



GRT INSTITUTE OF ENGINEERING AND TECHNOLOGY, Tiruttani.

DEPARTMENT OF AUTOMOBILE ENGINEERING

R – 2013

ME6352

MANUFACTURING TECHNOLOGY

**L T P C
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OBJECTIVES:

- The automobile components such as piston, connecting rod, crankshaft, engine block, front axle, frame, body etc., are manufactured by various types of production processes involving casting, welding, machining, metal forming, power metallurgy etc. Hence B.E. Automobile Engineering students must study this course Production Technology.

UNIT I CASTING

8

Casting types, procedure to make sand mould, types of core making, moulding tools, machine moulding, special moulding processes – CO₂ moulding; shell moulding, investment moulding, permanent mould casting, pressure die casting, centrifugal casting, continuous casting, casting defects.

UNIT II WELDING

8

Classification of welding processes. Principles of Oxy-acetylene gas welding. A.C metal arc welding, resistance welding, submerged arc welding, tungsten inert gas welding, metal inert gas welding, plasma arc welding, thermit welding, electron beam welding, laser beam welding, defects in welding, soldering and brazing.

UNIT III MACHINING

13

General principles (with schematic diagrams only) of working and commonly performed operations in the following machines: Lathe, Shaper, Planer, Horizontal milling machine, Universal drilling machine, Cylindrical grinding machine, Capstan and Turret lathe. Basics of CNC machines. General principles and applications of the following processes: Abrasive jet machining, Ultrasonic machining, Electric discharge machining, Electro chemical machining, Plasma arc machining, Electron beam machining and Laser beam machining.

UNIT IV FORMING AND SHAPING OF PLASTICS

7

Types of plastics - Characteristics of the forming and shaping processes – Moulding of Thermoplastics – Working principles and typical applications of - Injection moulding – Plunger and screw machines – Blow moulding – Rotational moulding – Film blowing – Extrusion - Typical industrial applications – Thermoforming – Processing of Thermosets – Working principles and typical applications - Compression moulding – Transfer moulding – Bonding of Thermoplastics – Fusion and solvent methods – Induction and Ultrasonic methods

UNIT V METAL FORMING AND POWDER METALLURGY

9

Principles and applications of the following processes: Forging, Rolling, Extrusion, Wire drawing and Spinning, Powder metallurgy – Principal steps involved advantages, disadvantages and limitations of powder metallurgy.

TOTAL: 45 PERIODS



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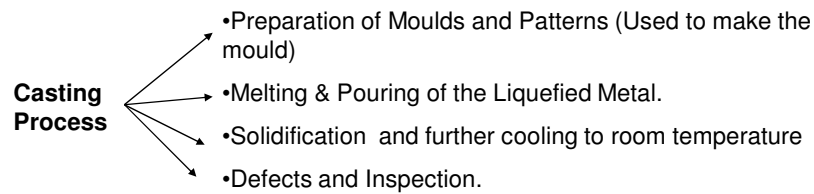
LECTURE NOTES

UNIT I

CASTING

Fundamentals of Casting

- Material is first liquefied by properly heating it in a suitable furnace
- Molten metal is poured in to the prepared mould cavity & it is allowed to solidify.
- Then product is taken out of the mould cavity, trimmed and cleaned to shape.





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Advantages:

The metal casting process is extensively used in manufacturing because of its many advantages.

1. Molten material can flow into very small sections so that **intricate shapes** can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized or eliminated.
2. It is possible to **cast practically any material** that is ferrous or non-ferrous.
3. As the metal can be placed exactly where it is required, large **saving in weight** can be achieved.
4. The necessary tools required for casting molds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.
5. There are certain parts made from metals and alloys that can only be processed this way.
6. **Size and weight of the product is not a limitation** for the casting process.

Limitations:

1. **Dimensional accuracy and surface finish** of the castings made by sand casting processes are a **limitation** to this technique. Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish. Some of these processes are **die casting process, investment casting process, vacuum-sealed molding process, and shell molding process**.
2. The metal casting process is a **labor intensive process**

Casting Terms

1. **Flask:** A metal or wood frame, without fixed top or bottom, in which the mold is formed. Depending upon the position of the flask in the molding structure, it is referred to by various names such as **drag - lower molding flask, cope - upper molding flask, cheek - intermediate molding flask used in three piece molding.**
2. **Pattern:** It is the replica of the final object to be made. The mold cavity is made with the help of pattern.
3. **Parting line:** This is the dividing line between the two molding flasks that makes up the mold.
4. **Molding sand:** Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.
5. **Facing sand:** The small amount of carbonaceous material sprinkled on the inner surface of the mold cavity to give a better surface finish to the castings.
6. **Core:** A separate part of the mold, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
7. **Pouring basin:** A small funnel shaped cavity at the top of the mold into which the molten metal is poured.
8. **Sprue:** The passage through which the molten metal, from the pouring basin, reaches the mold cavity. In many cases it controls the flow of metal into the mold.

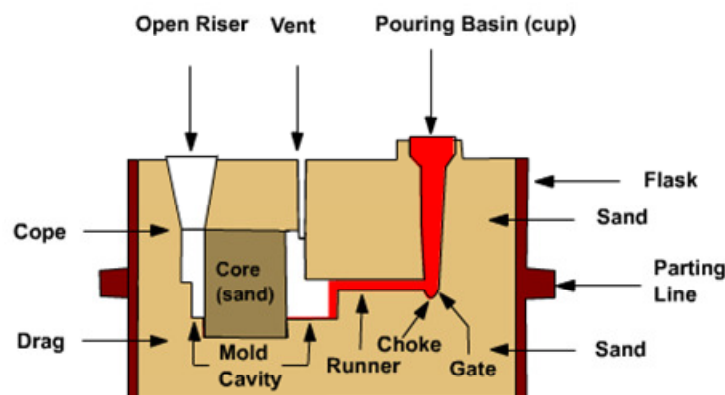


Figure 1 : Mold Section showing some casting terms

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Steps in Making Sand Castings

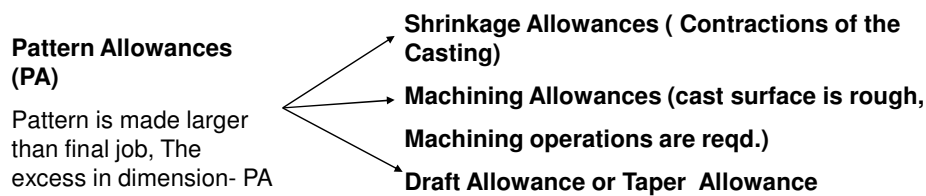
- Pattern making
- Core making
- Molding
- Melting and pouring
- Cleaning

Pattern Making:

- Physical model of the casting used to make the mold
- Mold is made by packing molding sand around the pattern
- When pattern is withdrawn, it imprints form the Mold Cavity
- Hollow Castings (Eg Pipe Fittings) ,Cores are used to form these cavities.

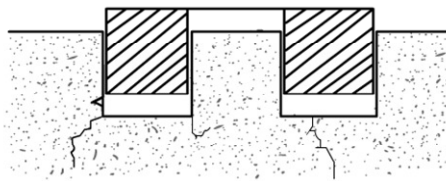
Core making:

- Made up of sand ,to form the interior surface of the casting,
- Openings & cavity in the casting

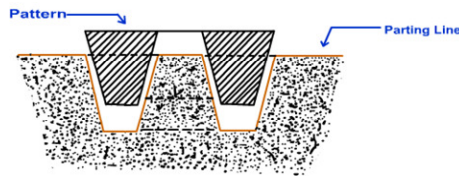


Draft Allowance or Taper Allowance

- Taper provided on the vertical surface of the pattern for easy withdrawal of the pattern from the mould cavity
- Draft facilitates easy withdrawal of the pattern
- Avg value of draft- 0.5 deg-2 deg



Pattern Having No Draft on Vertical Edges



Pattern Having Draft on Vertical Edges

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Mould:

- Mould- Assembly of two or more metal blocks
- Mould Cavity holds the liquid material
- Mould also contains secondary cavities for pouring and
- Channeling the Liquid Material in to the primary cavity & to act as a reservoir.

Flask: Four sided frame in which a sand mould is made

Mould- More Than One Part- Top Portion-**Cope**, Bottom One-**Drag**

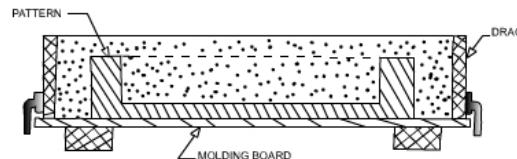
Core: For producing hollow sections ,the entry of liquid metal is prevented in the corresponding portion of the mould cavity.

- Cores are separate structures made of special sand used to form hollow interior of the casting.
- To produce castings with holes & Slots of various sizes & shapes.

Core Prints: Projections on the pattern which forms a seat for locating & supporting the core in the mould.

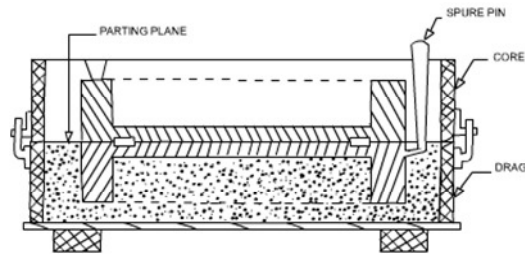
Types of Core Prints: Horizontal Core Print, Vertical Core Print, Balancing core print is used when a horizontal core doesn't extent entirely thru the casting.

Sand Mold Making Procedure

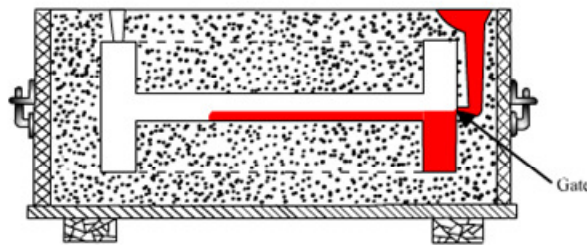


- The first step in making mold is to place the **pattern** on the molding board
- The **drag** is placed on the board
- **Dry facing sand** is sprinkled over the board and pattern to provide a non sticky layer.
- Molding sand is then riddled in to cover the pattern with the fingers; then the drag is completely filled.
- The sand is then firmly packed in the drag by means of **hand rammers**. The ramming must be proper i.e. it must **neither be too hard or soft**.
- After the ramming is over, the excess sand is leveled off with a straight bar known as a **strike rod**.
- With the help of vent rod, **vent holes** are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification.
- The finished drag flask is now **rolled over** to the bottom board exposing the pattern

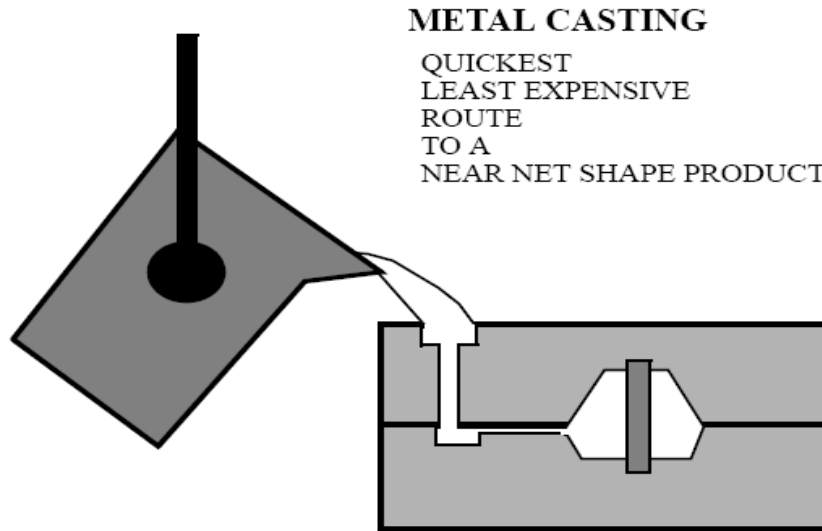
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- **Cope half of the pattern** is then placed over the drag pattern with the help of locating pins. The cope flask on the drag is located aligning again with the help of pins
- The **dry parting sand** is sprinkled all over the drag and on the pattern.
- A **sprue pin** for making the sprue passage is located at a small distance from the pattern. Also, riser pin, if required, is placed at an appropriate place.
- The operation of filling, ramming and venting of the cope proceed in the same manner as performed in the drag.



- The sprue and riser pins are removed first and a pouring basin is **scooped out** at the top to **pour the liquid metal**.
- Then pattern from the cope and drag is removed and **facing sand** in the form of paste is applied all over the mold cavity and runners which would give the finished casting a good surface finish.
- The mold is now assembled. The mold now is ready for pouring

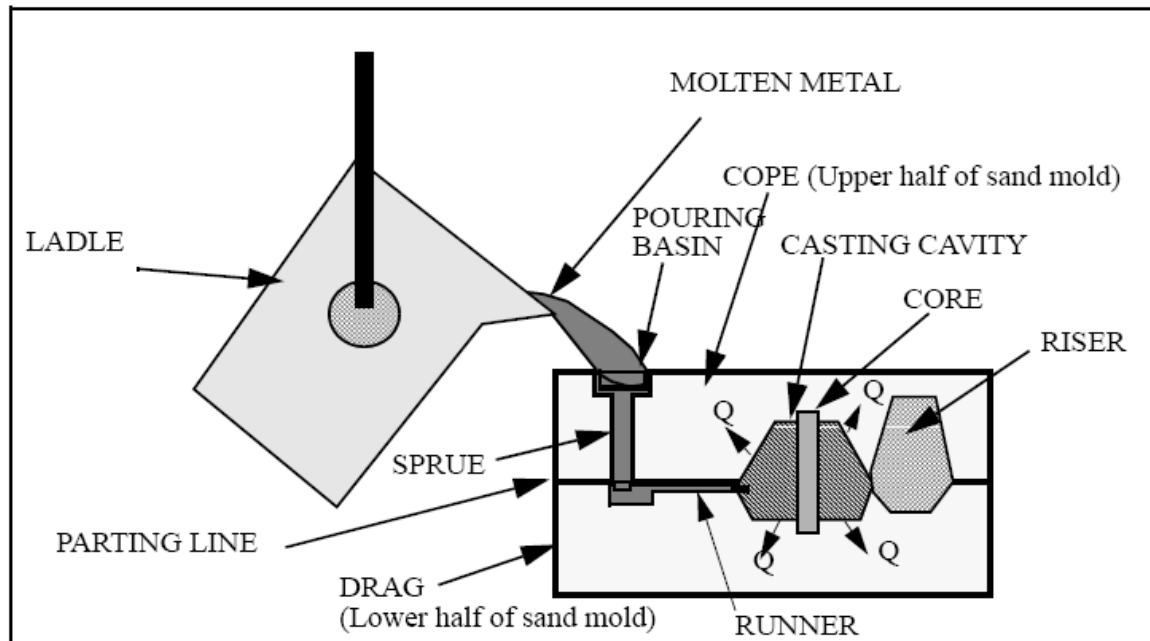


Types of moulds

Permanent pattern expendable mold
Expendable pattern expendable mold
Permanent mold

Table 1: Casting Processes, Mold and Metal Details

Casting Processes	I. Mold Material	II. Manner of Entry	III. State of Metal	IV. State of Mold Cavity
Sand Casting	Sand(Bonded with clay and water or chemicals)	Gravity	100% Liquid	Air
Permanent Mold	Metal	Gravity	100% Liquid	Air
Die Casting	Metal	Pressure	100% Liquid	Air
Investment	Ceramic	Gravity	100% Liquid	Air, Vacuum, Gas
Lost Foam EPC	Sand (Unbonded)	Gravity	100% Liquid	Styrofoam, PMMA
Thixocasting Rheocasting	Metal	Pressure	>50% Liquid Balance Solid	Air
Cosworth	Sand	Vacuum	100% Liquid	Air
V Process	Sand(Unbonded with Vacuum and Enclosing Plastic Film)	Gravity	100% Liquid	Air
Centrifugal	Metal, Graphite	Centrifugal Forces	100% Liquid	Air, Gas Shroud
Ingot - NOT Cast to Shape	Metal or electro-magnetic Field	Gravity	100% Liquid	Air or Gas Shroud



Basic components of a molding process (Sand Casting Process)

Solidification time (Chvorinov's rule)

$$S.T \propto (\text{volume/surface area})^2$$

$$S.T = C (V/S.A)^2$$

Where 'C' is the constant which reflects metal properties (thermal conductivity, specific heat, heat of fusion and melting temp.)

Fluidity of molten metal

Two basic factors influences fluidity

- 1) Characteristics of molten metal

Viscosity

Surface tension

Inclusions

Solidification pattern of metal



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2) Casting parameters

Mold design

Mold material & its surface characteristics

Degree of superheat

Rate of pouring

Heat transfer

Properties of molding sand

Porosity

Molten metal contains a certain amount of dissolved gases which are evolved when metal freezes

When molten metal comes in contact with moist sand, generates steam/water vapour

Gases & water vapour will result in gas holes & pores in the casting

Sand must be sufficiently porous to allow the gases to escape while pouring

Flowability

Refers to its ability to behave like a fluid

While ramming, sand has to flow to all portions of the mould and pack all around the pattern

Collapsibility

Free contraction of metal should occur to avoid tearing/ cracking during solidification

After molten metal gets solidified the mould must be collapsible

Adhesiveness

Sand particles must be capable of adhering to another body (i.e) they should cling to the slides of the sides of the molding boxes.

Due to this property the sand mass can be successfully held in a molding box without allowing it to fall

Cohesiveness/strength

Ability of sand particles to stick together

Insufficient strength may lead to a collapse in the mould

Mould may also get damaged during pouring of molten metal.

Refractoriness

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Sand must be capable of withstanding the high temperature of the molten metal.

Core making:

Casting require to have holes & slots of various sizes & shapes

Cores are separate structures made of special sand used to form hollow interior of the casting

Cores are made in a separate box called core box

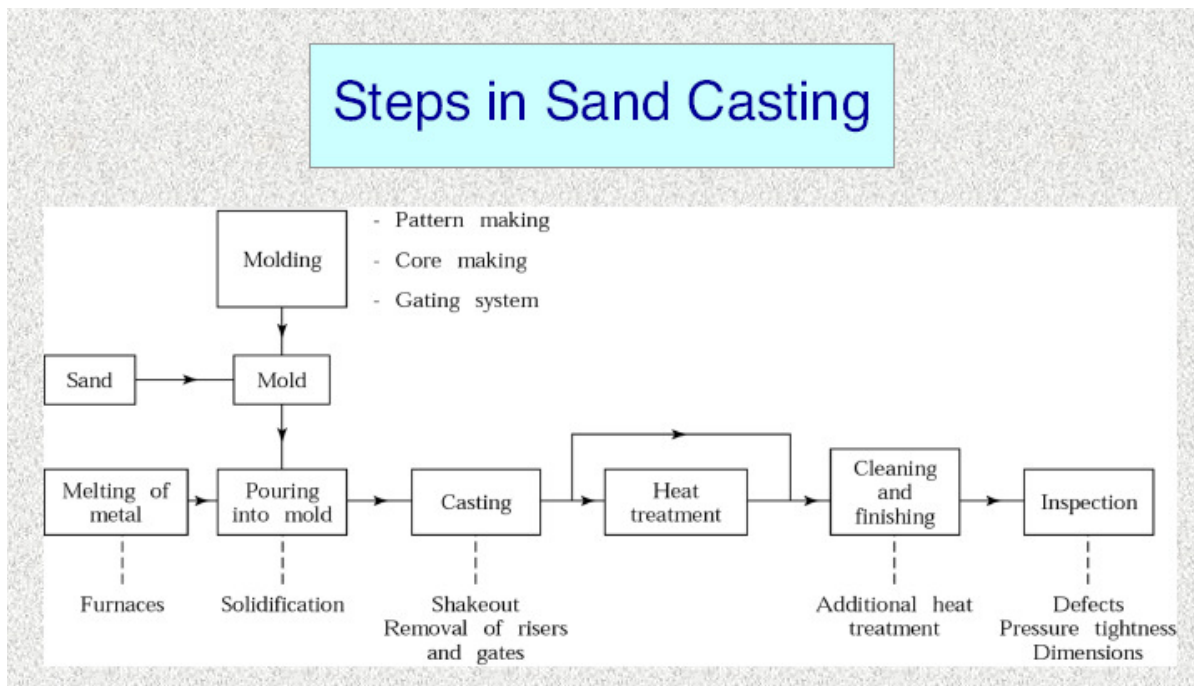
Core print : projection on a pattern which forms a seat ,used to support & locate the core in the mould

Types of core print:

Horizontal core print

Vertical core print

Balancing core print : used when a horizontal core does not extent entirely through the casting



Sand Mold Features

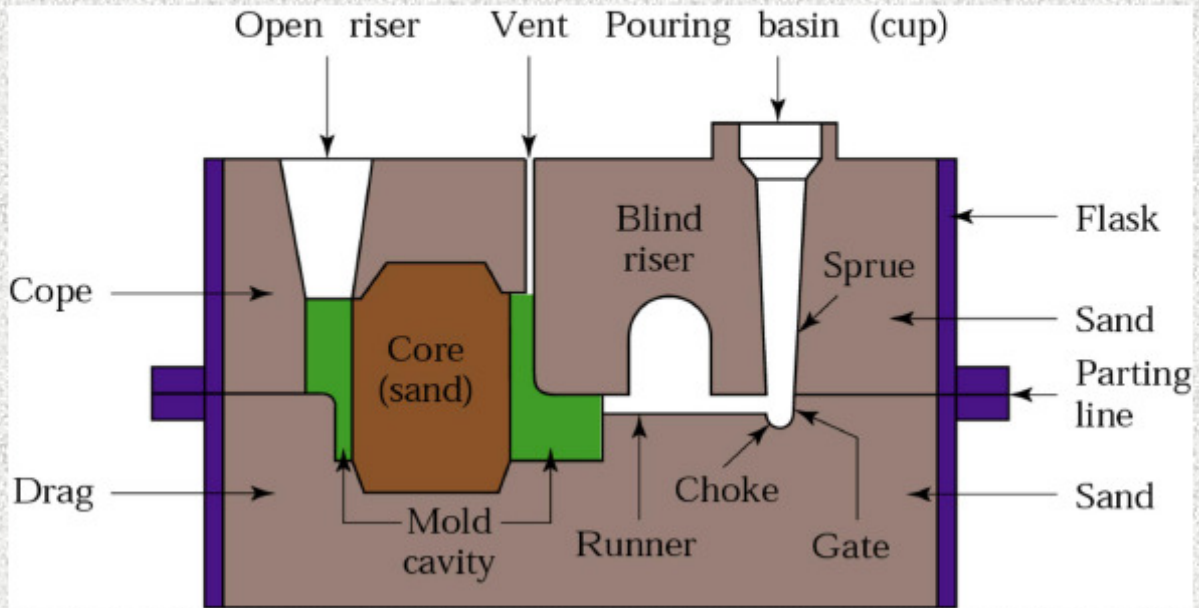


Figure 11.4 Schematic illustration of a sand mold, showing various features.

