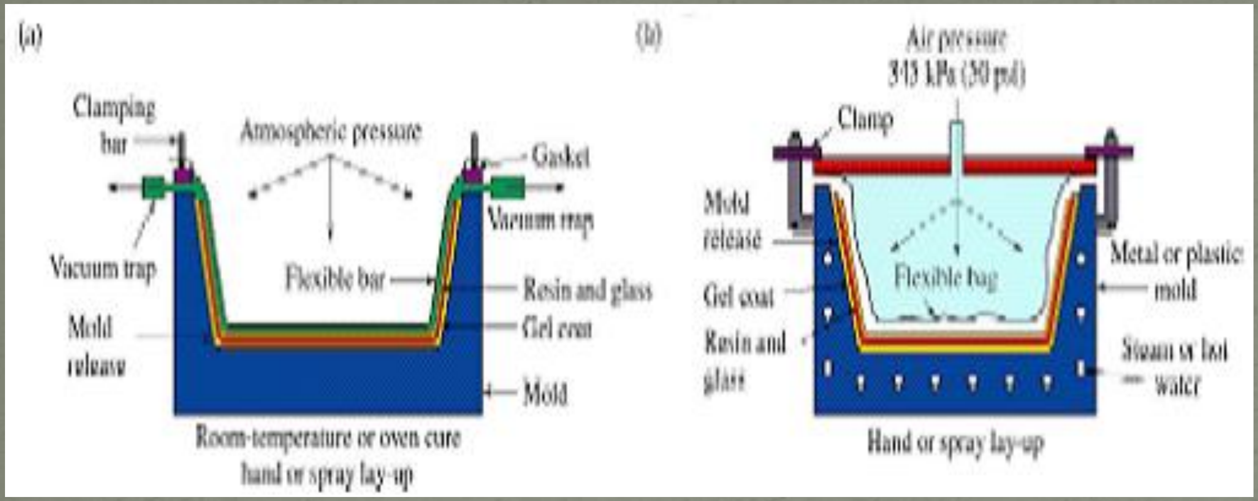


Fig : (a) Vacuum-bag forming.
(b) Pressure-bag forming.

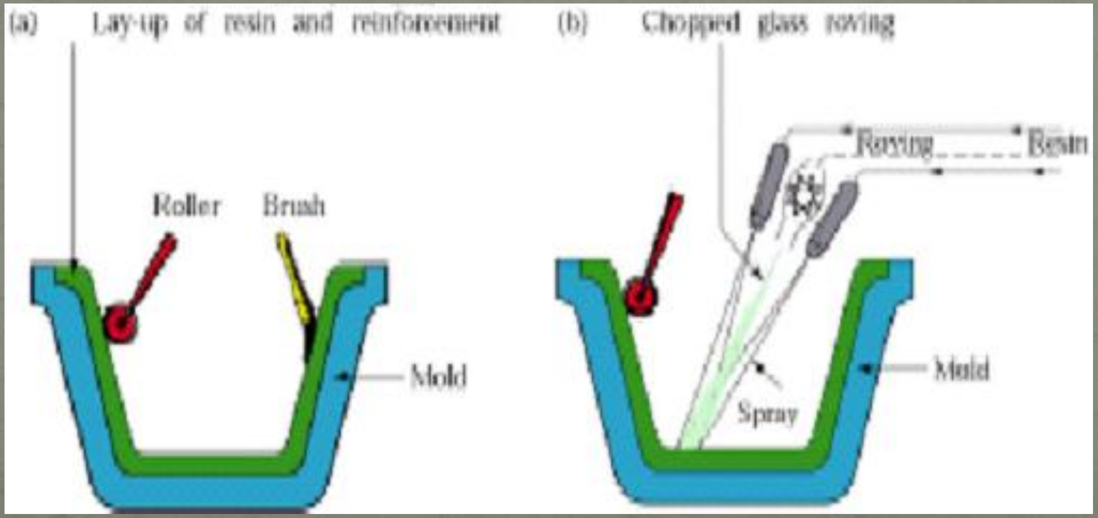


Fig : Manual methods of processing reinforced plastics: (a) hand lay-up and (b) spray-up. These methods are also called open-mold processing.

THANK YOU