Shell molding

Pattern – made of copper alloys, Cast iron, Aluminum or Steel

Shell – dry, fine silica

5-10% thermosetting phenolic resin (phenol formaldehyde)

Heated: 200 - 300 C

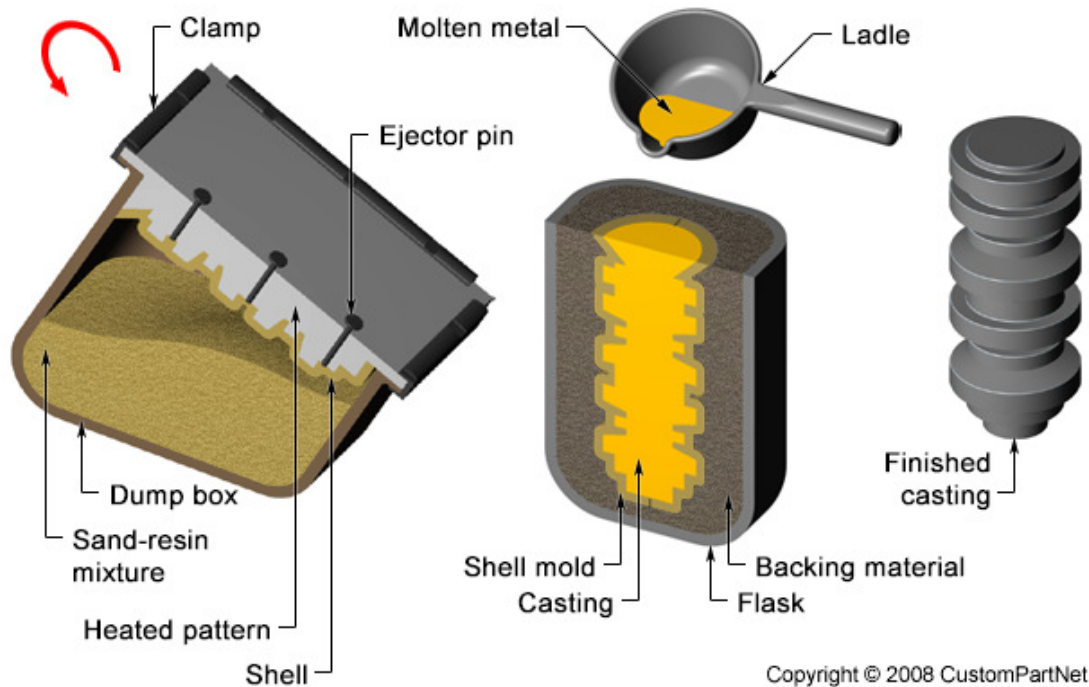
Curing of shell for 1 - 3 min at 250 C – 450 C

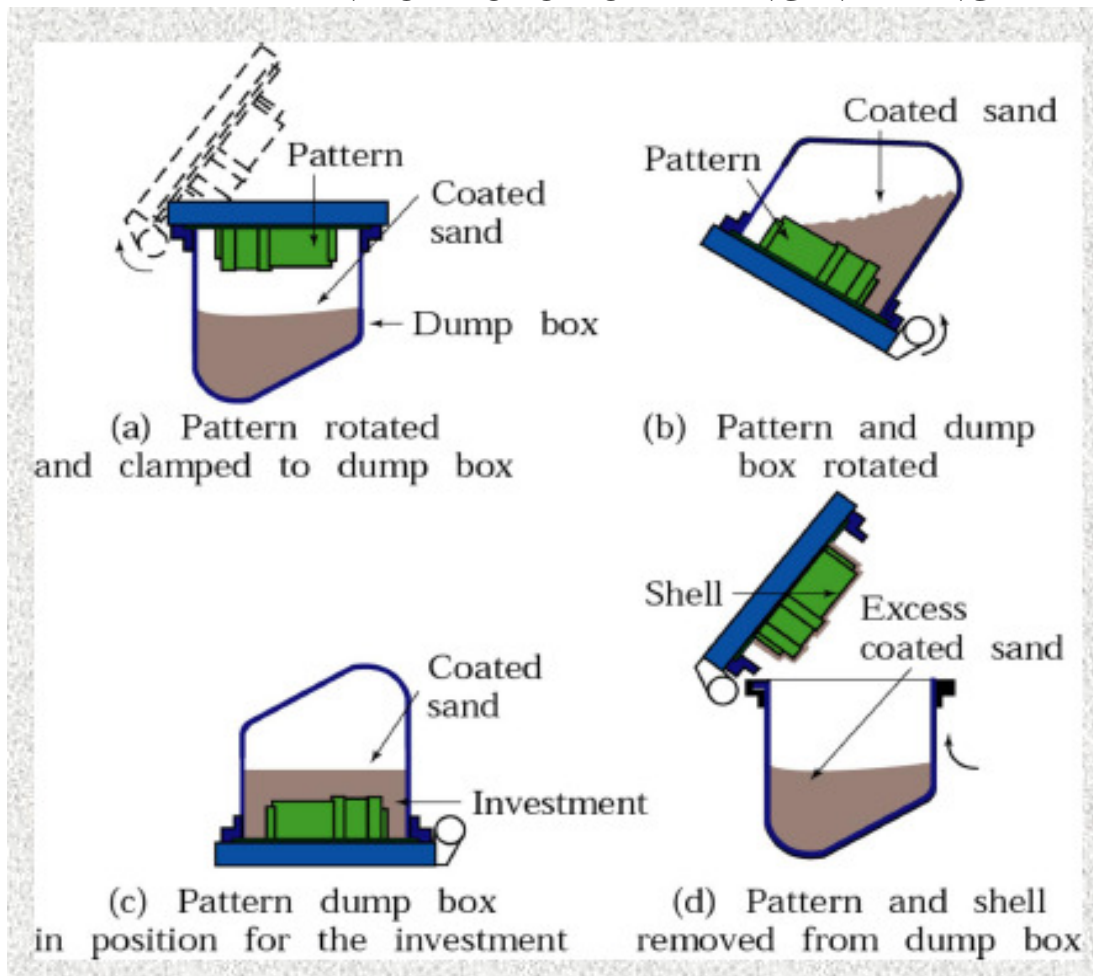
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Shell-Making
(Cross-section)

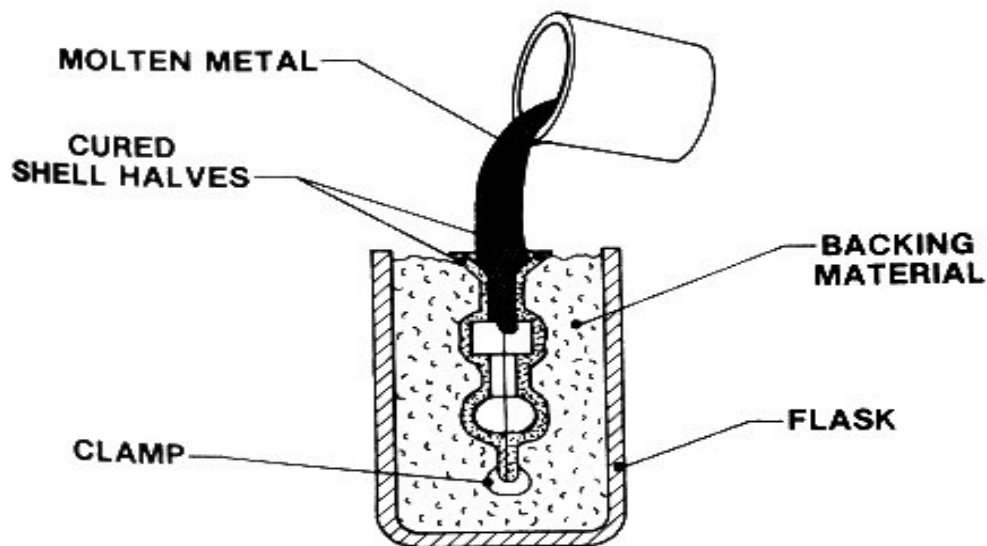
Shell Mold Casting
(Cross-section)

Casting





SHELL MOLD CASTING





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Advantages

- high precision / accurate castings / smooth surface finish
- complex parts
- cleaning of casting is reduced /eliminated
- size of casting is 10 - 13.5 kg
- minimum wall thickness 2 - 2.5mm is possible.

Examples:

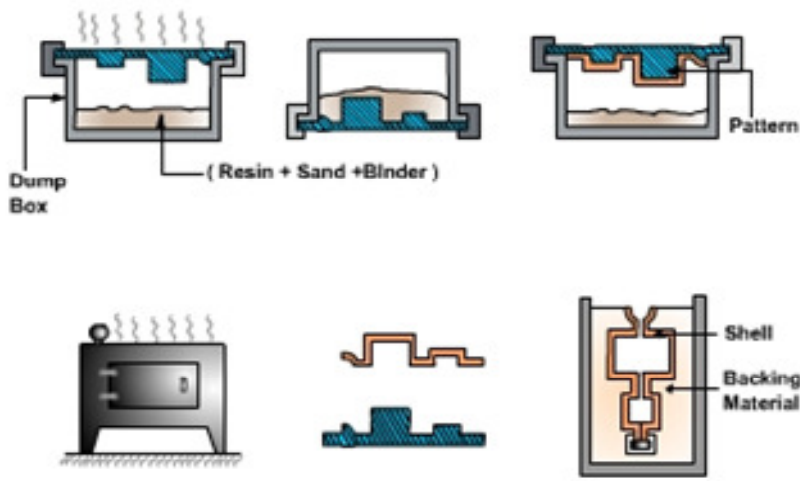
Brake drum, bushing, cam/cam shaft, piston, piston rings, pinions, pipe bends, air compressor crank cases, etc.,

Dry Sand Molding

- Air-dried molds are sometimes preferred to green sand molds to lower the formation of gas.
- Two types of drying of molds are often required.
- Skin drying and
 - Complete mold drying.

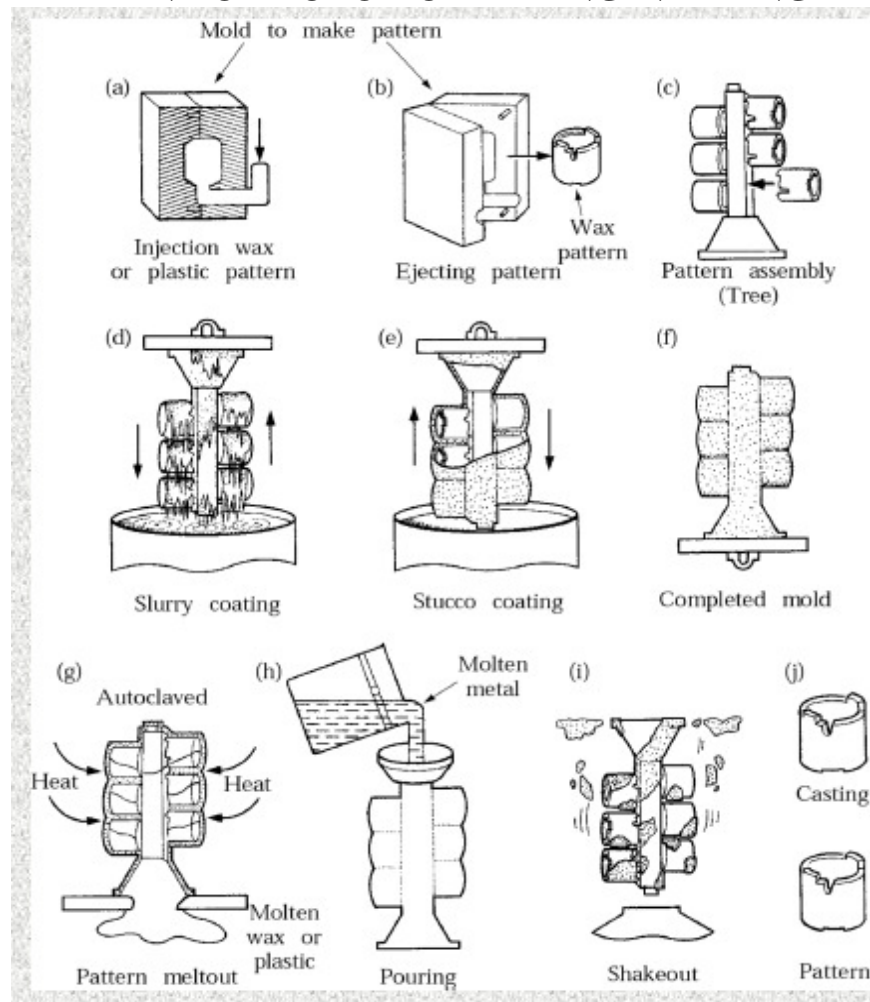
Shell Molding Process

- It is a process in which, the sand mixed with a thermosetting resin is allowed to come in contact with a heated pattern plate (200 degC),
 - Skin (Shell) of about 3.5 mm of sand/plastic mixture to adhere to the pattern
 - Then the shell is removed from the pattern
 - This process can produce complex parts with good surface finish 1.25 μm to 3.75 μm , and dimensional tolerance of 0.5 %
 - A good surface finish and good size tolerance reduce the need for machining.
 - The process overall is quite cost effective due to reduced machining and cleanup costs.
 - The materials that can be used with this process are cast irons, and aluminum and copper alloys.
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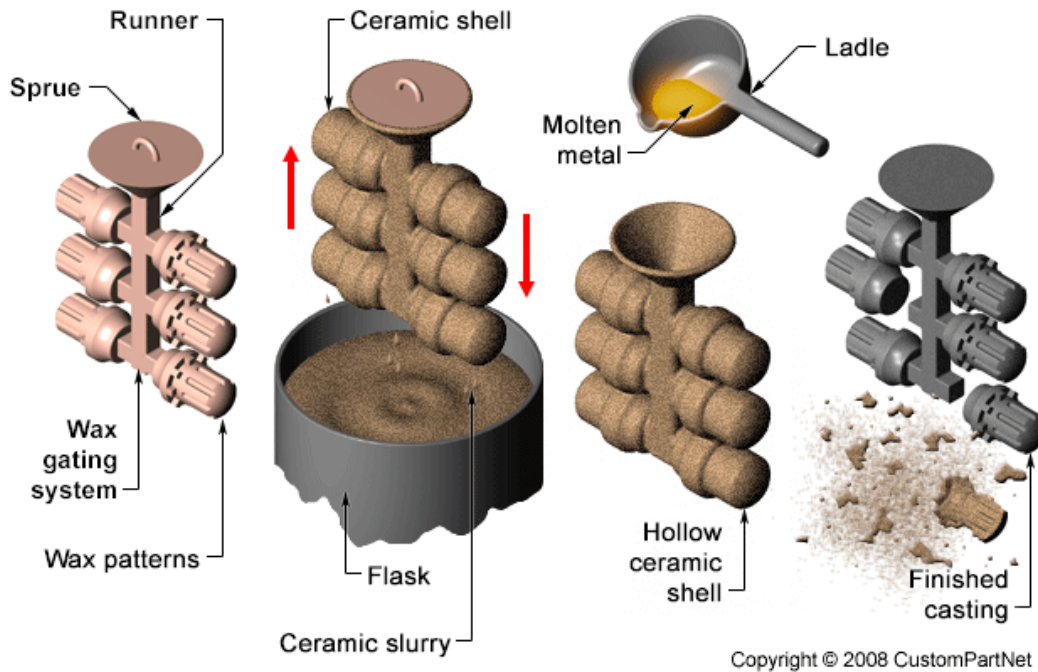


Investment casting

- ✓ Pattern is made up of wax / polystyrene polyethylene
- ✓ Dipping is done in extremely fine silica and water/gypsum solution.
- ✓ Baked in a oven for 2 hours to melt out the wax (100-120 C)
- ✓ Mold is cured for sometime at 800-900 C



- intricate details can be cast
- smooth surface /no parting line
- high accuracy
- unmachinable alloys (HRS + Nimonic alloys)
- minimum wall thickness of 1-2mm



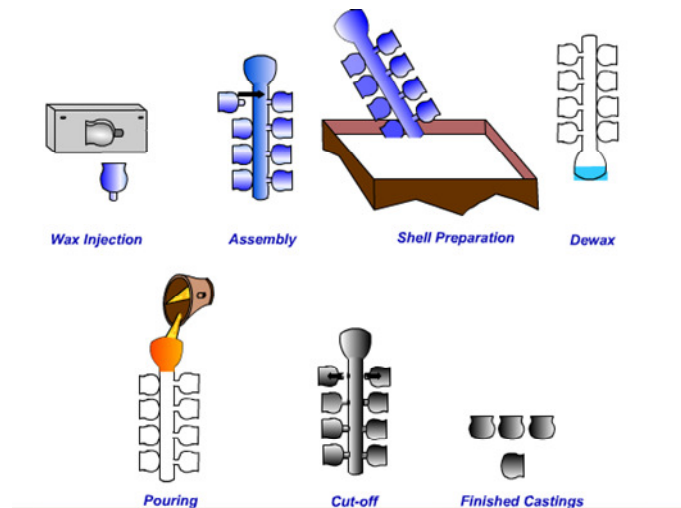
Application

- Parts for aerospace industry / aircraft engines
- Food / beverage machinery
- m/c tools, scientific instruments, sewing machine
- nozzles, vanes, blades for gas turbines.

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Investment Casting Process

- To create intricately **detailed jewelry, pectorals and idols**
- Also called **lost wax process** begins with the production of wax replicas or patterns of the desired shape of the castings.
- The patterns are prepared by **injecting wax or polystyrene in a metal dies**.
- A number of patterns are attached to a **central wax sprue** to form a assembly.
- The mold is prepared by **surrounding the pattern with refractory slurry that can set at room temperature**.
- The mold is then **heated** so that pattern melts and flows out, leaving a clean cavity behind.
- The mould is further **hardened by heating** and **the molten metal is poured while it is still hot**.
- When the **casting is solidified**, the mold is broken and the casting taken out



Basic Steps of the Investment Casting Process



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The basic steps of the investment casting process are

1. Production of heat-disposable wax, plastic, or polystyrene patterns
 2. Assembly of these patterns onto a gating system
 3. “Investing,” or covering the pattern assembly with refractory slurry
 4. Melting the pattern assembly to remove the pattern material
 5. Firing the mold to remove the last traces of the pattern material
 6. Pouring
 7. Knockout, cutoff and finishing
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Centrifugal Casting Process

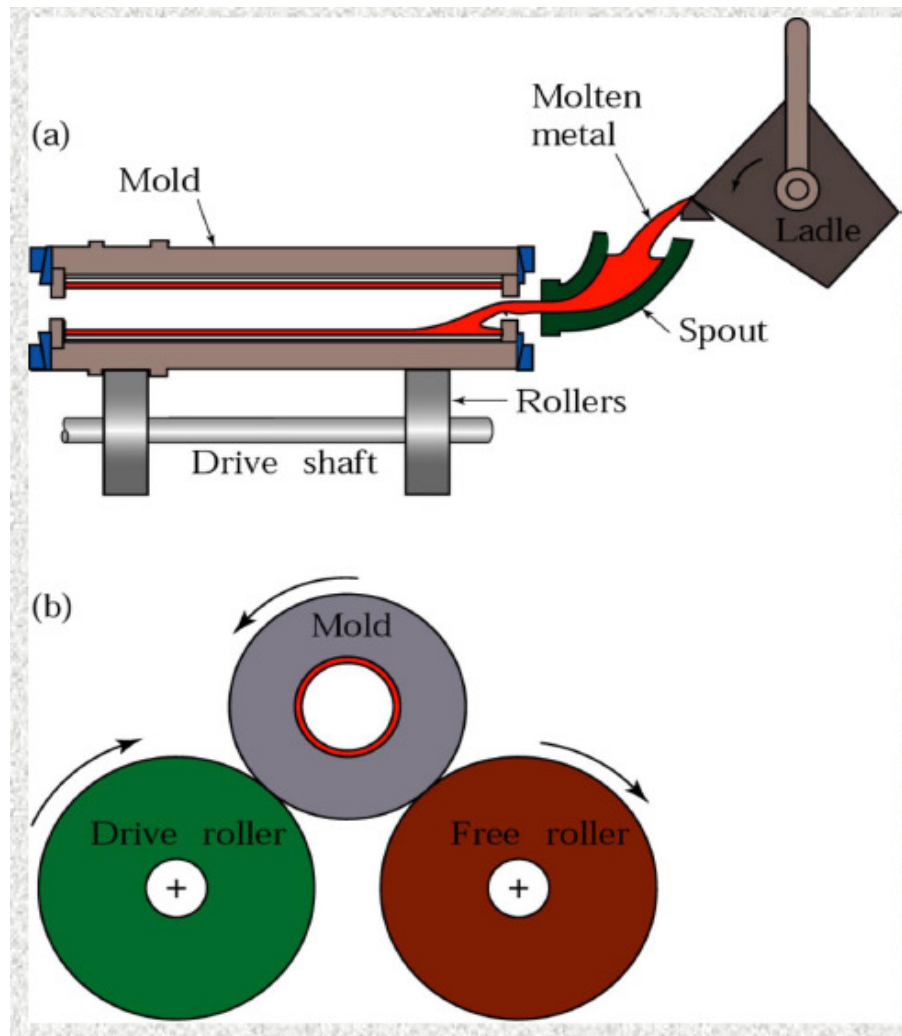
Three types:

True centrifugal casting

Semi centrifugal casting

Centrifuging (centrifuge casting)

True centrifugal casting



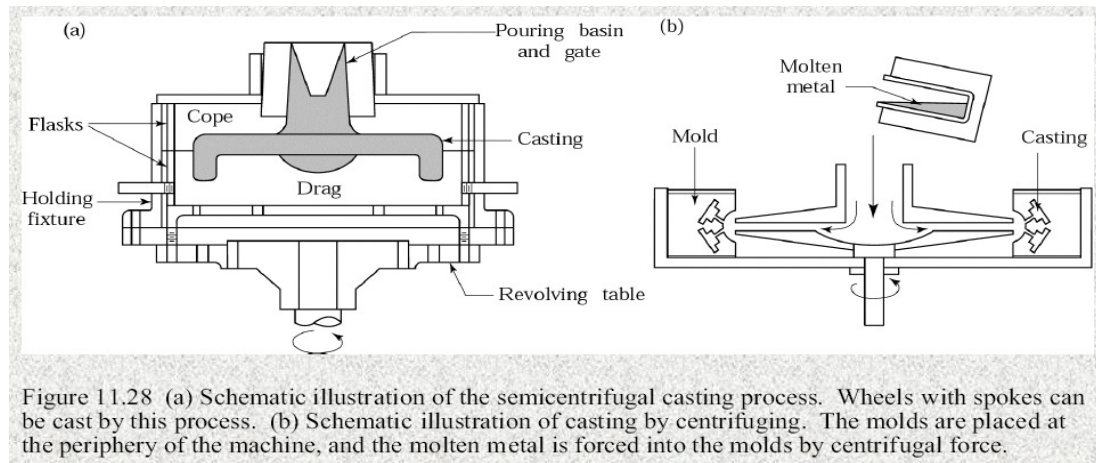


Figure 11.28 (a) Schematic illustration of the semicentrifugal casting process. Wheels with spokes can be cast by this process. (b) Schematic illustration of casting by centrifuging. The molds are placed at the periphery of the machine, and the molten metal is forced into the molds by centrifugal force.



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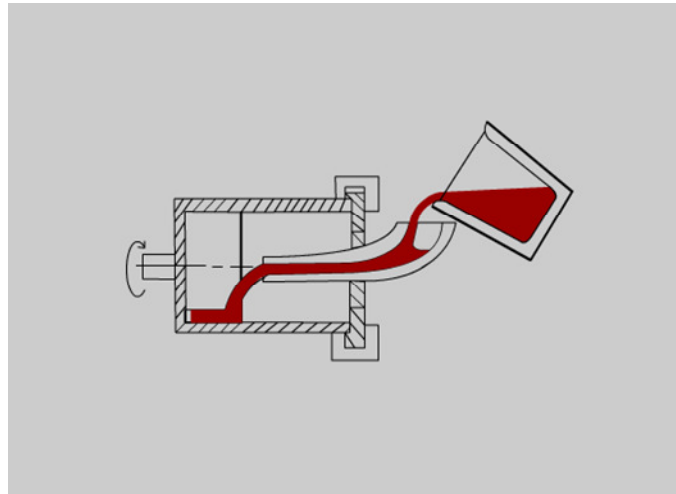
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Centrifugal Casting

- Mold is rotated rapidly about its central axis as the metal is poured into it.
- Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies.
- The slag, oxides and other inclusions being lighter, get separated from the metal and segregate towards the center.
- This process is normally used for the making of hollow pipes, tubes, hollow bushes, etc., which are axisymmetric with a concentric hole.
- Since the metal is always pushed outward because of the centrifugal force, no core needs to be used for making the concentric hole.
- The mold can be rotated about a vertical, horizontal or an inclined axis or about its horizontal and vertical axes simultaneously.
- The length and outside diameter are fixed by the mold cavity dimensions while the inside diameter is determined by the amount of molten metal poured into the mold

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-



Horizontal Centrifugal Casting

Cleaning of Castings

Shake out

-manually /mechanically

Fettling: Removal of cores, runners, risers and gate

- Knocking with iron bars
- Pneumatic /hydraulic devices
- Removal of gates ,risers ,runners

Snagging

- Removal of fins /unwanted projections
- Grinding, chipping with hand /pneumatic tools, flame cutting, filing.
- Breaking with hammer
- Sawing
- Torch cutting
- Electric arc cutting
- Abrasive wheel cutting

Removal of adhering sand and oxide scale



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- Wire brush
- Sand blasting
- Shot blasting
- Hydro blasting (non –ferrous)

Casting Defects

The following are the major defects, which are likely to occur in sand castings

1. Gas defects
2. Shrinkage cavities
3. Molding material defects
4. Pouring metal defects
5. Mold shift

1. Gas Defects

- Trapping of gas in the molten metal or by mold gases evolved during the pouring of the casting
 - Blowholes, Porosity, Pinholes
 - Blowholes are spherical or elongated cavities present in the casting on the surface or inside the casting
 - Pinhole, porosity occurs due to the dissolution of hydrogen gas, which gets entrapped during heating of molten metal.
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Causes of Gas Defects:

- The lower gas-passing tendency of the mold, which may be due to lower venting, lower permeability of the mold or improper design of the casting
- The lower permeability is caused by finer grain size of the sand, high percentage of clay in mold mixture, and excessive moisture present in the mold.
- Metal contains gas
- Mold is too hot
- Poor mold burnout

2.Shrinkage Cavities:

- caused by liquid shrinkage occurring during the solidification of the casting.
 - To compensate proper feeding of liquid metal is required & risers are placed at the appropriate places in the mold.
 - Sprues may be too thin, too long or not attached in the proper location, causing shrinkage cavities.
 - It is recommended to use thick sprues to avoid shrinkage cavities
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Metal penetration

- molten metal enters into the gaps between sand grains.
- rough casting surface.
- the sand is coarse or no mold wash was applied on the surface of the mold.
- The coarser the sand grains more the metal penetration.

Fusion

- Fusion of the sand grains with the molten metal.
- Brittle, glassy appearance on the casting surface.
- Clay or the sand particles are of lower refractoriness or that the pouring temperature is too high.

Swell

- metallostatic forces, move the mold wall back causing a swell in the dimension of the casting.
- A proper ramming of the mold will correct this defect.

Inclusions

- Particles of slag, refractory materials, sand or deoxidation products are trapped in the casting during pouring & solidification.
- The provision of choke in the gating system and the pouring basin at the top of the mold can prevent this defect.

Pouring Metal Defects

- Mis-runs
 - Cold shuts.
-



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Mis-run:

- when the metal is unable to fill the mold cavity completely and thus leaves unfilled cavities.
- A mis-run results when the metal is too cold to flow to the extremities of the mold cavity before freezing.
- Long, thin sections are subject to this defect and should be avoided in casting design.

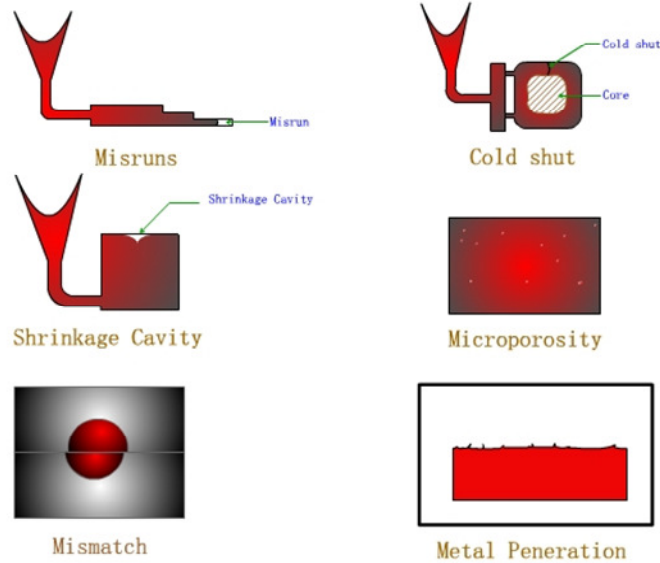
Cold shut :

- When two streams of molten metal while meeting in the mold cavity, do not fuse together properly thus forming a discontinuity in the casting.
- When the molten metal is poured into the mold cavity through more-than-one gate, multiple liquid fronts will have to flow together and become one solid.
- If the flowing metal fronts are too cool, they may not flow together, but will leave a seam in the part.
- Such a seam is called a cold shut, and can be prevented by assuring sufficient superheat in the poured metal and thick enough walls in the casting design.

-
- The mis-run and cold shut defects are caused either by a lower fluidity of the mold or when the section thickness of the casting is very small.
 - Fluidity can be improved by changing the composition of the metal and by increasing the pouring temperature of the metal.

Mold Shift

- The mold shift defect occurs when cope and drag or molding boxes have not been properly aligned
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Casting Defects



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DEPARTMENT OF AUTOMOBILE ENGINEERING UNIT II

WELDING

Metal Joining Processes

Welding: process of joining similar /dissimilar metals by application of heat with /without application of pressure, and filler materials

Types

- Pressure welding [plastic] Ex: Resistance, Friction
- Non Pressure Welding [Fusion] Ex: Gas, Arc

Arc welding

- Consumable electrode

Shielded Metal Arc Welding (SMAW)

Metal Inert Gas (MIG) Welding / GMAW

Submerged Arc Welding (SAW)

Flux Cored Arc Welding (FCAW)

Electro Slag Welding (ESW)

Electro Gas Welding (EGW)

- Non consumable electrode

Tungsten Inert Gas (TIG) Welding / GTAW

Plasma Arc Welding (PAW)

Atomic Hydrogen Welding (AHW)

Gas welding

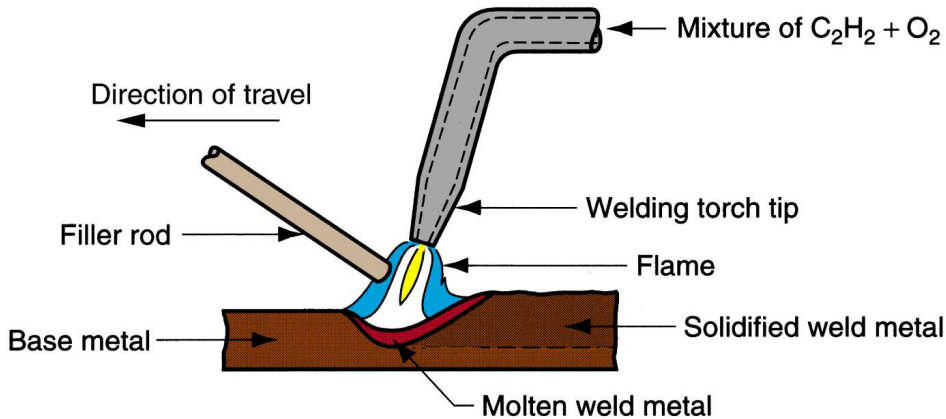
-performed by burning a combustible gas with air or oxygen: results in a concentrated flame of high temperature

-purpose of flame is to heat and melt the parent metal and filler rod.

Oxy acetylene welding

-done by melting the edges or surfaces to be joined by

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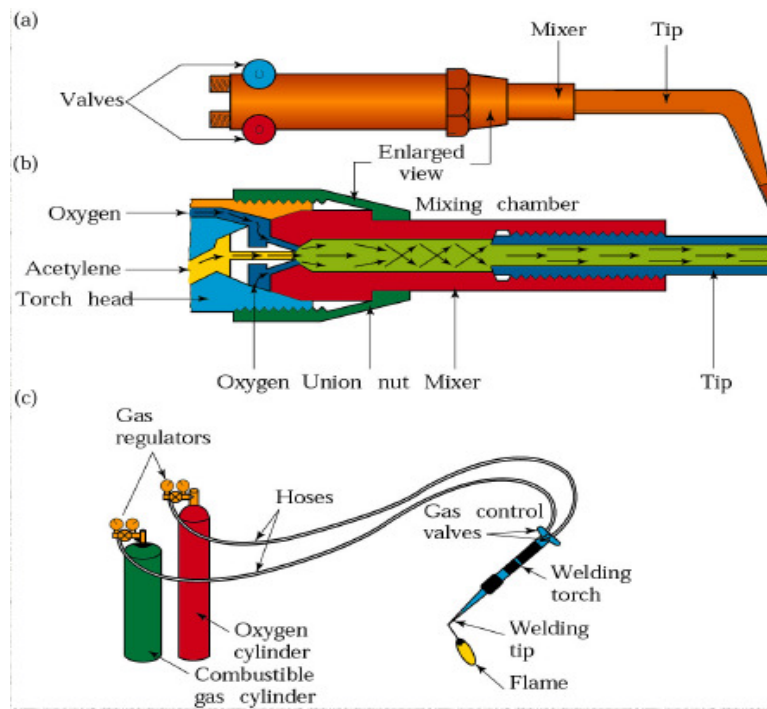
gas flame and allowing the molten metal to flow together to form a solid continuous joint.

-Suitable for joining the metal sheets and plates having thickness of 2-50 mm.

-filler metal is added in the form of welding rod for material >16mm thickness.

-Oxygen –acetylene mixture is used to a greater extent than the other combination

-The temperature produced by the oxy–acetylene flame - $3200^{\circ}C$ (sufficient to melt the 50mm thick plate)



Gas flame

-correct adjustment of flame is important for reliable work.



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- when oxygen and acetylene are supplied in nearly equal volumes a neutral flame is produced having a maximum temperature of 3200°C
- condition of flame is determined by its appearance.
- neutral flame is desired for most welding operation.
- When excess of oxygen is used –oxidizing flame.
- When excess of acetylene is used –carburizing flame.

Neutral flame:

Neutral flame has two definite zones

- sharp brilliant cone extending a short distance from the tip of torch
- Outer envelope –bluish in colour.
- inner cone develops heat and the outer envelope protects the molten metal from oxidation
- neutral flame is used for welding steel, SS, C.I, Cu, AL, etc.

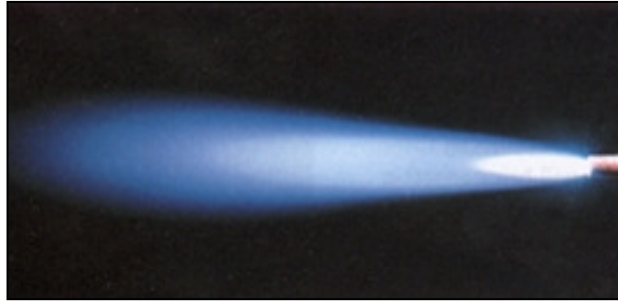


Carburizing flame:

Percentage of acetylene is more and 3 zones

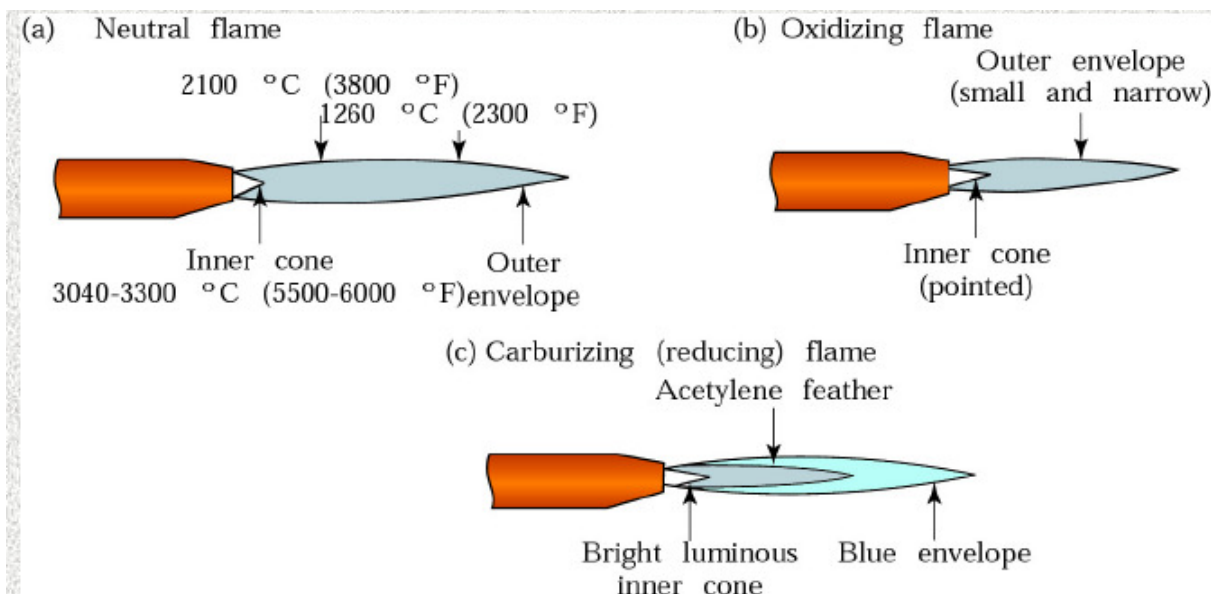
- sharply defined inner cone
- intermediate cone of whitish colour (feather)
- bluish outer cone
- the length of intermediate cone is an indication of proportion of excess acetylene in flame.

While welding steel ,the presence of more acetylene tend to give the weld a higher carbon content then parent metal ,resulting in a hard and brittle weld.



Oxidizing flame:

- percentage of oxygen is more
- have two zones
- small inner cone which has purple colour
- outer cone/envelope
- in oxidizing flame the inner cone is not sharply defined
- this flame is used for welding brass metal



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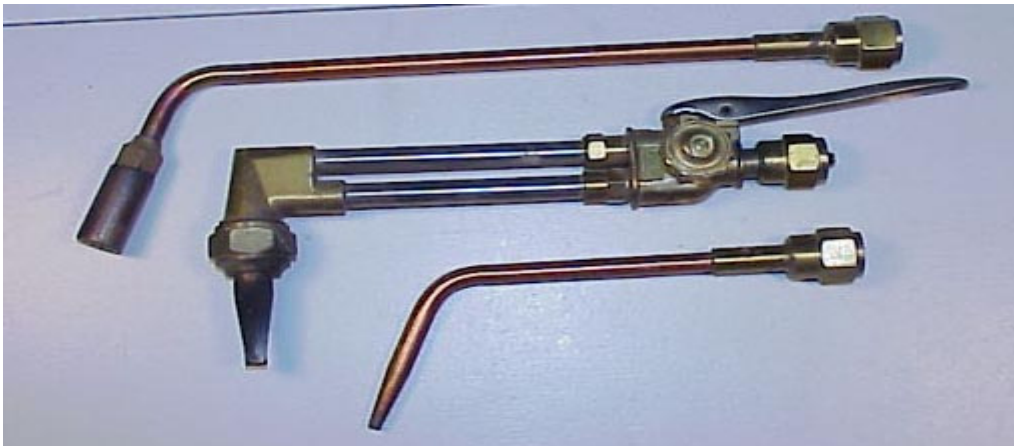
Welding equipment:

Commonly used equipment for oxy –acetylene welding consists of welding torch, welding tip, pressure regulator, hose and hose fittings, goggles, spark lighter and gas cylinders.



Welding tip

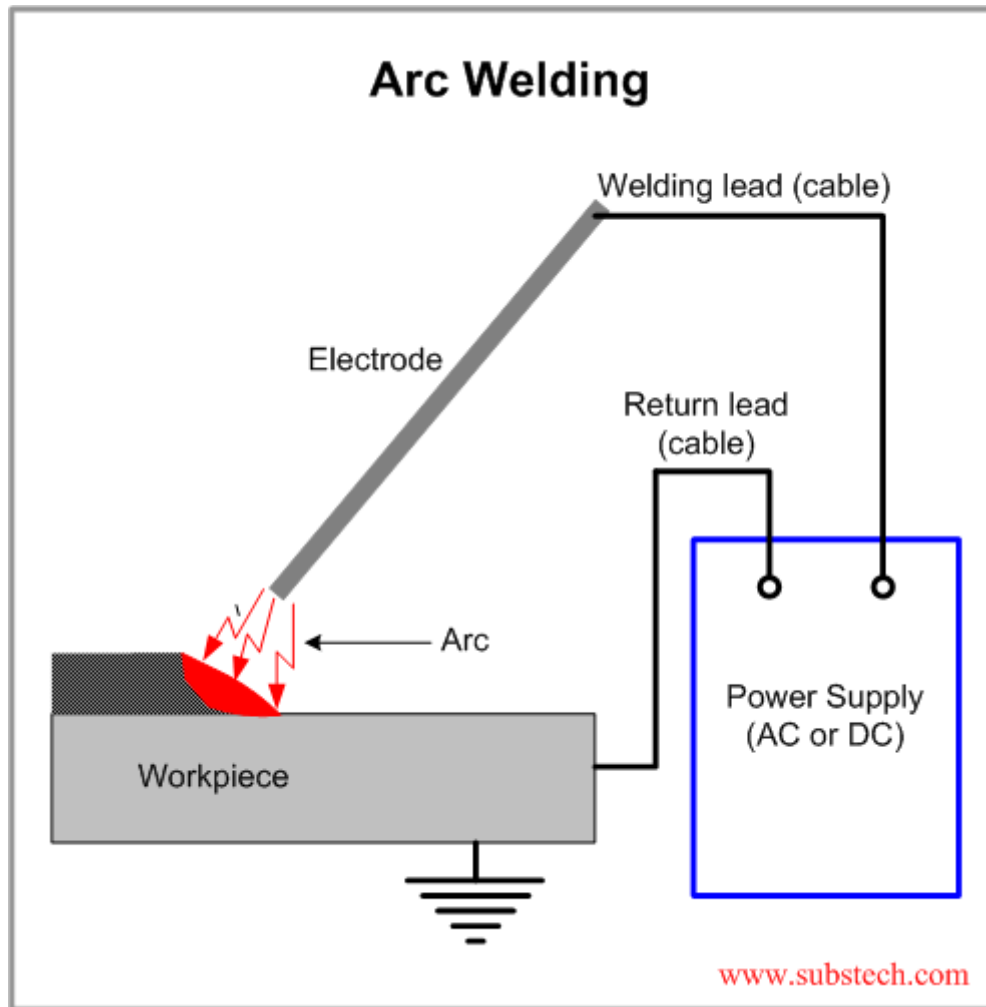
- it is the portion through which the gases pass out for burning
- interchangeable welding tips of different size, shape and construction available.
- tips sizes are governed by the diameter of opening
- diameter of tip opening depends upon the type of metal to be welded and thickness of metal.



ARC WELDING

Principle of arc

- arc: generated between two conductors of electricity [i.e.,] cathode and anode
- arc is a sustained electric discharge through the ionized gas column and between +ve and –ve terminal .



Arc welding equipment

Source of electric power

- A.C Machine
- D.C machine

D.C Machine:

- heat is liberated near the anode
- workpiece is made anode when more heat is required

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-termed as St. polarity / DCEN [polarity –direction of current flow]

Results in higher penetration

When less heat is required the polarity is reversed by making the work piece as –ve

Termed as reverse polarity or DCEP

Results in less penetration

A.C Machine:

Cathode and anode change continuously so the temperature across arc is uniform

Results in average penetration

BAD characteristics under different conditions

1. current too low: excessive piling of metal
2. current too high: excessive splatter
3. voltage too high : bead too small
4. welding speed too slow: excessive piling up of metal
5. proper current & timing :smooth ,regular bead

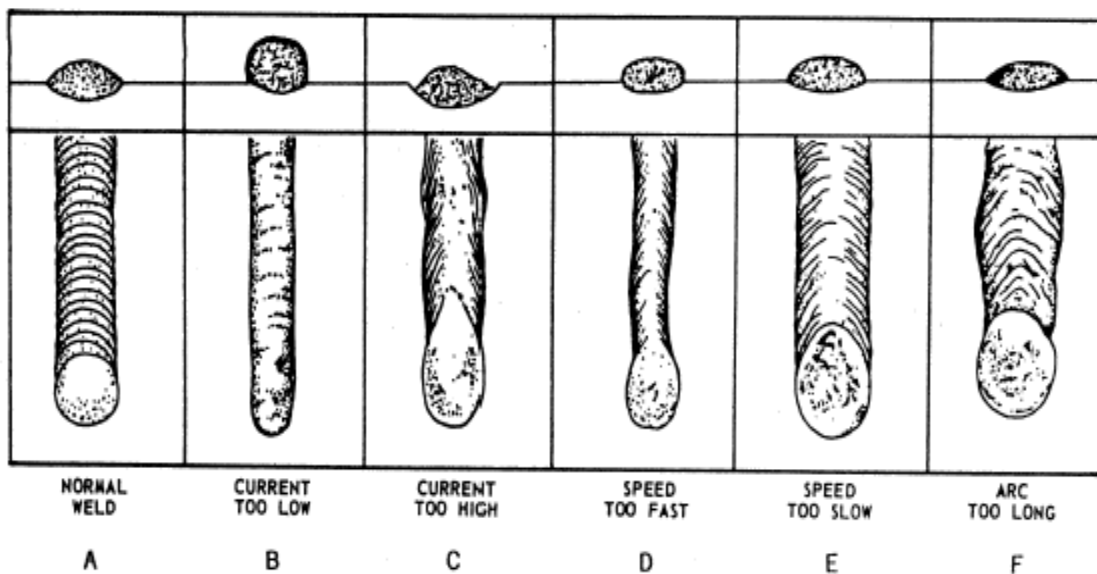


Figure 7-12. Comparison chart of welds.

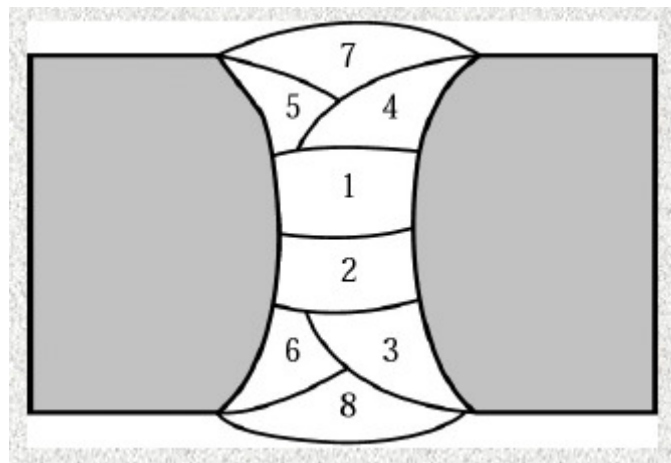
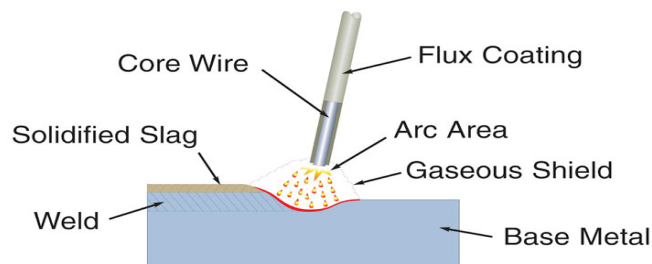
Shielded metal arc

welding

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- Simplest ,versatile joining process
- Job of any thickness can be welded
- Range 3 to 20 mm thick
- Current usage vary from 50-500A
- Voltage 20-40 V
- Slow speed welding
- >20 mm thick –multiple pass technique

Diagram of Shielded Metal Arc Welding

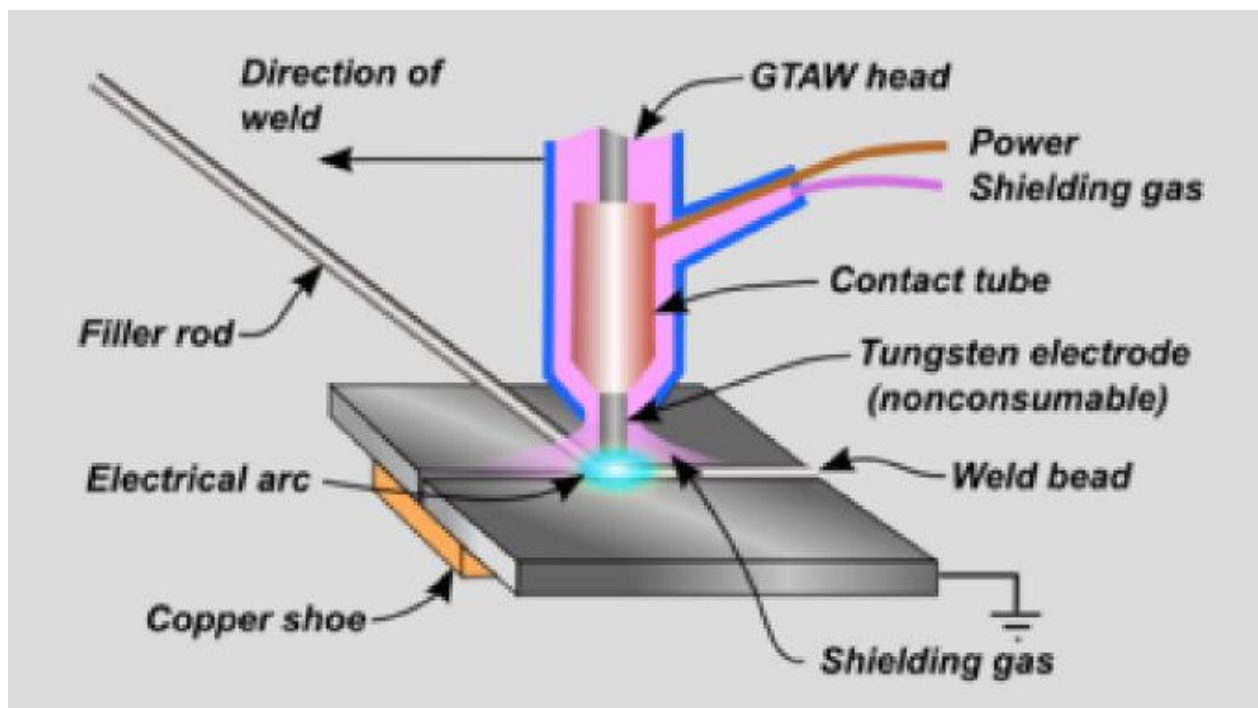
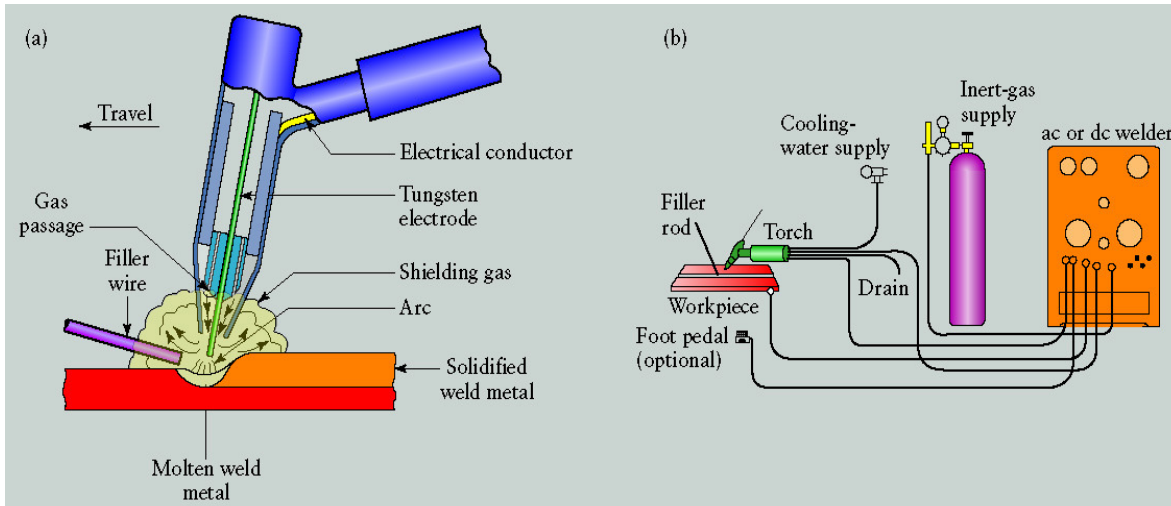


Gas tungsten arc welding or tungsten inert gas

- Arc: non consumable tungsten electrode & work piece
- Electrode is used only to generate arc
- Melting point of tungsten -3300°C
- Filler wire / if w/p is thick
- End of welding gun made of ceramic / water cooled

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- Can weld dissimilar metal also
- Applicable for Al alloys, SS, Cu, Ni alloys



Advantages of TIG welding

- Produces high quality welds in non ferrous metals
- Practically no weld cleaning is necessary
- The arc & weld zone are clearly visible to welder

Shielding gas



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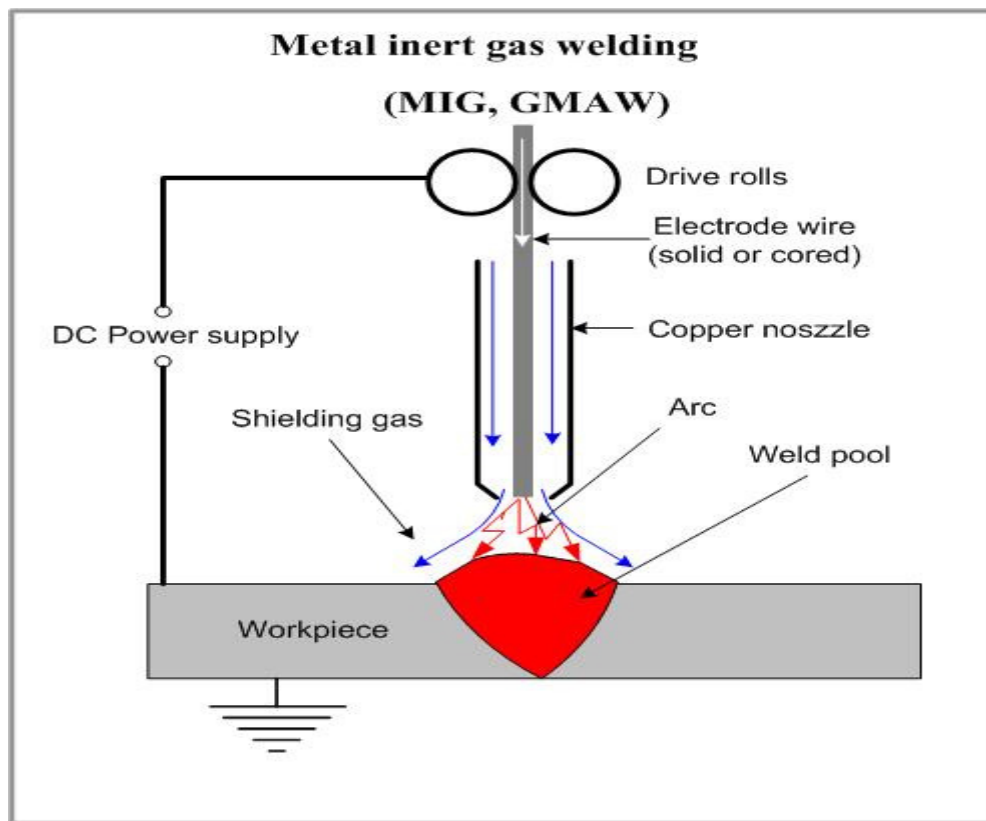
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- Shielding gas provide a shielding at the area of welding
- Gas displaces the air surrounding the arc & weld zone
- Prevents contamination of the weld metal by O_2 & N_2 in the air
- For welding Al & Cu –argon /argon –He mixture
- S.S – argon - O_2 /argon –helium mixture
- Titanium – pure argon
- Cu-Ni / high Ni alloys – argon - He mixture
- Carbon steel - CO_2 is used

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Gas metal arc welding or metal inert gas welding

- Arc: consumable electrode & W/P
- Metal wire fed continuously
- Current [100 - 400A]
- Dia of wire: 0.09 - 1.6 mm
- Speed of melting of wire - 5m/min
- Welding gun –air / water cooled



Advantages:

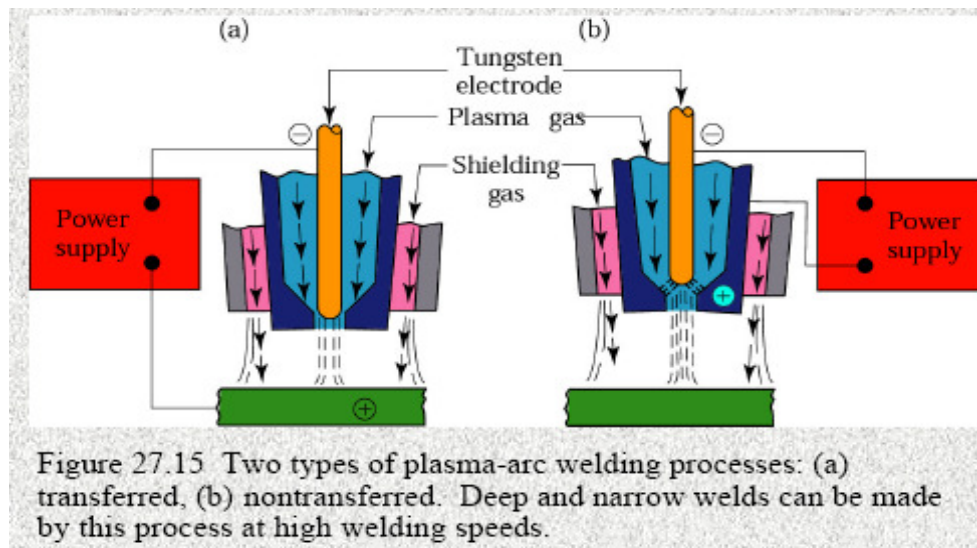
- High welding speed
- No additional filler material
- Easily automated
- Can weld Al, SS

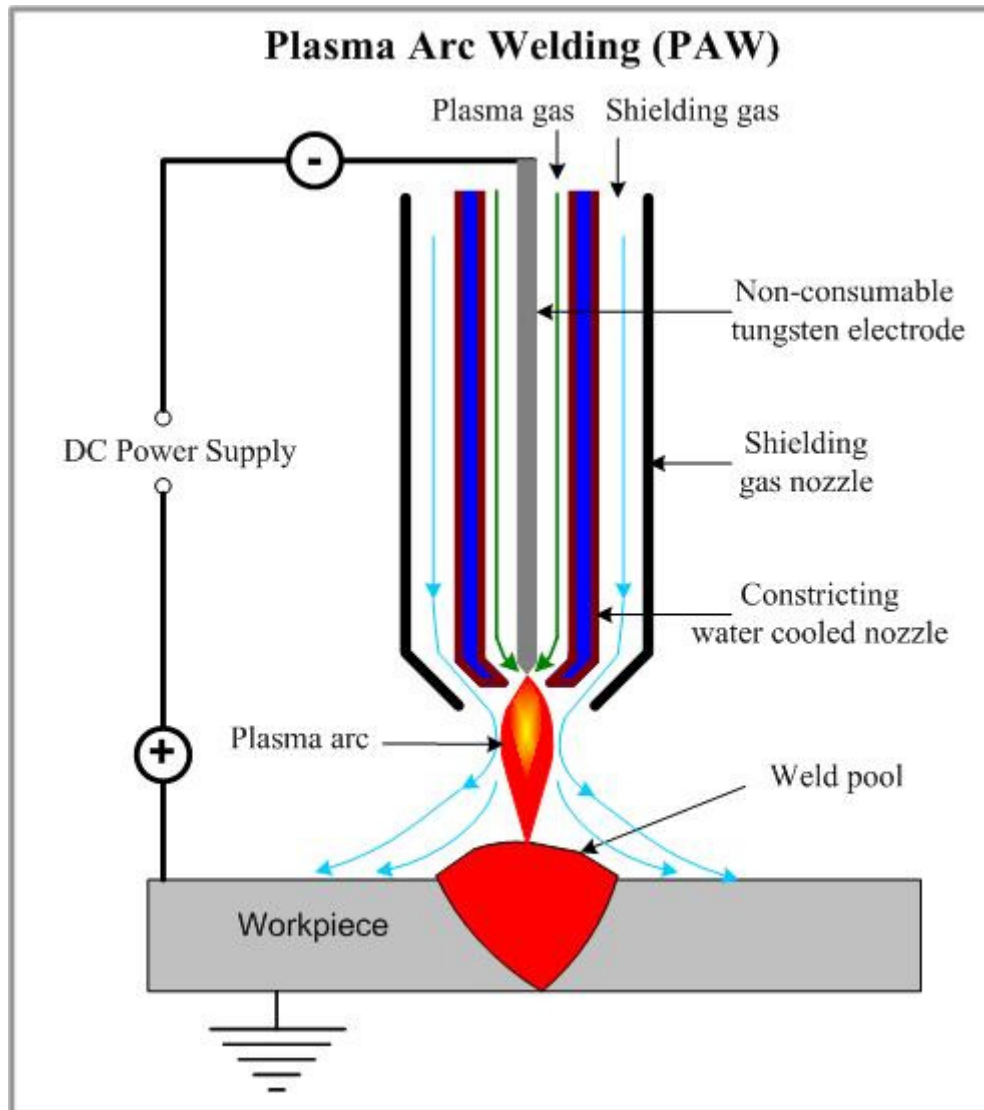
Plasma arc welding

- Similar to TIG welding
- Non consumable tungsten electrode

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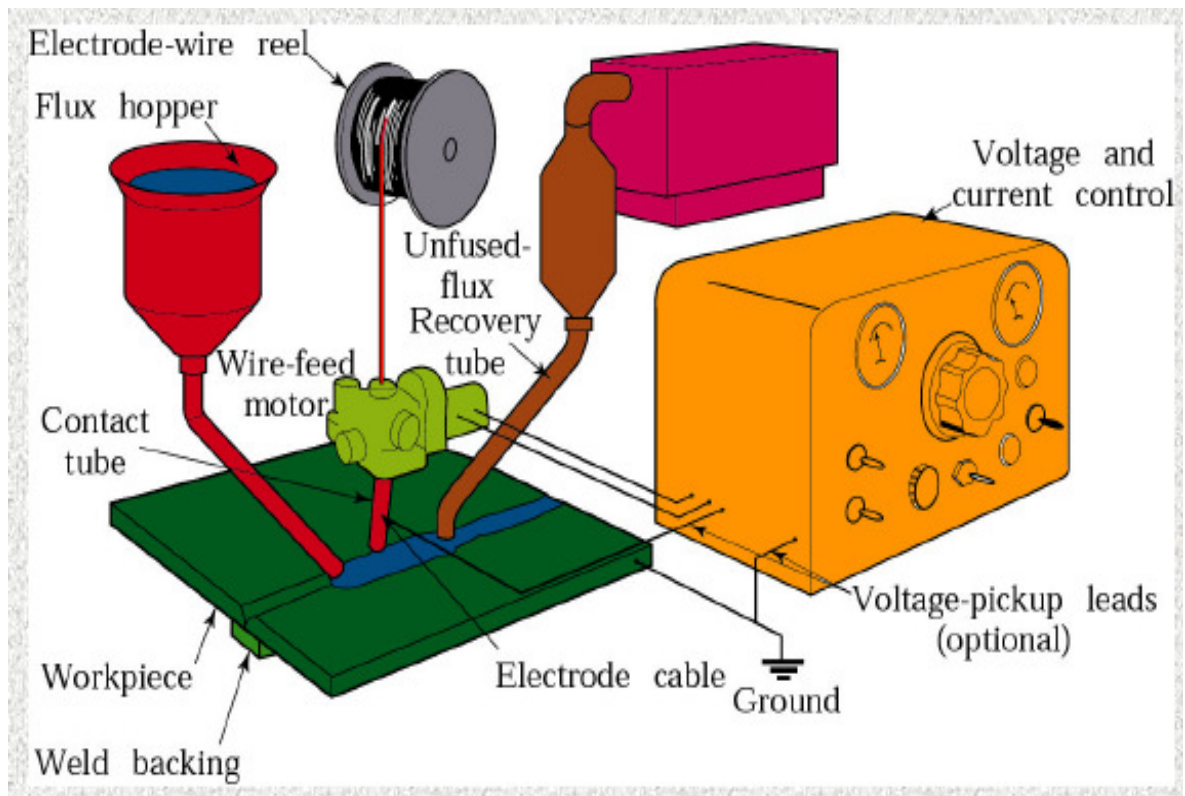
- Pure argon gas is allowed through the orifice surrounding the electrode to form plasma arc.
- Electrical arc is produced between electrode & w/p or electrode & nozzle
- Argon gas pass through the arc & become ionized gas (i.e.,) its atoms loose electrons and due to multiple collision of these electrons more heat is generated
- This high temperature ionized gas is called as PLASMA and used for welding
- Temp range 10000 - 30000°C
- Water cooled nozzle is provided.

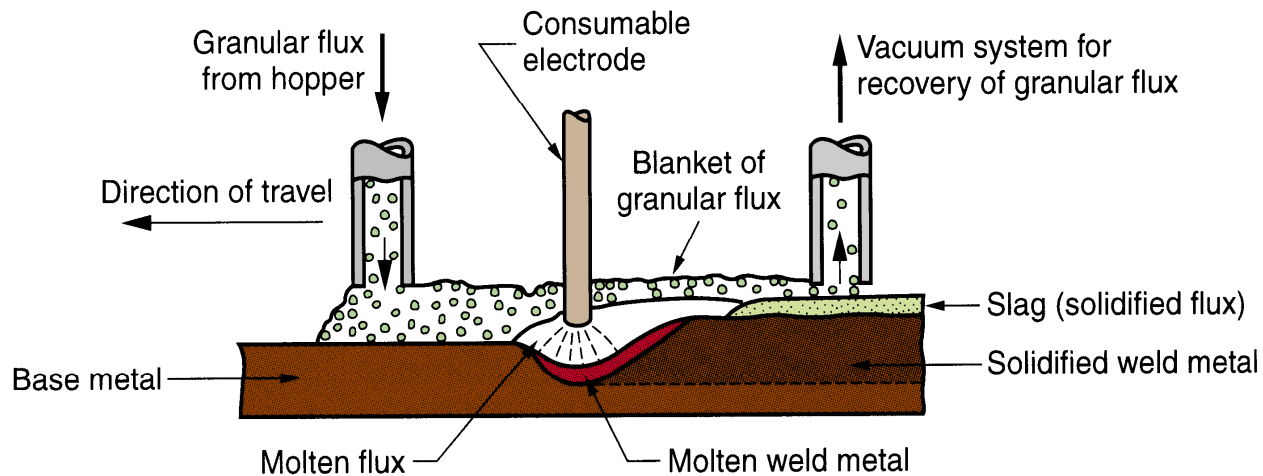




Submerged arc welding

- Arc: between consumable electrode and work piece
- Welding zone: covered by the large amount of granulated flux: delivered ahead of the electrode through welding flux feed tube
- Flux: silica +metal oxides fused together + crushed to proper size.
- Arc is completely submerged under the flux
- Part of flux melts, form slag and covers the weld zone
- No splatter of molten metal
- Prevent weld zone from contamination





Advantages

- Can be automated /much faster than regular arc welding
- Speed upto 3.8 m/min is possible 3mm thick steel
- Deep penetration with high quality weld is possible
- Capable of welding welding 75mm thick plate in a single pass

Pressure welding / Solid state welding

Resistance welding

Metals parts to be joined are heated to a plastic state over a limited area by their resistance to the flow of an electric current and mechanical pressure is used to complete the weld

Preferably two copper electrodes are incorporated in a circuit of low resistance and the metals to be welded are pressed between the electrodes

Electrical resistance at the joint of the metals to be welded is so high, that if the current is heavy enough the highest temperature will be produced directly at the joint

Heat generated in the weld may be expressed by

$$H = I^2 RT$$

Where

H is the heat generated

I is the current

R is the resistance of the assembly

T is the time or duration of current flow



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Heat developed by the current is in proportional to the electrical resistance of the joint

Machine used for the making resistance welds contains

- A transformer
- A clamping device for holding the pieces
- A mechanical means for forcing the work pieces together
to complete the weld

The electrodes are cooled by the water, circulating through the hollow electrodes

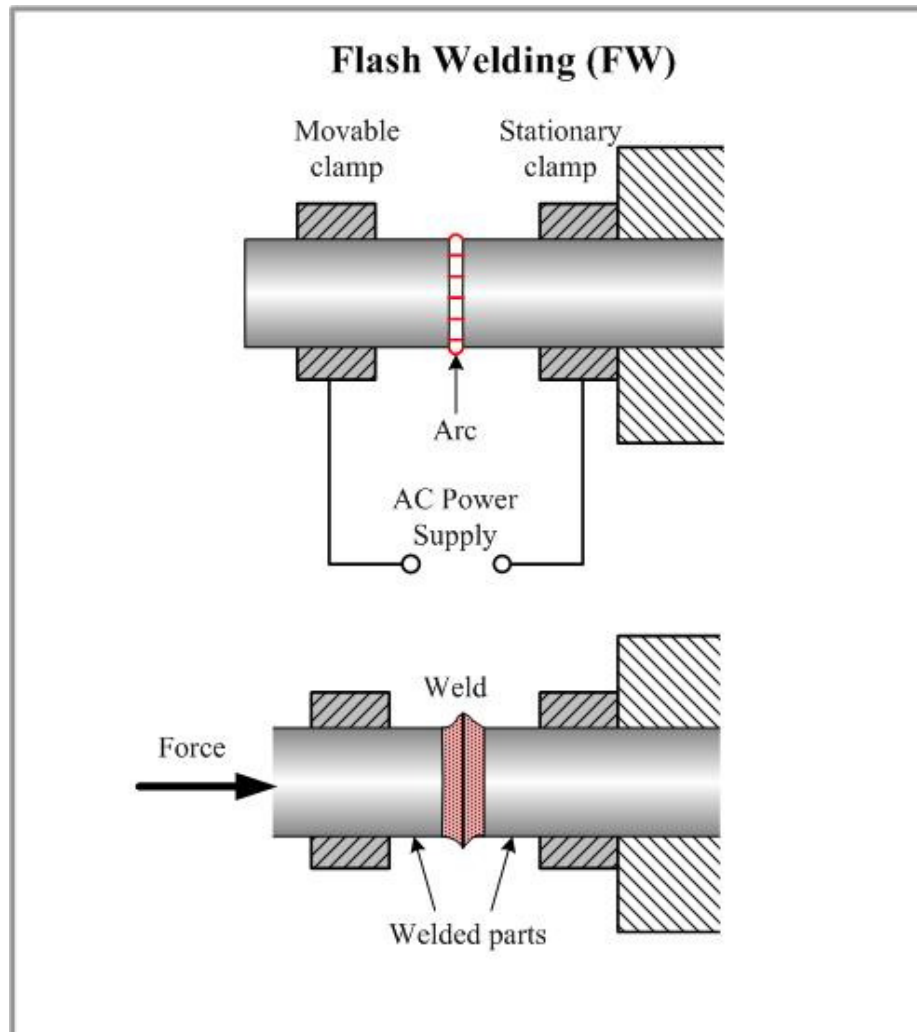
Metals of medium and high resistance such as Steel, SS, Monel metal are easily welded.

Types of resistance welding

- Butt welding
- Spot welding
- Seam welding

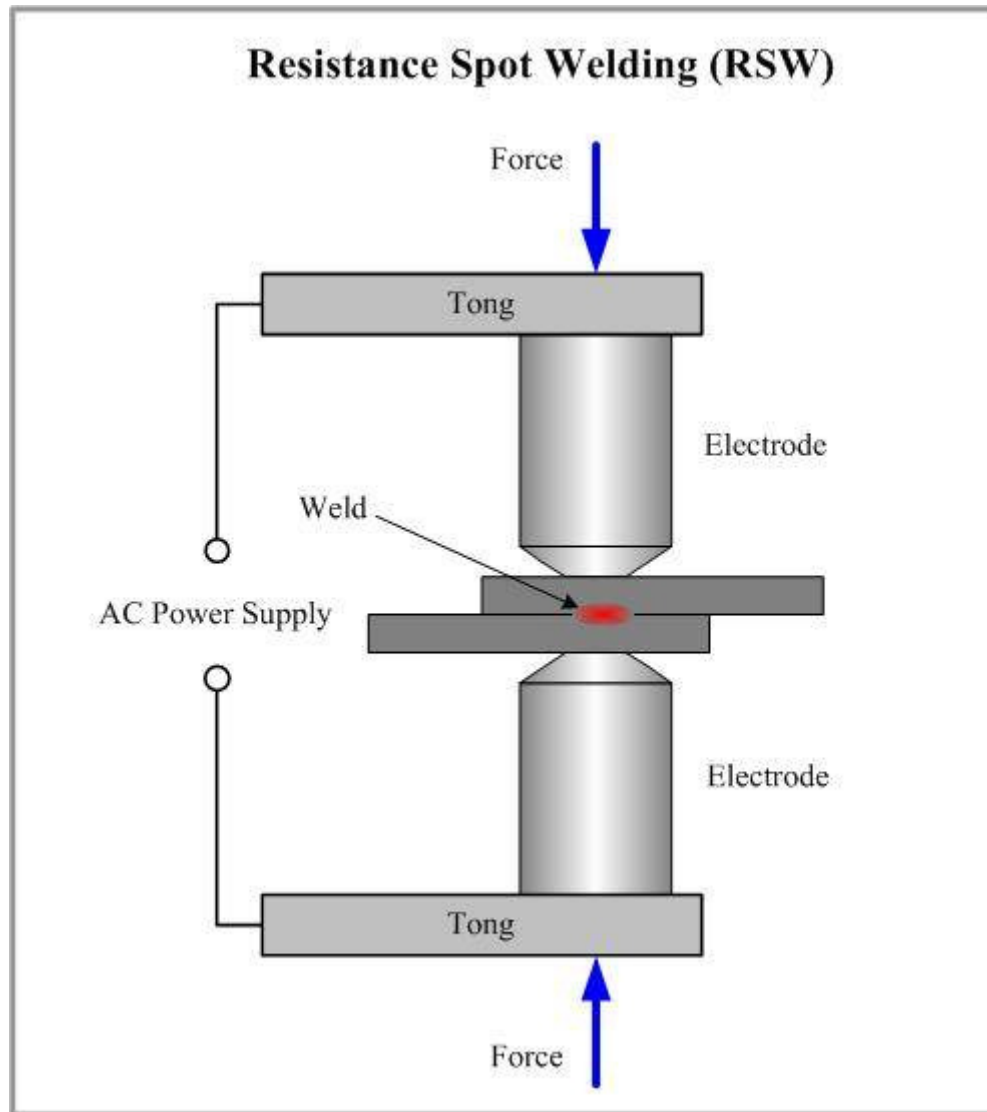
Butt welding

- Parts to be welded are clamped edge to edge in copper jaws of welding machine
- Parts have a solid contact and have high electric resistance while current flows and heat is generated.
- At this juncture, the pressure applied forges the part together.
- Applied for non ferrous material, wires etc.,



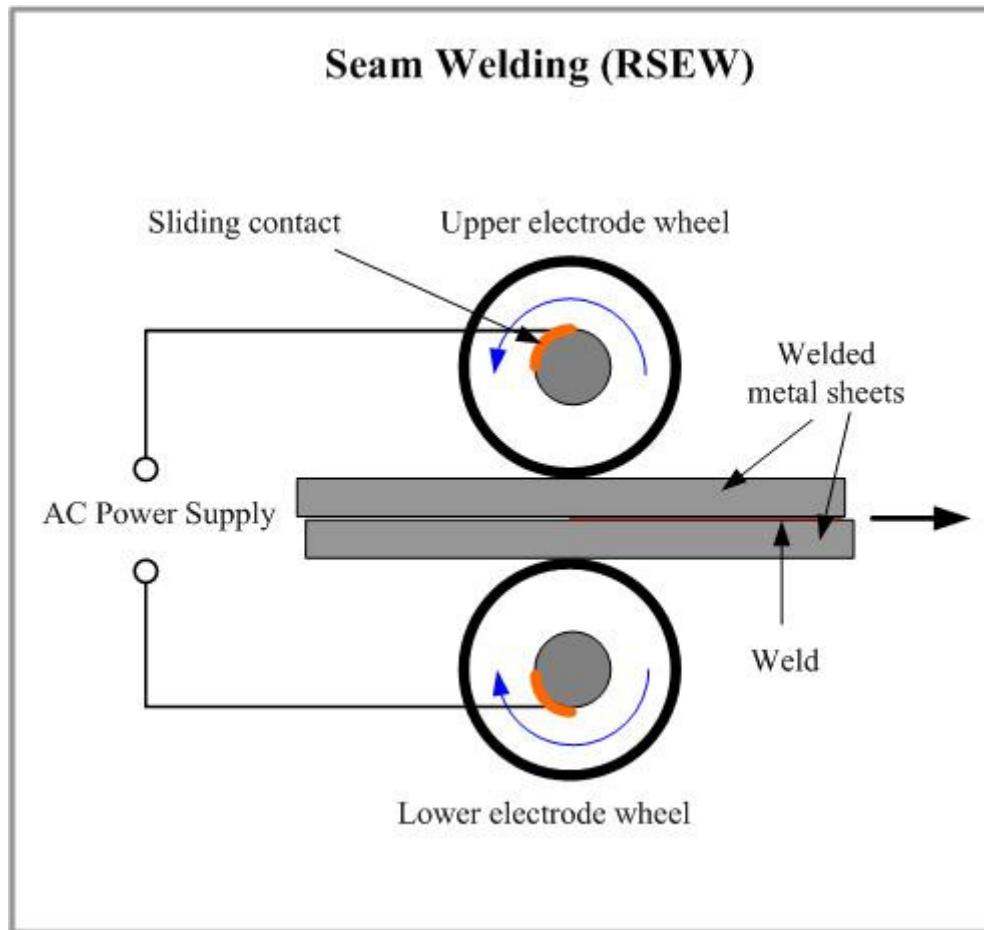
Spot welding

- Employed to join over lapping metal strips, sheets, plates of small area
- Work pieces are clamped and placed between 2 electrodes.
- Electrodes are made of copper, alloys of copper and tungsten, copper and chromium.
- Supply of current is turned and the pieces are heated at the area of contact.
- With the aid of mechanical pressure the electrodes are forced against the metal to be welded.
- Pressure developed by foot lever or pneumatic or hydraulic device.
- Weld steel and other metal parts up to thickness of 12mm



Seam welding

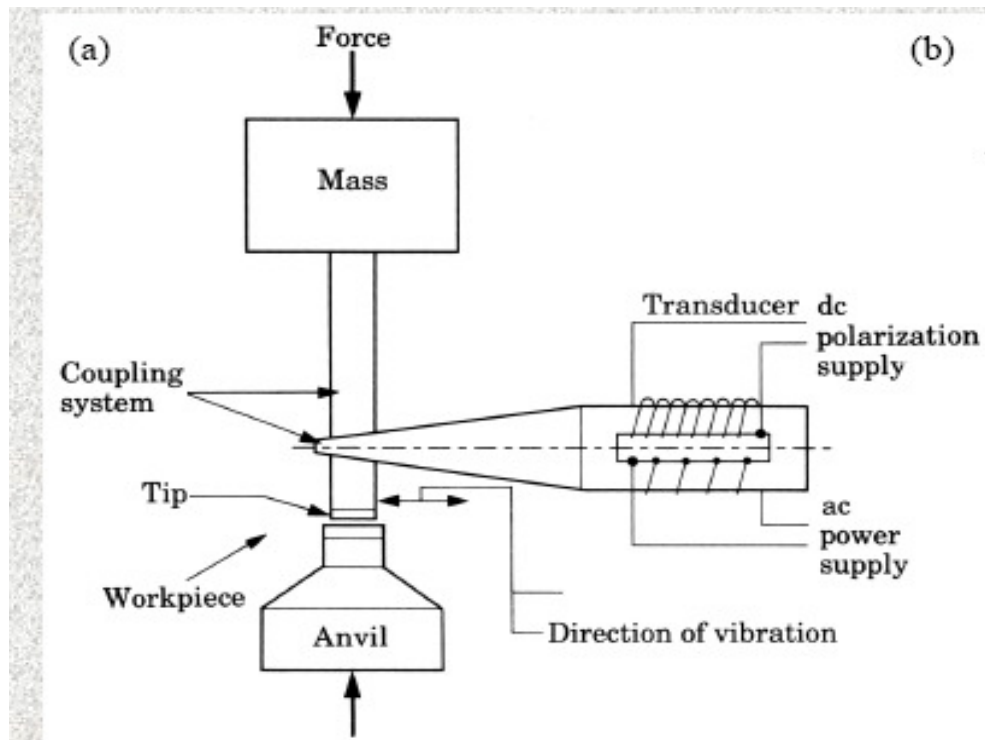
- Method of making a continuous joint between two overlapping pieces of sheet metal
- Place the work piece between the wheels which serve as conductors for producing continuous welds
- Overlapping surfaces of metals are forced together by means of driving wheel as fast as they are heated.
- Steels plates of 10mm thickness have been seam welded to hold about 200 kg/mm² pressure
- Pressure tight or leak proof tanks for boiler vessels, other pressure vessels.

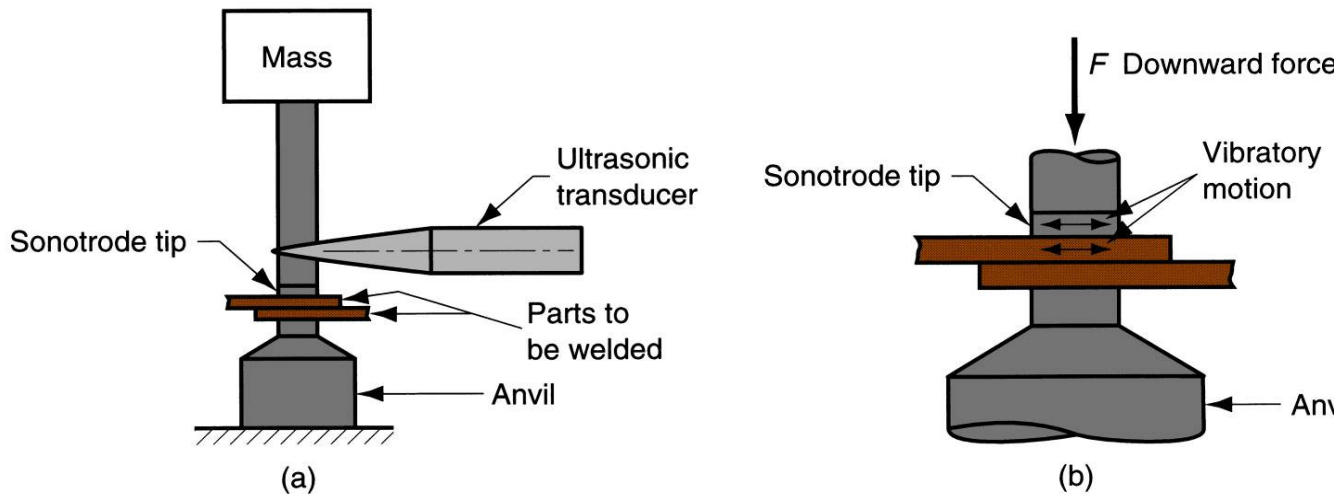


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Ultra sonic welding

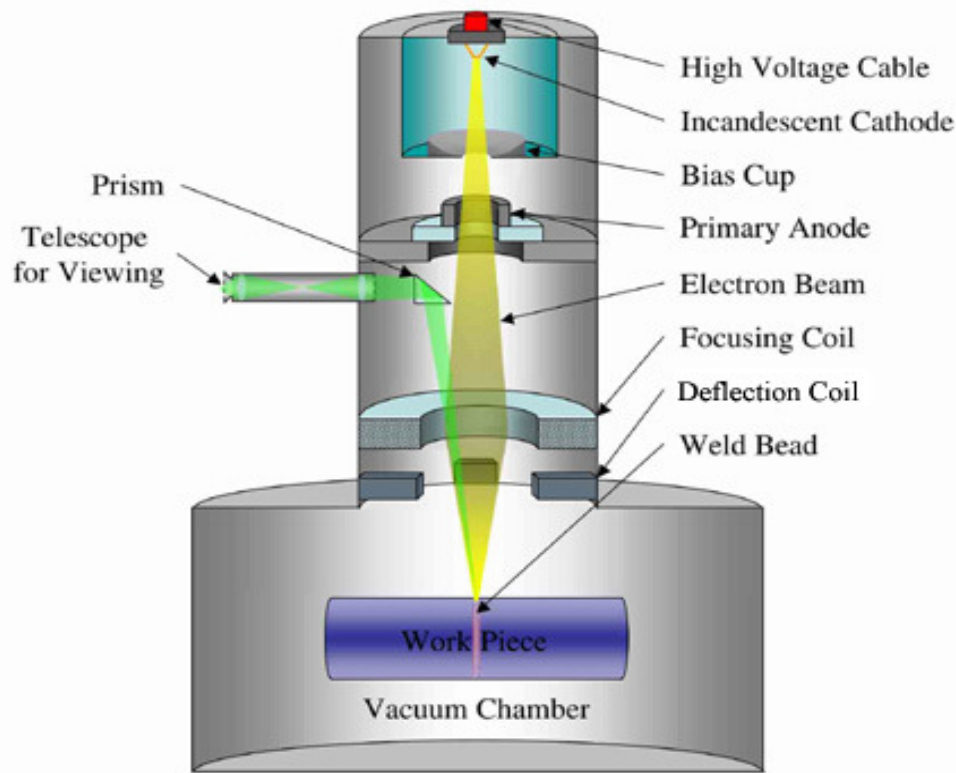
- Surface of two work piece are subjected to a static normal force and oscillating shearing stresses.
- The lateral vibrations of the tool tip cause plastic deformation and bonding at the interface of the work pieces.
- The shearing stresses are applied by the tip of the transducer.
- Can be used for a wide variety of metallic and non metallic materials.
- Dissimilar metals (bimetallic strips)
- Joining plastics
- Automotive, consumer electronics industries for welding of sheets, foils, etc.,





Electron beam welding

- Utilizes the energy from the fast moving beam of electrons focused on work piece
- Electrons strike the metal surface and the kinetic energy is converted to heat
- Beam is created in high vacuum (10^{-3} to 10^{-5} mm hg)
- Contamination is prevented and pure welds can be made
- High vacuum is necessary around the filament
- In order to prevent it from burning
- In order to produce and focus a stable beam.
- Tungsten filament which serves as a cathode emits a max of electrons that are accelerated and focused to a 0.25 – 1mm Dia beam of high energy density up to 0.5 to 10 Kw /mm²
- Heat generated is about 2500 C sufficient to melt the work piece and fills a narrow weld gap.
- Automobile, aerospace components, farm equipments, ball bearing over 100mm are being welded by EBW process.

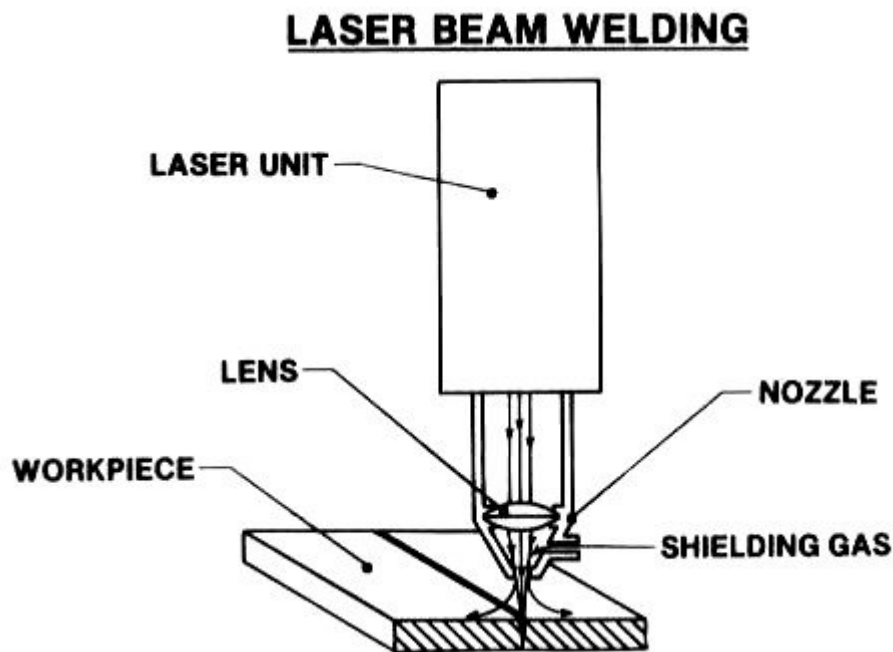


Advantages of EBW:

- Welds are clean with no porosity & no shielding gas is used.
- As energy input is in a narrow concentrated beam distortion is eliminated
- Speed is as fast as 2500mm/min
- Weld any metal to thick of 150 mm.

Laser Beam Welding

In laser beam welding, materials melt under the heat obtained from a narrow beam of coherent, monochromatic light (a laser beam). Typically, no filler metal is used.



Process characteristics

- Is used for thin-gage work pieces
- Is used for welding areas that are not readily accessible
- Provides excellent welding precision
- Permits joining of dissimilar alloys
- Uses no electrodes
- Causes little or no thermal damage to the workpiece
- Is easily automated

Thermit Welding (TW)

FW process in which heat for coalescence is produced by superheated molten metal from the chemical reaction of thermite

- Thermite = mixture of Al and Fe_3O_4 fine powders that produce an exothermic reaction when ignited
- Also used for incendiary bombs
- Filler metal obtained from liquid metal
- Process used for joining, but has more in common with casting than welding

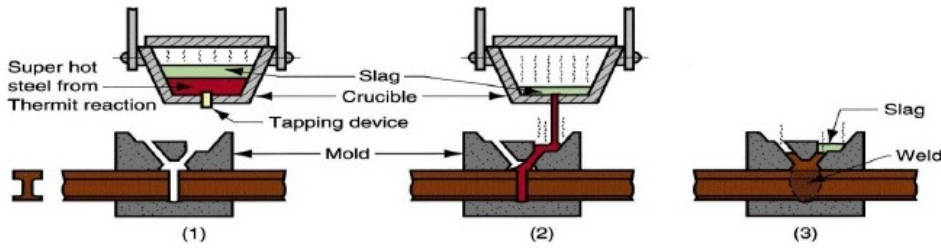
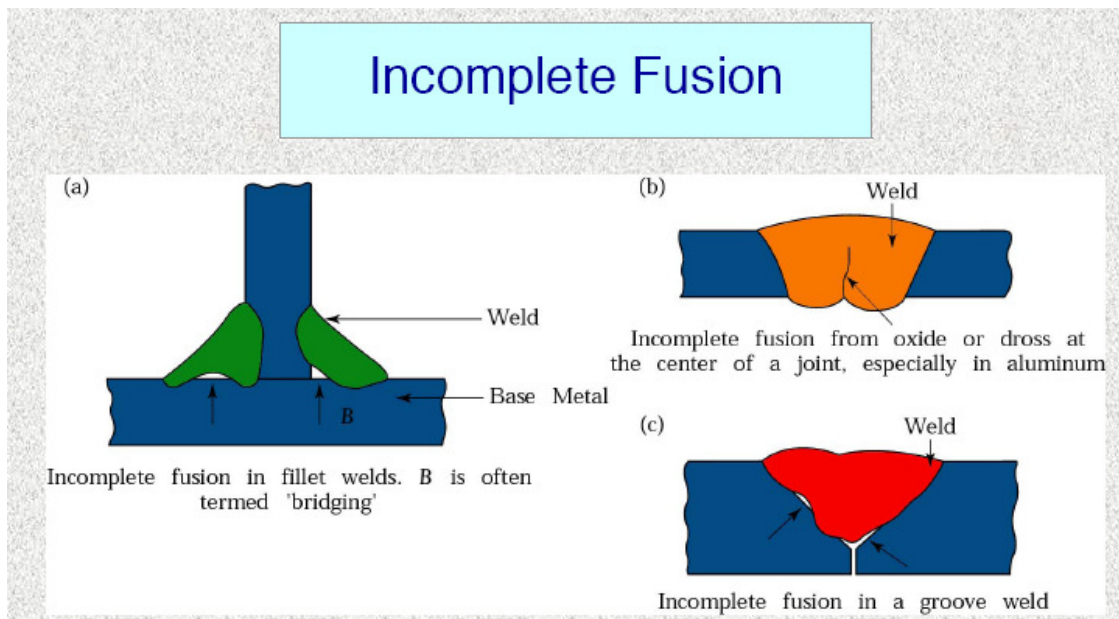


Fig: Thermit welding: (1) Thermit ignited; (2) crucible tapped, superheated metal flows into mold; (3) metal solidifies to produce weld joint.

Applications

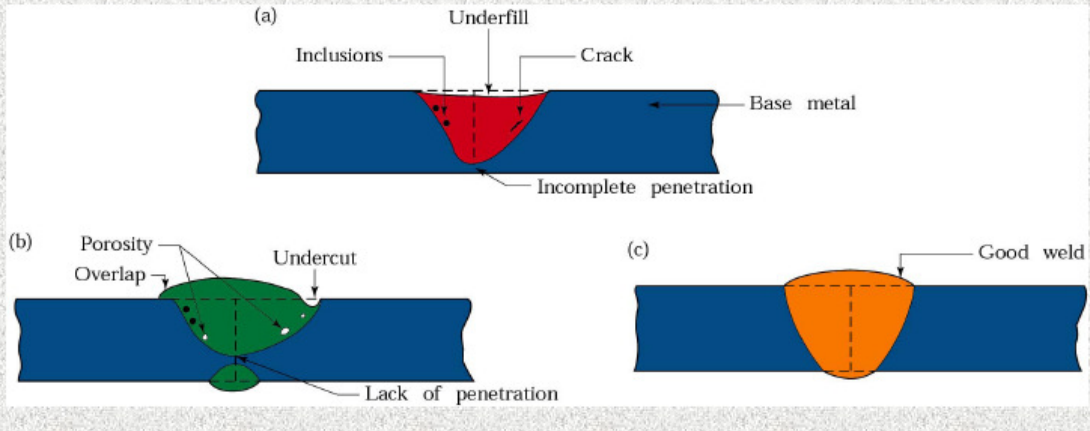
- Joining of railroad rails
- Repair of cracks in large steel castings and forgings
- Weld surface is often smooth enough that no finishing is required

Welding Defects



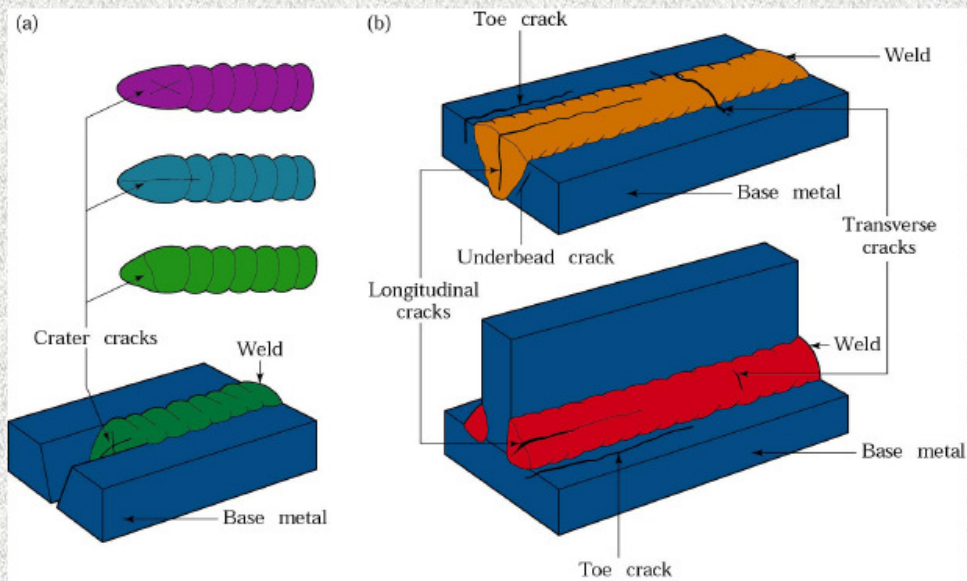
Discontinuities in Fusion Welds

Figure 29.7 Schematic illustration of various discontinuities in fusion welds. *Source: American Welding Society.*



Cracks in Welded Joints

Figure 29.8 Types of cracks (in welded joints) caused by thermal stresses that develop during solidification and contraction of the weld bead and the surrounding structure. (a) Crater cracks. (b) Various types of cracks in butt and T joints.



Distortion After Welding

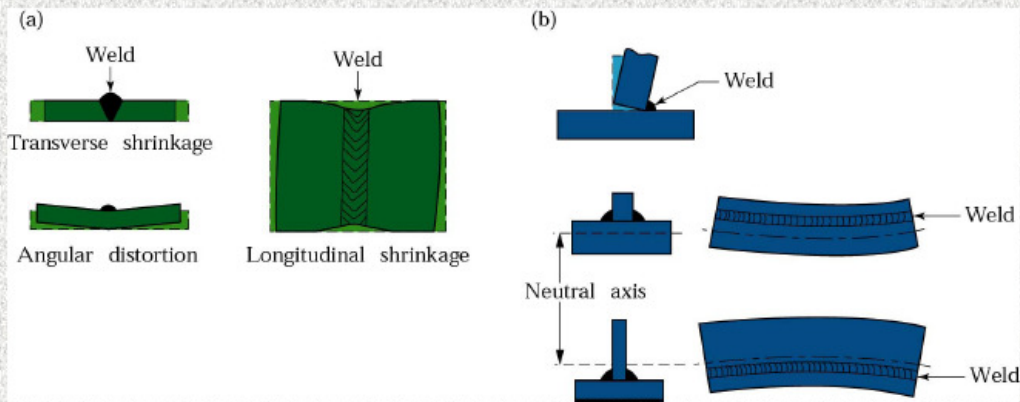


Figure 29.10 Distortion of parts after welding: (a) butt joints; (b) fillet welds. Distortion is caused by differential thermal expansion and contraction of different parts of the welded assembly.

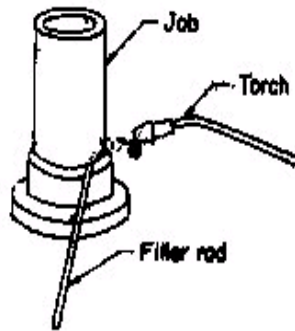
Brazing and Soldering

Brazing

It is a low temperature joining process. It is performed at temperatures above 840° F and it generally affords strengths comparable to those of the metal which it joins. It is low temperature in that it is done below the melting point of the base metal. It is achieved by diffusion without fusion (melting) of the base

Depending upon the method of heating, brazing can be classified as

1. Torch brazing
2. Dip brazing
3. Furnace brazing
4. Induction brazing



BRAZING

Fig 9 Brazing

Advantages

- Dissimilar metals which cannot be welded can be joined by brazing
- Very thin metals can be joined
- Metals with different thickness can be joined easily
- In brazing thermal stresses are not produced in the work piece. Hence there is no distortion
- Using this process, carbides tips are brazed on the steel tool holders

Disadvantages

- Brazed joints have lesser strength compared to welding
- Joint preparation cost is more
- Can be used for thin sheet metal sections

Soldering

It is a low temperature joining process. It is performed at temperatures below 840°F for joining.

Soldering is used for,

- Sealing, as in automotive radiators or tin cans
- Electrical Connections
- Joining thermally sensitive components
- Joining dissimilar metals

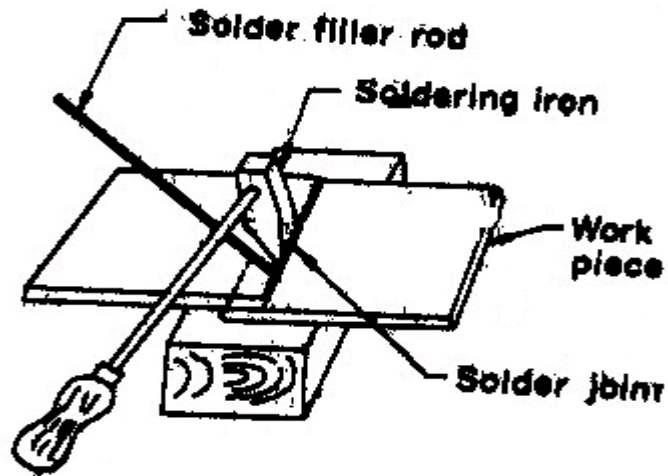


Fig 9 Soldering



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MACHINING

Definition

Lathe is a machine, which removes the metal from a piece of work to the required shape and size

Common types of lathes:

Engine Lathe:

The most common form of lathe, motor driven and comes in large variety of sizes and shapes.

Bench Lathe:

A bench top model usually of low power used to make precision machine small work pieces.

Tracer Lathe:

A lathe that has the ability to follow a template to copy a shape or contour.

Automatic Lathe:

The lathe in which the work piece is automatically fed and removed without use of an operator. Cutting operations are automatically controlled by a sequencer of some form.

Turret Lathe:

The lathes which have multiple tools mounted on turret either attached to the tailstock or the cross-slide, which allows for quick changes in tooling and cutting operations.

Computer Controlled Lathe:

Highly automated lathes, where cutting, loading, tool changing, and part unloading are automatically controlled by computer coding.

The figure (1) shows **Photographic view of Engine Lathe**

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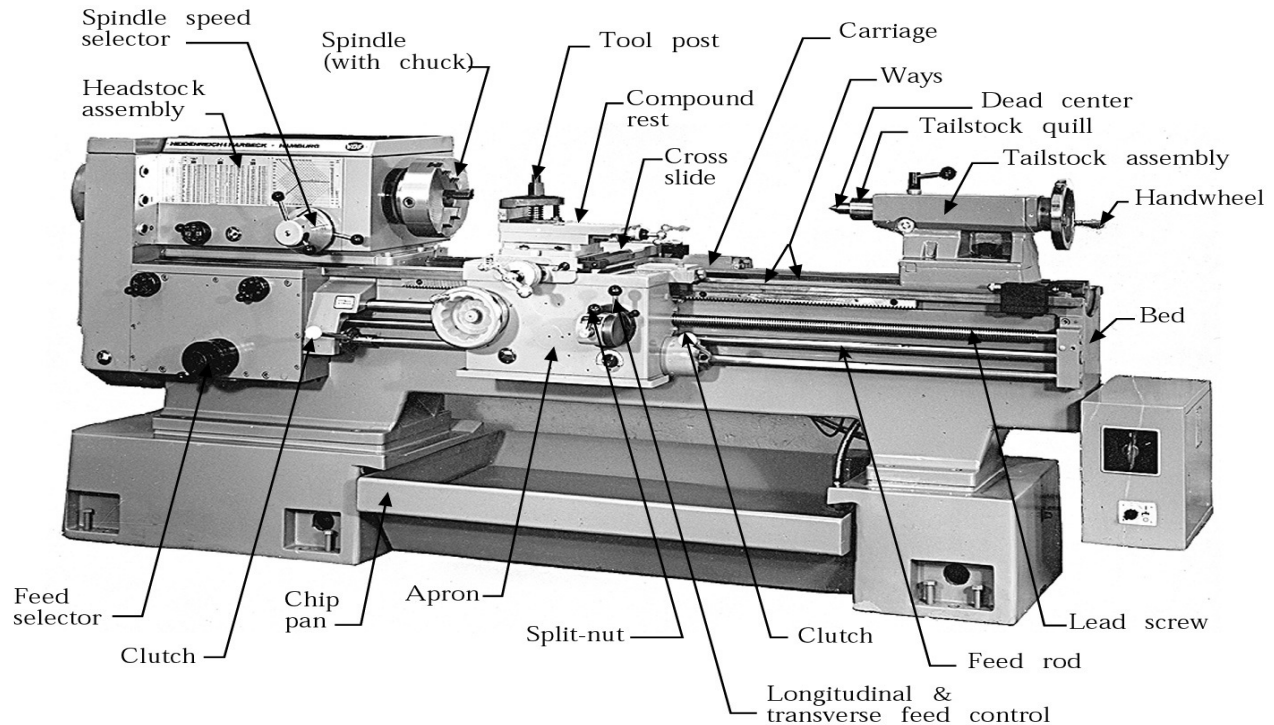


Fig (1) Engine Lathe

Centre lathe – constructional features

- Head stock
- Tail stock
- Bed
- Carriage
- Feed rod
- Lead screw
- Feed change gear box

Lathe specifications

- Distance between centers
- Swing over the bed
- Swing over the cross slide
- Horse power of the motor
- Number of speeds



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- Number of feeds

Lathes and Lathe Operations

- Lathes are the oldest machine tools
- Lathe Components
 - Bed: supports all major components
 - Carriage: slides along the ways and consists of the *cross-slide, tool post, apron*
 - Headstock – Holds the jaws for the work piece, supplies power to the jaws and has various drive Speeds
 - Tailstock – supports the other end of the work piece
 - Feed Rod and Lead Screw – Feed rod is powered by a set of gears from the headstock

LATHE BED

- The bed is the base of the lathe and supports all the major components of lathe.
- Lathe bed material made of grey cast iron , to resist deflection and absorb vibrations during cutting

Carriage Feed

- Longitudinal Feed or “Turning” - The tool is fed *along* the work.
- Cross Feed or “Facing” – The tool is fed *across* the work.

Tail Stock:

It's like a stationary drill press

It is centered with your work piece

For drilling use a drill chuck that fits your bits

Jam the drill chuck into the tail stock

To remove the chuck turn the tail stock back to zero and the chuck should pop out

Cutting Tools

There are basically two types of cutting tools:

- Single point (e.g. turning tools). (fig .2)
- Multiple point (e.g. milling tools).

Fig (2) shows single point cutting tool

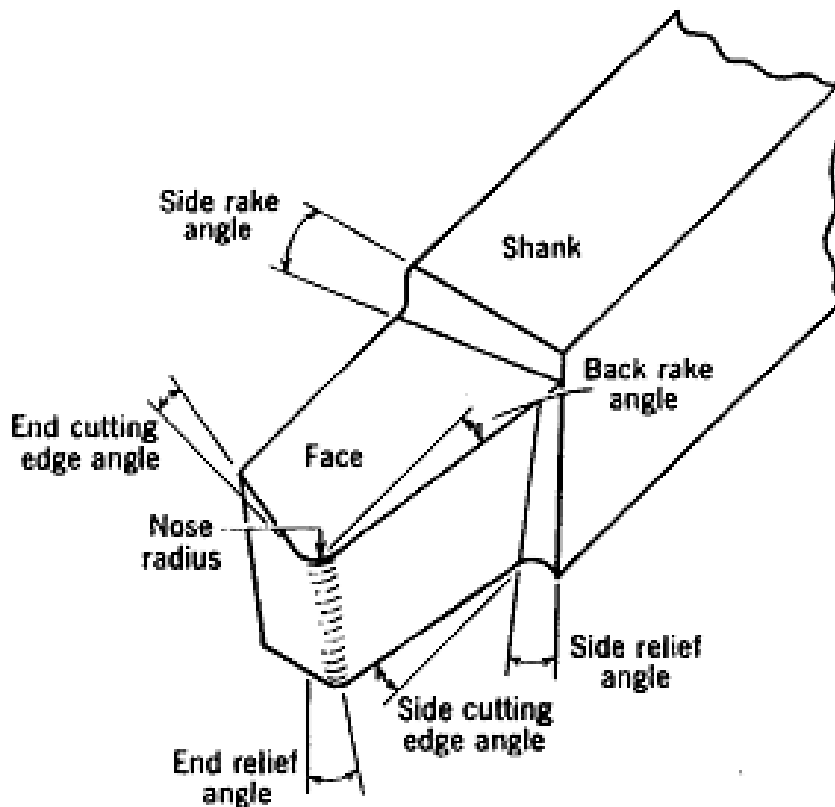


Fig (2)

Various lathe operations

- Turning – produces straight, conical, curved, or grooved work pieces
- Facing – produces a flat surface at the end of the part
- Boring – to enlarge a hole
- Drilling - to produce a hole

- Cutting off – to cut off a work piece
- Threading – to produce threads
- Knurling – produces a regularly shaped roughness

Fig (3) shows different types of lathe operations

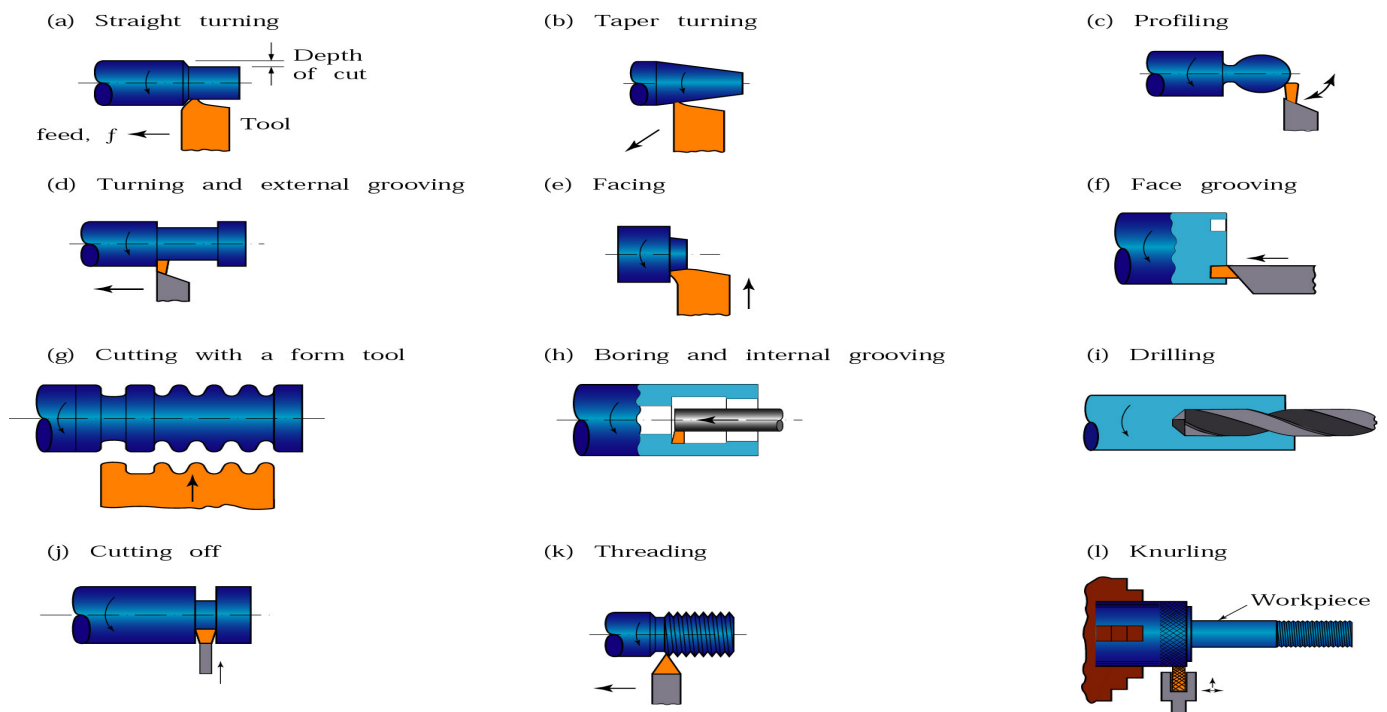


Fig (3) Types of Lathe operations



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Work holding Devices for Lathes:

Many different devices, such as chucks, collets, faceplates, drive plates, mandrels, and lathe centers are used to hold and drive the work while it is being machined on a lathe.

Work pieces can be held by various methods

- Work piece mounted between centers
- Work piece mounted within a single chuck
- Work piece mounted within a collet
- Work piece mounted on a faceplate

Three Jaw chuck: It usually has three jaws, the jaws are moved simultaneously within the chuck (fig.4).

Four Jaw chuck: This is independent chuck generally has four jaws , which are adjusted individually on the chuck face by means of adjusting screws(fig.5).

Magnetic chuck: Thin jobs can be held by means of magnetic chucks.

Face plates: The face plate is used for irregularly shaped work pieces that cannot be successfully held by chucks or mounted between centers (fig.6).

Mandrels: A work piece which cannot be held between centers because its axis has been drilled or bored and which is not suitable for holding in a chuck or against a faceplate is usually machined on a mandrel.

Collet chuck : Collet chuck is used to hold small work pieces.

3 JAW CHUCK

4 JAW CHUCK

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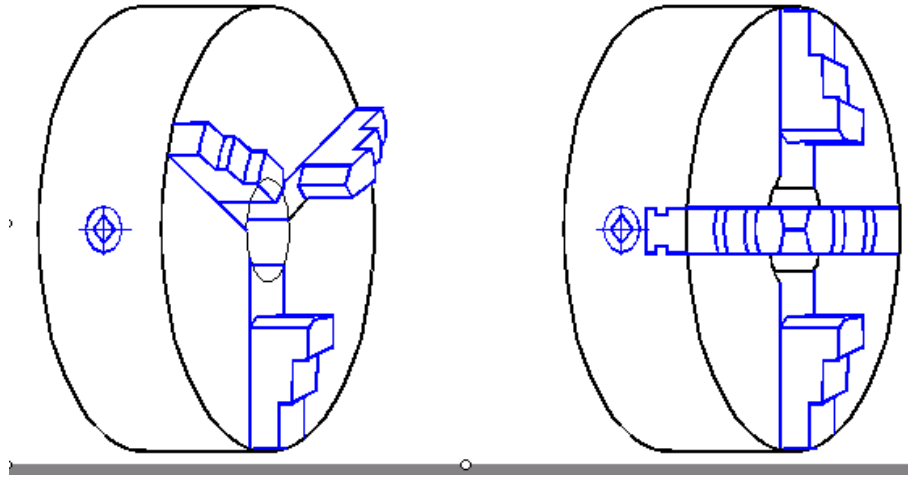


Fig.(4)

Fig.(5)

FACE PLATE

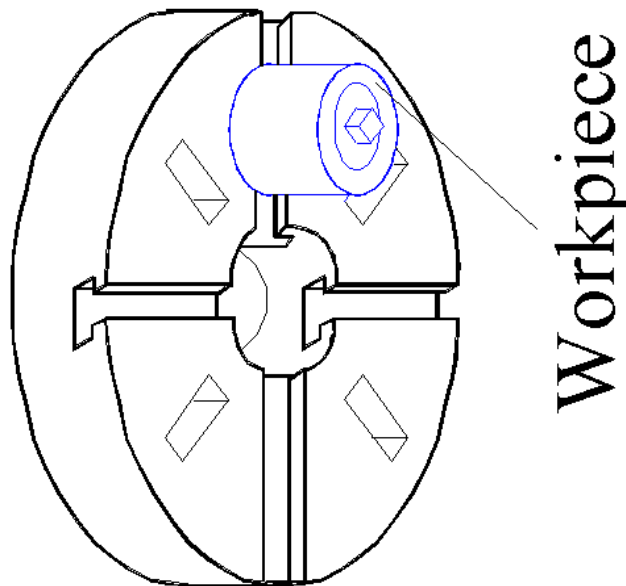


Fig.,6 Face plate

Formulas:



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Cutting speed (V) = $\pi DN/1000$ M/min

Depth of cut (D) = $(D_1 - D_2)/2$ mm

Where D_1 =original diameter and D_2 = final diameter of the work piece

Metal Removal Rate (MRR) = $\pi \times D \times d \times f$ mm³

In terms of cutting speed (V in mm/min), $MRR = 1000 \times V \times d \times f$

Where D represents original diameter of the work piece in mm

Where N represents revolution per minute (rpm)

Where d represents depth of cut in mm

Where f represents feed in mm/rev

Taper Turning

$\tan \alpha = (D_1 - D_2)/2L$ where α = angle of taper

D_1 = major diameter in mm

D_2 = minor diameter in mm

L= Length of taper in mm

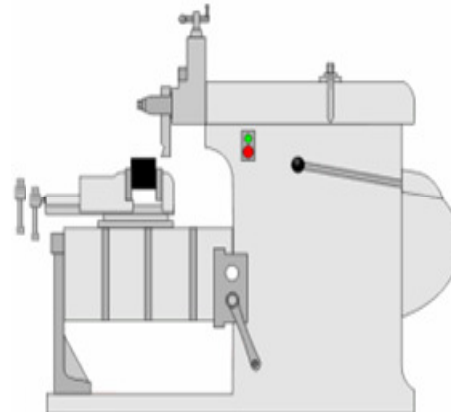
The Conicity K of the taper is defined as $K = (D_1 - D_2)/L$



SHAPER

The shaper is a relatively simple machine used for machining flat surfaces which may be horizontal, vertical or inclined with single point cutting tool.

Here *the tool reciprocates and the work is stationary*. Tooling is simple, and shapers do not always require operator attention while cutting.

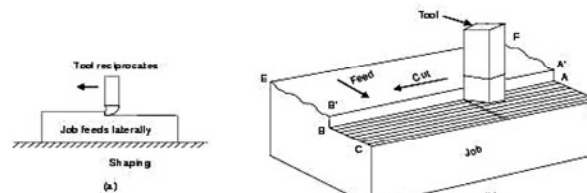


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ASST./PROF. (MECHANICAL DEPT.)



SHAPER – PRINCIPLE OF OPERATION

The tool is fitted on the tool post on the front end of the ram. The ram reciprocates along with the tool to remove the metal in the forward stroke called as *cutting stroke*. The tool does not cut the metal in the return stroke called as *idle stroke*. There fore one pass is nothing but the combination of one cutting stroke and one idle stroke.



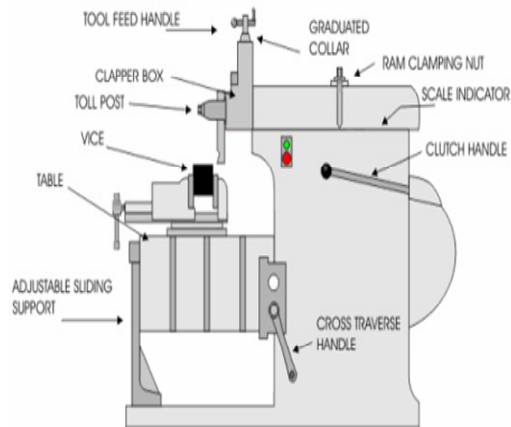
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PARTS OF A SHAPER

BASE:

The base is a heavy and robust in construction which is made of cast iron by casting process. It should absorb vibration due to load and cutting forces while machining.



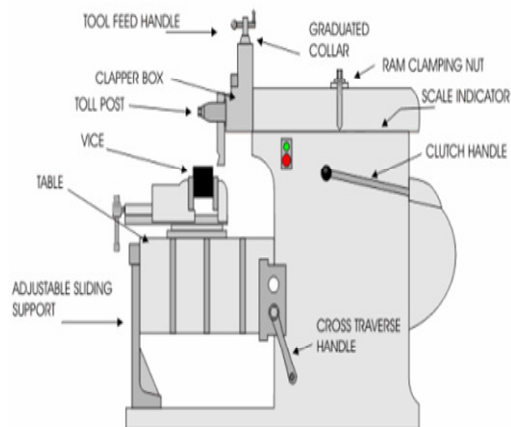
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PARTS OF A SHAPER

RAM:

The ram slides back and forth in dovetail or square ways to transmit power to the cutter. The starting point and the length of the stroke can be adjusted.



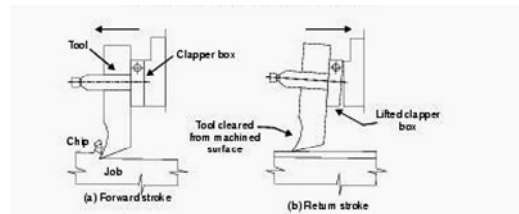
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PARTS OF A SHAPER

CLAPPER BOX:

The clapper box is needed because the cutter drags over the work on the return stroke. The clapper box is hinged so that the cutting tool will not dig in. Often this clapper box is automatically raised by mechanical, air, or hydraulic action.



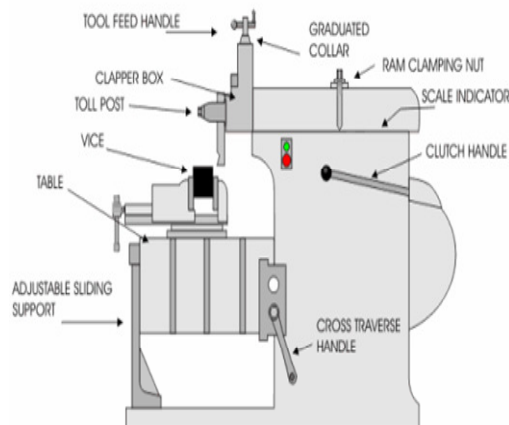
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PARTS OF A SHAPER

TABLE:

The table is moved left and right, usually by hand, to position the work under the cutter when setting up. Then, either by hand or more often automatically, the table is moved sideways to feed the work under the cutter at the end or beginning of each stroke.



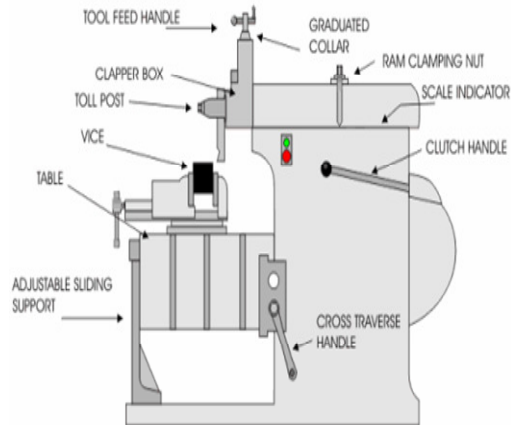
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PARTS OF A SHAPER

SADDLE:

The saddle moves up and down (Y axis), usually manually, to set the rough position of the depth of cut. Final depth can be set by the hand crank on the tool head.



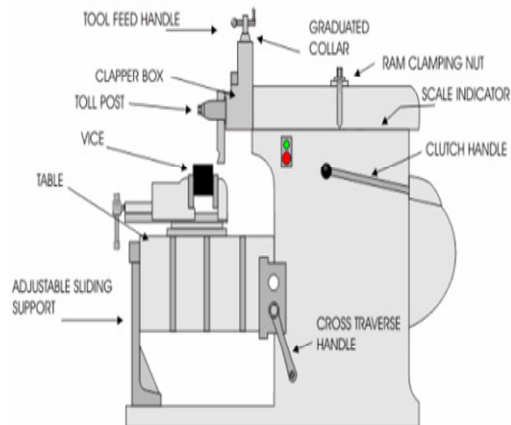
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PARTS OF A SHAPER

COLUMN:

The column supports the ram and the rails for the saddle. The mechanism for moving the ram and table is housed inside the column.



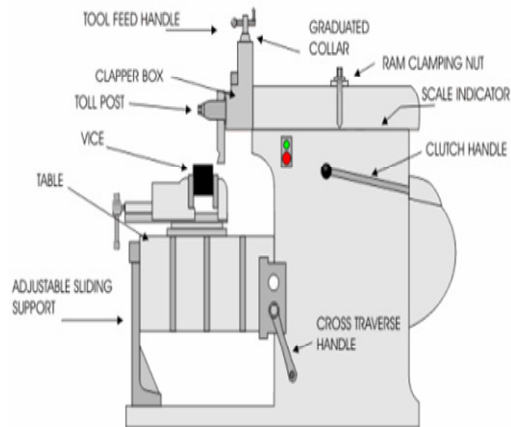
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PARTS OF A SHAPER

TOOLHEAD:

The toolhead is fastened to the ram on a circular plate so that it can be rotated for making angular cuts. The toolhead can also be moved up or down by its hand crank for precise depth adjustments.



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TOOLHEAD – FUNCTIONS & OPERATIONS

- Holds the tool *rigidly*, provides *vertical & angular movement*.
- Allows the tool to have an *automatic relief* during *return stroke*.
- The vertical slide of the tool head is *graduated in degrees* so that we can work at *any desired angle*.
- Apron consisting of a *clapper box, clapper block and tool post* is clamped upon the vertical slide by a screw.
- On the *forward cutting stroke* the clapper block fits securely to the clapper box to make rigid tool support.
- On the *return stroke*, a slight frictional drag of the tool on the work lifts the block out of the clapper box by a sufficient amount preventing the tool cutting edge from dragging and consequent wear.



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SHAPING OPERATIONS

- The tool post has been turned at an angle so that side of the material can be machined
- Major Applications: Square edges, side machining of blocks, etc



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SHAPING OPERATIONS

- The tool post is not angled so that the tool can be used to level a surface.
- Major Applications: Surface cutting of metal work piece etc.



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SHAPING OPERATIONS

- The top slide is slowly feed into the material so that a 'rack' can be machined for a rack and pinion gear system
- Major Applications: Teeth cutting in gears and other applications where teeth like structures are required.

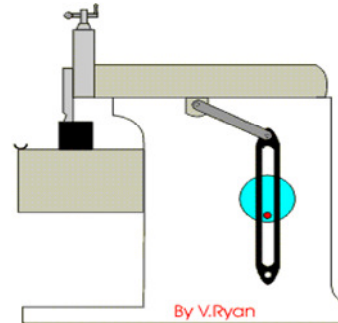
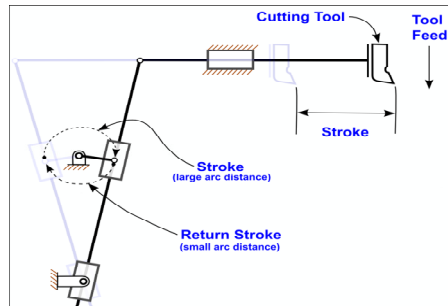


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QUICK RETURN MECHANISM

The reciprocating motion of the mechanism inside the shaping machine can be seen in the diagram. As the disc rotates the top of the machine moves forwards and backwards, pushing a cutting tool. The cutting tool removes the metal from work which is carefully bolted down.

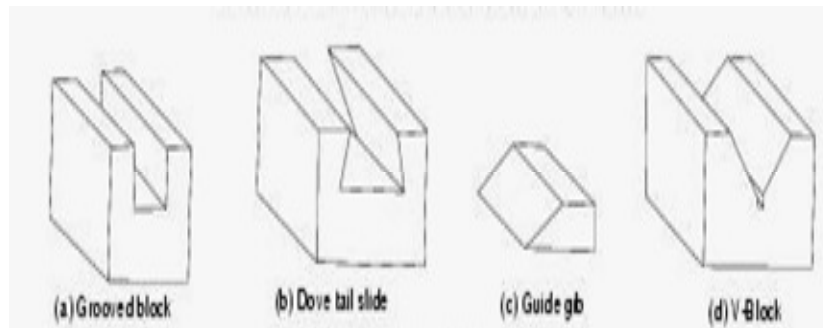


By V.Ryan
THE SHAPING MACHINE

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JOB SURFACES GENERATED BY SHAPER



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PLANER



- WP MOUNTED ON TABLE
RECIPROCATES BUT TOOL IS
STATIONARY
- SPC
- TOOL – VERTICALLY – MOVES
ON A CROSS RAIL
- LARGE AND HEAVY WP

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1

PLANER

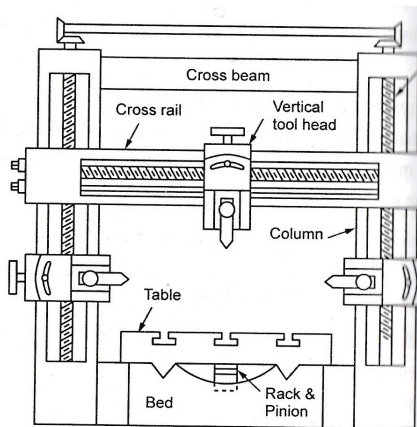


Fig 3.20. Double housing planer

- 2 VERTICAL COLUMNS WITH
VERTICAL GUIDEWAYS WITH CR
– TOOL HEADS TH
- CROSS BEAM AT TOP
- CF – TH ALONG CR
- VF- TH DOWN
- TOOL SLIDE TILTED
- FEED MANUAL & AUTOMATIC
- FS & RS
- LATHE BED , GUIDEWAYS

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2

PLANER TYPES

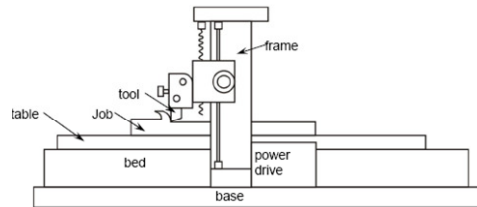


Fig. 2.12 Schematic view of a planning machine

- DOUBLE HOUSING
PLANER
- OPEN SIDE PLANER
- PIT PLANER
- EDGE PLANER
- DIVIDED TABLE PLANER

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3

PLANER

DOUBLE HOUSING PLANER

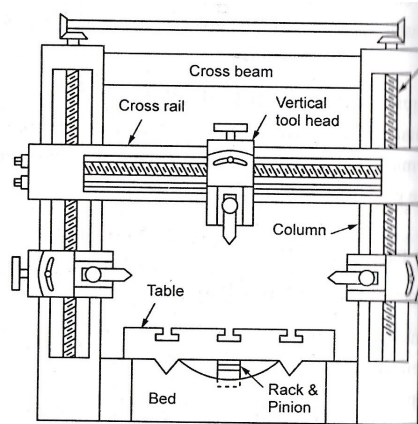


Fig 3.20. Double housing planer

- **BED** – BOX- CASTING –LENGTH TWICE THE TABLE – V GUIDEWAYS – CROSS RIBS
- **TABLE** – BOX – RECIPROCATES ON BED GUIDEWAYS – TSLOTS-CLAMP THE WP
- **COLUMNS**- TWO LONG STRUCTURAL MEMBERS – GUIDEWAYS – CONNECTED BY CR & CROSS BEAM – CR FEED MECHANISM &POWER TRANSMISSION
- **CROSS RAIL CR** - RIGID STRUCTURAL MEMBER MOUNTED B/W 2 COLUMNS –AT ANY HT
- **TOOL HEAD** – MAX 4 . 2 ON CR & 2 ON GUIDEWAYS OF BOTH COLUMNS

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4

PLANER OPERATIONS

• **PLANING HORIZONTAL SURFACE** - R, L TOOL, DOC – FEEDING THE DOWN FEED SCREW – FEED – ROTATE CR FEED SCREW – TOOL SETTING - SHAPER

• **PLANING OF AN ANGLE** - V GROOVES, DOVETAIL MACHINING, VERTICAL SLIDE TO ANGLE, RELIEF TO CE OF TOOL

• **PLANING VERTICAL SURFACE** – VERTICAL SLIDE PERPENDICULAR TO PLANE TABLE – APRON SWIVELLED – FEED- FEEDING THE DOWN FEED SCREW – DOC - ROTATE CR FEED SCREW

BEND TOOL - SLIDE IS MADE PERPENDICULAR TO WP - SWIVELLING THE APRON NOT NECESSARY - FEED – MOVE TOOL HEAD IN VERTICAL DIRECTION

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PLANER OPERATIONS

PLANING CURVED SURFACE

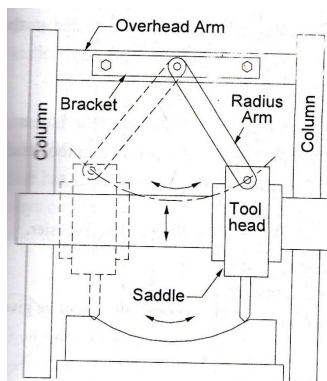


Fig. 3.34. Planing curved surface

- SPECIAL ATTACHEMENT
- BRACKET IS FITTED TO OVER HEAD ARM
- ONE END OF RADIUS ARM IS PIVOTED TO BRACKET – OTHER END CONNECTED TO VERTICAL SLIDE OF TOOL HEAD
- DOWN FEED SCREW OF TOOL HEAD IS DISENGAGED
- TOOL HEAD MOVES CROSSWISE & SLIDE MOVES UP & DOWN BY ROTATING THE CROSS FEED SCREW
- TOOL MOVEMENT – CURVED PATH – CURVED SURFACE

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PLANER VS SHAPER

- TOOL STATIONARY – WP RECIPROCATES
- LARGE & HEAVY WP
- MORE ACCURACY – TOOL RIGIDLY SUPPORTED
- PRODUCTION TIME MORE
- WORK SETTING MORE SKILL
- HEAVY CUT , STRONG BASE, STRONG TOOLS

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MILLING

PRINCIPLE OF OPERATION

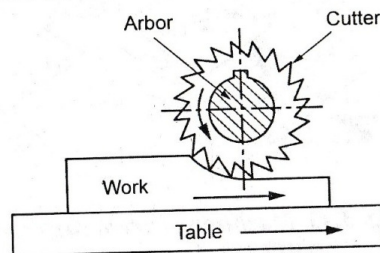


Fig. 3.44.

- WORK FEED AGAINST ROTATING MULTIPOINT CUTTER
- METAL REMOVED - SMALL CHIPS
- MRR HIGH – HIGH SPEED – MANY CUTS
- MPC – BETTER SF
- FLAT & IRREGULAR SURFACE

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1

MILLING

PRINCIPLE OF OPERATION

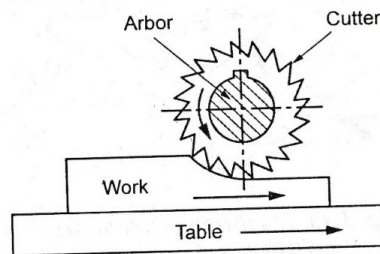


Fig. 3.44.

- MPC ROTATING CUTTER
- CUTTER MOUNTED ON ROTATING SPINDLE OR ARBOR
- FEED- LONG, CROSS, VERTICAL, ANGULAR RARE
- ONE CE DO CUTTING – OTHER CE WILL BE IDLE- COOLED. STRESS ON CE IS NOT CONTINUOUS – MORE LIFE TO CE

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2

MILLING

HORIZONTAL MILLING MACHINE

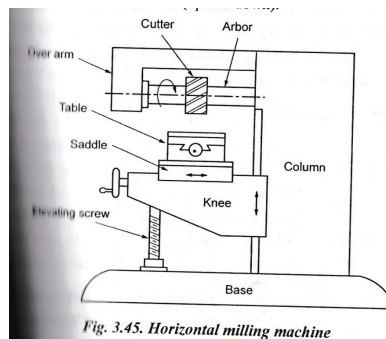


Fig. 3.45. Horizontal milling machine

- COLUMN AND KNEE TYPE MILLING MACHINES – FLOOR WORK, MAINTENANCE WORK, TOOL ROOM WORK
- VERTICAL COLUMN ON ITS BASE – COLUMN HAS MACHINED GUIDEWAYS ON FRONT FACE- KNEE SLIDES UP AND DOWN ON THESE WAYS
- COLUMN – HOUSING FOR SPEED AND FEED MECHANISMS
- KNEE – SADDLE AND WORK TABLE
- HORZ TYPE – AXIS OF ROTATION OF ARBOR - HORZ
- VERZ TYPE - AXIS OF ROTATION OF ARBOR - VERTICAL

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5

MILLING

HORIZONTAL MILLING MACHINE

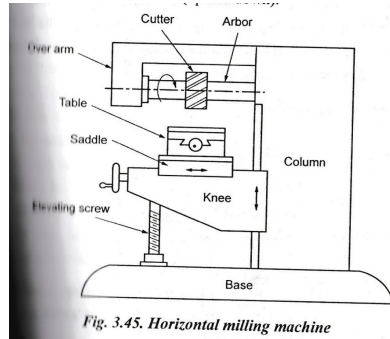


Fig. 3.45. Horizontal milling machine

- PLAIN OR HORIZONTAL MILLING M/C
- BASE – GCI- RESERVOIR FOR CF
- COLUMN – MAIN SUPPORT FOR M/C - MOTOR AND OTHER DRIVING MECHANISMS – GUIDE WAYS
- KNEE – PROJECTS FROM COLUMN , SLIDES UP AND DOWN – SUPPORT SADDLE AND TABLE – ELEVATING SCREW UP AND DOWN
- SADDLE SUPPORTS AND CARRIES TABLE – TRAVERSED MOVEMENT
- TABLE – TOP SURFACE ACCURATELY MACHINED - T SLOTS ALONG THE LENGTH FOR HOLD WP

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MILLING

HORIZONTAL MILLING MACHINE

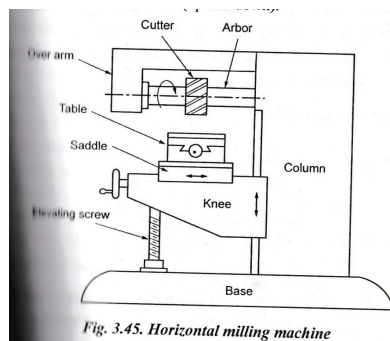


Fig. 3.45. Horizontal milling machine

- TABLE – RESTS ON GUIDE WAYS OF SADDLE – TRAVELS LONGITUDINALLY IN HORZ PLANE – SUPPORT WP
- OVERARM - MOUNTED ON & GUIDED BY TOP OF COLUMN – HOLD OUTER END OF ARBOR TO PREVENT IT FROM BENDING
- ARBOR – CUTTER MOUNTED- TAPERED AT ONE END TO FIT THE SPINDLE NOSE – 2 SLOTS TO FIT THE NOSE KEYS FOR LOCATING AND DRIVING IT

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DRILLING

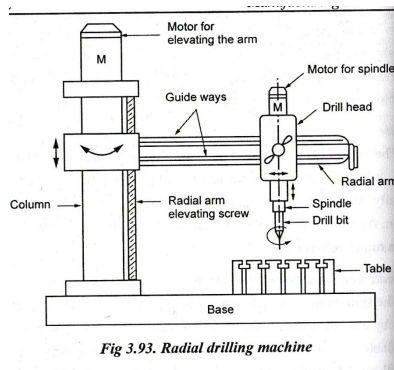
- HOLE ON WP – ROTATING CUTTER DRILL
- DRILLING M/C OR DRILL PRESS
- VERTICAL PRESSURE
- AXIAL MOVEMENT TO TOOL OR WP
- LOW COST
- BORING, COUNTER BORING, COUNTER SINKING, REAMING, TAPPING AND SPOT FACING

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1

DRILLING

RADIAL DRILLING MACHINE



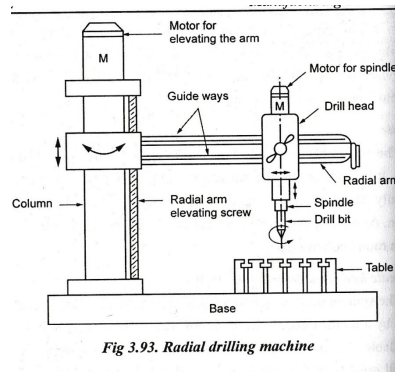
- Medium to large & heavy WP
- Consist of heavy ,round, vertical column mounted on a large base
- Column supports a radial arm raised & Lowered
- Arm can be swung around any position over the work bed.
- ARM – LOCKED AT ANY DESIRED POSITION AS PER JOB SIZE
- Drill head-mechanism for rotating & feeding the drill (mounted on radial arm) & can be moved horizontally on the guideways & clamped at any desired position

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DRILLING

RADIAL DRILLING MACHINE



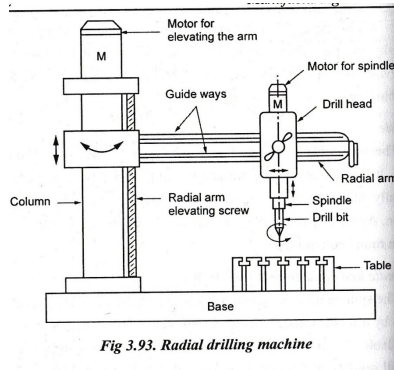
- 3 movements in RDM permit the drill to be located at desired position
- Used for drilling several holes on the same WP
- RDM is versatile & work on large WP

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DRILLING

RADIAL DRILLING MACHINE



- BASE – TSLOTS – LARGE WP
- COLUMN – RADIAL ARM, DRILL HEAD, MOTOR-ELEVATING SCRE ROTATED BY MOTOR
- RADIAL ARM – DRILL HEAD , ARM CAN BE SWIVELED AROUND THE COLUMN
- DRILL HEAD – SEPARATE MOTOR – SPINDLE – DRILL – DRILL BIT
- SPINDLE HEAD AND FEED MECHANISM – FEED MANUAL OR AUTOMATIC

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DRILLING

RADIAL DRILLING MACHINE



- Plain RDM:** provisions are made for vertical adjustment of the arm, horizontal movement of drill head along the arm & Circular movement of the arm in horizontal plane about the vertical column.
- Semiuniversal Machine:** In addition to the 3 movements, drill head can be swung about a horizontal axis perpendicular to the arm –drill hole at an angle to horizontal plane
- Universal Machine:** In addition to the 4 movements, arm holding the drill head can be rotated on a horizontal axis –these 5 movements enable to drill

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DEPARTMENT OF AUTOMOBILE ENGINEERING

UNIT IV ABRASIVE PROCESS AND GRINDING

GRINDING : METAL REMOVING PROCESS – METAL IS REMOVED WITH THE HELP OF ROTATING GRINDING WHEEL

WHEELS MADE OF FINE GRAINS OF ABRASIVE MATERIALS - **BOND**

HIGH HARDNESS & HIGH HEAT RESISTANCE

VERY GOOD SURFACE FINISH WITH HIGH ACCURACY

MATERIAL REMOVAL – **0.25 mm TO 0.5 mm**

WHILE GRINDING - WHEEL IS ROTATED & WORK IS FED AGAINST THE WHEEL

ABRASIVE GRAINS IN WHEEL SHEAR OFF SMALL METAL PARTICLES FROM WORK PIECE

DURING MACHINING, BLUNT ABRASIVE GRAINS WILL BE RELEASED FROM THE WHEEL SURFACE - NEW ABRASIVE GRAINS PROJECT FROM SURFACE OF WHEEL - **SELF SHARPENING OF THE GRINDING WHEEL**

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MANUFACTURING TECHNOLOGY – II

1

ABRASIVE PROCESS AND GRINDING

GRINDING PURPOSE:

- REMOVE SMALL AMOUNT OF METAL FROM WP AND FINISH THEM TO CLOSE TOLERANCES
- BETTER SURFACE FINISH
- MACHINE HARD SURFACES THAT CAN'T BE MACHINED BY HIGH SPEED STEELS
- SHARPENING OF CUTTING TOOLS
- GRINDING OF THREADS
- BIGGER STOCKS OF METALS

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2

ABRASIVE PROCESS AND GRINDING

PLAIN CENTRE TYPE CYL GRINDING M/C

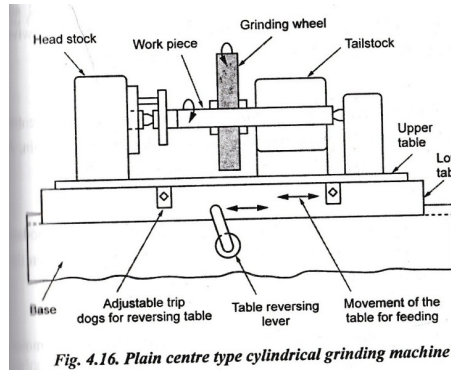


Fig. 4.16. Plain centre type cylindrical grinding machine

- CYL PARTS
- TAPERS, FILLETS, CONTOURED CYLINDERS
- **BASE** – MAIN CASTING ON FLOOR, SUPPORT THE PARTS, HORZ GUIDEWAY – TABLE SLIDES TO GIVE TRAVERSE MOTION TO WP
- **TABLE** - UPPER TABLE & LOWER TABLE, LOWER TABLE SLIDES ON GUIDEWAYS OF BED
- **LOWER TABLE** – LONG FEED OF WORK PAST THE GRINDING WHEEL – HAND/POWER
- **ADJUSTABLE DOGS** – SIDE OF LOWER TABLE – REVERSE THE TABLE END STROKE

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ABRASIVE PROCESS AND GRINDING

PLAIN CENTRE TYPE CYL GRINDING M/C

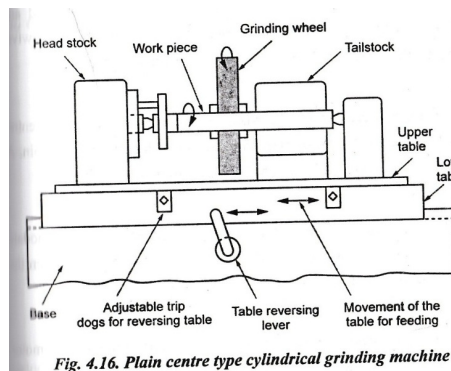


Fig. 4.16. Plain centre type cylindrical grinding machine

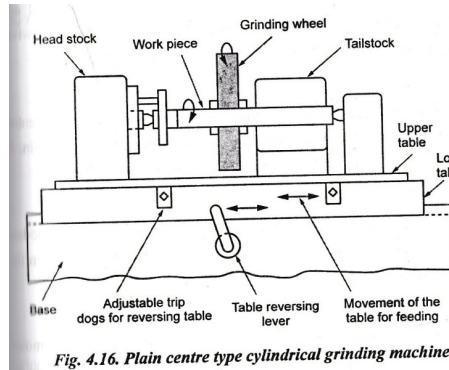
- UPPER TABLE MOUNTED ON LOWER TABLE, CARRIES HS, TAIL STOCK
- HS, TS ADJUSTED ACCORDING TO LENGTH OF WP
- UPPER TABLE CAN BE SWIVELED AND CLAMPED IN POSITION
- MAX ANGLE FOR SWIVEL – 10 DEG ON EITHER SIDE
- SWIVELING – GRINDING TAPERS

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ABRASIVE PROCESS AND GRINDING

PLAIN CENTRE TYPE CYL GRINDING M/C



- **HEADSTOCK** – SUPPORTS THE WP BY MEANS OF DEAD CENTRE – WP DRIVEN BY HS THRU DOG & DRIVING PIN- SEPARATE MOTOR IS HOUSED IN HS TO ROTATE THE WP

- **TAILSTOCK** – ADJ & CLAMPED TO ACCOMMODATE DIFFERENT LENGTH OF WP- WP IS HELD IN BETWEEN CENTRE OF HEADSTOCK AND TAILSTOCK

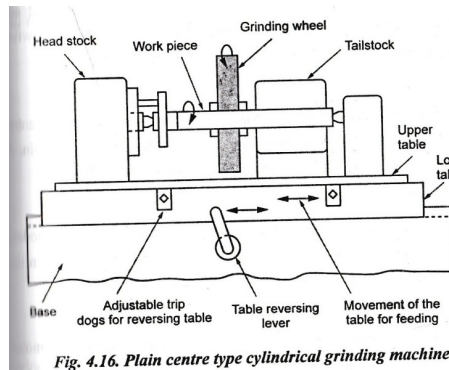
- **WHEEL HEAD** – CARRIES A GRINDING WHEEL, ROTATED BY A MOTOR IN HS, PLACED OVER BED AT BACK- MOVE PERPENDICULAR TO TABLE HAND OR POWER – CROSS FEED

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ABRASIVE PROCESS AND GRINDING

PLAIN CENTRE TYPE CYL GRINDING M/C



- **WORKING** – WP HELD B/W CENTRES

- ROTATED BY DOG OR FACEPLATE

- GRINDING WHEEL ROTATES ABOUT ITS OWN AXIS IN OPP DIRECTION OF WP

- GRINDING WHEEL IS FED BY HAND TOWARDS THE WP FOR CUTS

- WORK SPEED – 20 -30 SURFACE SPEED METERS PER MIN (s.m.p.m)

- WHEEL SPEED – 1500 -2000 s.m.p.m

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ABRASIVE PROCESS AND GRINDING

PLAIN CENTRE TYPE CYL GRINDING M/C

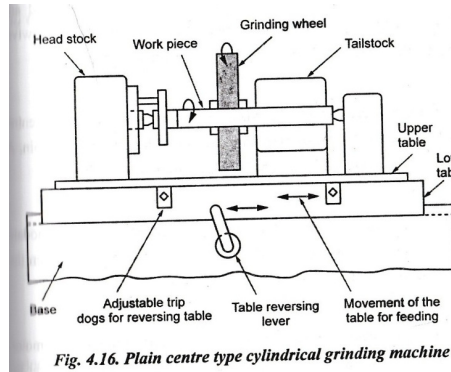


Fig. 4.16. Plain centre type cylindrical grinding machine

• DOC AT EACH REVERSAL- 0.025 mm TO 0.125 mm – FOR ROUGH GRINDING

•DOC AT EACH REVERSAL- 0.0125 mm TO 0.0625 mm – FOR FINISHING

LONG FEED – 0.25 TO 0.75 WIDTH OF WHEEL FACE

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ABRASIVE PROCESS AND GRINDING

PLAIN CENTRE TYPE CYL GRINDING M/C

Centre type universal grinder:

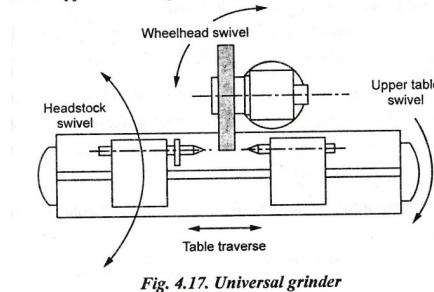


Fig. 4.17. Universal grinder

Center type universal grinders are widely used in tool room for grinding tools. The features of this machine are similar to those of plain grinders but in addition, it is provided with the following features.

1. The centre of the head stock spindle can be used as alive or dead. The work can be held and revolved by a chuck. It can also be held between centres and revolved.
2. The wheel head can be swiveled in a horizontal plane in any angle. The wheel head can be fed in the inclined direction also.
3. The headstock can be swiveled to any angle in the horizontal plane.
4. The wheel head can also be arranged for internal grinding.

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DEPARTMENT OF MECHANICAL ENGINEERING



PART PROGRAM

Part program is a set of instructions which instructs the machine tool about the processing steps to be performed for the manufacture of a component.

Part programming is the procedure by which the sequence of processing steps and other related data, to be performed on the CNC machine is planned and documented.

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INFORMATION NEEDED BY A CNC MACHINE

- 1. Preparatory Information: units, incremental or absolute positioning**
- 2. Coordinates: X,Y,Z, RX,RY,RZ**
- 3. Machining Parameters: Feed rate and spindle speed**
- 4. Coolant Control: On/Off, Flood, Mist**
- 5. Tool Control: Tool and tool parameters**
- 6. Cycle Functions: Type of action required**
- 7. Miscellaneous Control: Spindle on/off, direction of rotation**

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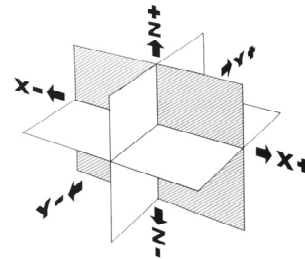


CARTESIAN COORDINATE SYSTEMS

The X and Y planes (axes) are horizontal and represent horizontal machine table motions.

The Z plane or axis represents the vertical tool motion.

The plus (+) and minus (-) signs indicate the direction from the zero point (origin) along the axis of movement.



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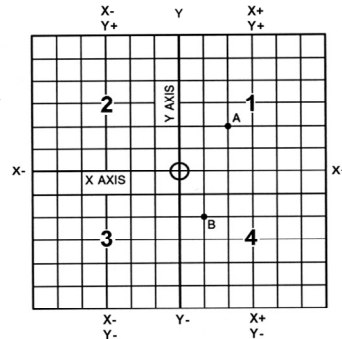


Point A would be 2 units to the right of the Y axis and 2 units above the X axis. Assume that each unit equals 1.000. The location of point A would be $X + 2.000$ and $Y + 2.000$. For point B, the location would be $X + 1.000$ and $Y - 2.000$. In CNC programming it is not necessary to indicate plus (+) values since these are assumed. However, the minus (-) values must be indicated. For example, the locations of both A and B would be indicated as follows:

A X2.000 Y2.000

B X1.000 Y-2.000

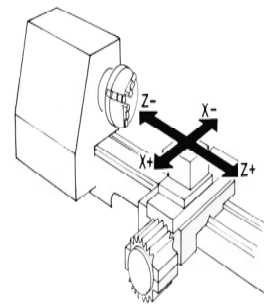
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LATHE

The engine lathe, one of the most productive machine tools, has always been an efficient means of producing round parts. Most lathes are programmed on two axes.

- The X axis controls the cross motion of the cutting tool. Negative X (X-) moves the tool towards the spindle centerline; positive X moves the tool away from the spindle centerline.
- The Z axis controls the carriage travel toward or away from the headstock.



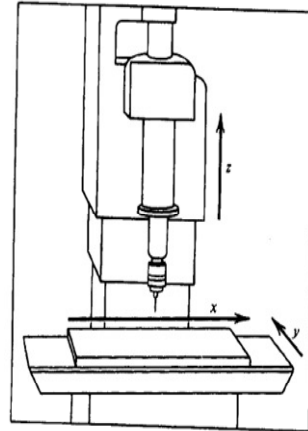
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MILLING MACHINE

The milling machine can be programmed on three axes:

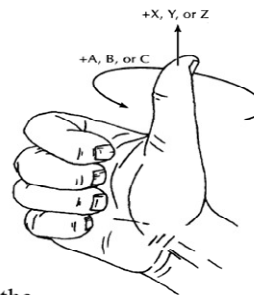
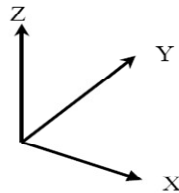
- The X axis controls the table movement left or right.
- The Y axis controls the table movement toward or away from the column.
- The Z axis controls the vertical (up or down) movement of the knee or spindle.



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Right Hand Rule



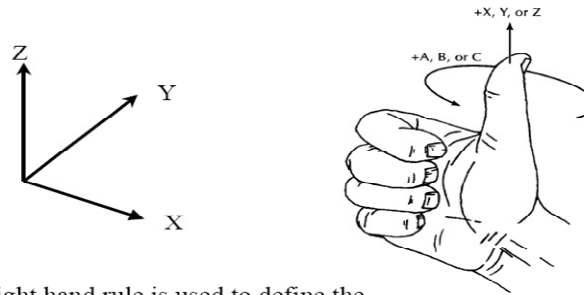
The right hand rule is used to define the positive direction of the coordinate axes.

Nanfara, Fig. 2.1

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Right Hand Rule



The right hand rule is used to define the positive direction of the coordinate axes.

Nanfara, Fig. 2.1

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INTERPOLATION

The method by which contouring machine tools move from one programmed point to the next is called interpolation. This ability to merge individual axis points into a predefined tool path is built into most of today's MCUs.

There are five methods of interpolation: linear, circular, helical, parabolic, and cubic. All contouring controls provide linear interpolation, and most controls are capable of both linear and circular interpolation. Helical, parabolic, and cubic interpolation are used by industries that manufacture parts which have complex shapes, such as aerospace parts and dies for car bodies.

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DEPARTMENT OF AUTOMOBILE ENGINEERING

Unit IV

FORMING AND SHAPING OF PLASTICS

Plastic Material & Processes

Polymers have increasingly replaced metallic components in various applications

- Corrosion resistance & resistance to chemicals
- Low electrical and thermal conductivity
- Low density
- High strength – to – weight ratio
- Noise reduction
- Wide choice of colors & transparencies
- Ease of manufacturing & complexity of design possibilities
- Relatively low cost

Polymers are long chain molecules that are formed by polymerization i.e. by linking & cross-linking of different monomers

Monomer is the basic building block of a polymer

“mer” indicates the smallest repetitive unit

Polymer means “many mers”, generally repeated hundreds or thousands of times in a chainlike structure.

Monomers are linked into polymers in repeating units to make longer & larger molecules, by a chemical process called a polymerization reaction

Degree of polymerization (DP): Ratio of the molecular weight of the polymer to the molecular weight of the repeating unit.

Ex. PVC has a mer wt. of 62.5 and molecular wt. of PVC is 50,000. DP of PVC is $50000/62.5 = 800$

General properties & Applications of Thermoplastics:

Linear polymers in which the molecules are synthesized in the shape of long threads.

No chemical change during moulding operation

Moulding is done with application of heat

Harden upon cooling



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Can be reshaped while in the softened state and reharden

Become too soft to use at temp. from 66 deg. to 315 deg.

Common Thermoplastics:

a) Cellulosics:

Comprises a wide variety of materials such as Cellulose acetate, Cellulose nitrate, Cellulose acetate butyrate & cellulose propionate etc.

Have good strength, toughness, transparency, surface gloss, chemical resistance and mouldability.

Cellulose acetate: Made in solid form for molded parts such as toys, handles, electrical parts, knobs etc.

Sheet form (cellophane) used as electrical insulating tape.

Cellulose nitrate (Celluloid): available in a wide variety of beautiful colors – spectacle frames, fibre-coating etc.

b) Nylons(Polyamides):

Nylon was originally in the form fibers & fabrics

In recent years it is successfully molded, extruded, formed into sheet & film, cast to prepare bearings, gears, drawer slides, m/c slides, rollers etc.

Many variety of filaments used in clothing, rope, brush bristles etc.

Outstanding features are

- low coefficient of friction
- Resistance to heat, abrasion & chemicals
- Strong, tough & light in wt.

Properties:

- Resistivity to solvents , alkalis
- Excellent dielectric properties
- Toughness
- Very low moisture absorption
- Relatively low cost
- Can be blow moulded ,injection moulded, estimated into a wide range of products
- House wares (bowls, plates, dishpans)
- Paint brush handles, flexible tubing,
- Bags for packaging vegetables, etc.



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c) Polystyrene:

- It is a crystal clear plastic with a high gloss.
- Has an excellent tensile strength.
- Can be used only up to 66 to 90⁰c
- Easily produced in any form & can be joined by cementing.
- Used for bottles, low cost utensil, model kits, Toys etc. in a wide choice of colors.

d) Polypropylene:

- Excellent insulator, can be moulded or extruded into sheet, film or pipe.
- Used for automobile accelerator pedals, hospital equipment.
- Unlimited colourability.
-

e) Polycarbonate

- Trade names are hexan, merlon & polycarbafil .
- Easy for moulding, extrusion & machining.
- Can be nailed and riveted without cracking.
- Due to their toughness, make excellent safety glass for street lamps, windows & m/c gaurds.
- Keep their toughness & strength at temp 120⁰c.
- House hold equipment, blow-moulded bottles etc.

f) Acrylic Resin

- * (polymethyl methacrylate, acrylic plexiglass or Lucite)
- * Can be easily shaped, most widely used in sheet form for sign boards.
- * Rods & tubes are cast in glass or metal cylinders or extruded can also be injection moulded.
- * Tough but easily scratched.
- * Widely used for outdoor signs, contact lenses, transparent bowls, drink dispensers etc.

g) Acetal (polyacetal)

- Newer plastics known by its made name derlin
- Developed as a material for mechanical parts including sprinkler nozzles, handles, gear housing etc.



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- Widely used for stereo tape cartridges, toys, lighter cases etc
- Has good tensile strength, resistance to temperature (115°C) low friction characteristics, resistant to most solvent and low moisture absorption.

h) Vinyl plastics: (pvc)

- Clear, transparent plastics, easily colored, resistant to most chemical, exposed to atmosphere, abrasion resistant, but low tensile strength.
- Can be extruded as wire insulation, tubing and refrigerator door gaskets.
- Coating of fabrics of all kinds for industrial uses (tents, tarpaulin-type cover)

Thermosetting plastics

- Made from chains which have been linked together (cross-linked)
- Have a 3 dimensional network of molecules and will not soften when heated.
- Practically insoluble, fireproof, hard & brittle.
- These plastics cannot be reused.

a) Epoxy resins

- Have excellent chemical resistance and electrical insulating properties.
- Working temperature is from 150 c to 260 c
- Coatings made from these resins combine the properties of toughness, flexibility, adhesion & chemical resistance.
- Epoxy adhesives are used in aircraft, automobiles etc. also used as coatings for pipe fitting & electrical equipment.
- Used in low pressure & high pressure laminates such as PCBs, boat bodies etc.

b) Amino resins:

- Two important groups of amino resins are urea & melamine formaldehyde resins.
- Both are used as adhesives in making plywood
- Melamine is laminated with cloth to make table tops.
- Melamine can be moulded into very hard, scratch resistant electric switch cover plates, radio cabinets etc.
- Urea compounds are less water resistant but better electrical insulators.

c) Phenolics: (bakelite)



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- Phenol& formaldehyde combine in the presence of a catalyst to produce phenolic resins.
- Hard, brittle, heat resistant, excellent insulator, and have heat distortion temp. upto 180 c and working temperature upto 260 c

d) Silicones:

- They are chemical hybrid, cross between organic & inorganic material
- Silicon base polymers possess a combination of properties: used to produce greases, oils, adhesives, resin & rubber compounds.
- Used for producing shoe polishes, furniture& glass polishes etc.

Elastomers:

- Intermediate between long-chain molecules & 3 dimensional networks
- They are polymers which are less tightly bound together
- Structurally they are non crystalline polymers at room temp.
- Unique property of high elasticity, stretching 5 to 10 times their original length on loading in tension & reverting back to their original dimensions on release of load.
- Example nature rubber(raw material is latex, viscous milky fluid containing linear polymer of polyisoprene)
- Most elastomers are manufactured by cross-linking.
- (ex) sulphur is used to vulcanize rubber at elevated temp.
- Elastomers are used for gaskets, mould, mattresses etc.

Materials for processing plastics:

- Plastic_resins have to be combined , compounded or chemically treated with processing materials before processing.

a. Plasticizers:

- organic solvents, resin and water are used as plasticizers.
- Act as internal lubricants improving flow, flexibility to material.
- Plasticizers are also used to prevent crystallization by keeping the chain separated from one another.



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- Ex. Vinyes are generally hard & brittle materials, by adding a plasticizer they can be made soft & flexible.

b. Fillers:

- Include wood flour, asbestos fiber, glass fiber, cloth fiber, mica etc. added in high proportion to plastic.
- To improve strength, dimensional stability & heat resistance.

c. Catalyst:

- Added to promote faster & complete polymerization.

d. Initiators:

- Used to initiate the reaction i.e. Begin polymerization. (ex) H_2O_2 is a common initiator.

e. Dyes & Pigments:

- Added to give brilliant colours.
- Disperse evenly through out the molten plastics.

f. Blowing agents:

- Plastic resin(polystyrene) is foamed by injecting an inert gas(argon / nitrogen) before molten material is forced into mould.
- Process creates porous interiors.

g. Modifiers:

- Added to improve mechanical properties/ characteristics of base resin.



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Moulding processes:

- Compression moulding
- Transfer moulding
- Injection moulding
- Reaction Injection Molding
- Extrusion moulding
- Calendering
- Thermoforming
- Blow moulding
- Rotational Molding

Compression moulding:

- Similar to forging process.
- Performed in a hot die.
- Widely used for forming thermosetting plastics.

Process:

Measured amount of material powder/resin/compressed preform called charge) placed into open mould cavity.

Apply heat & pressure through a downward moving die

Material is forced to fill the mould cavity.

In the closed mould, polymerization (cross-linking of polymer chains) takes place and the material hardens into the required shape.

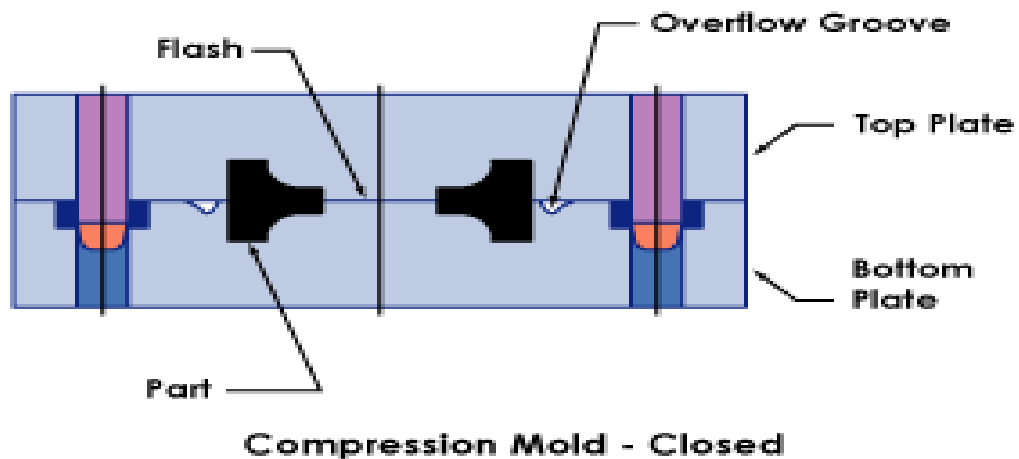
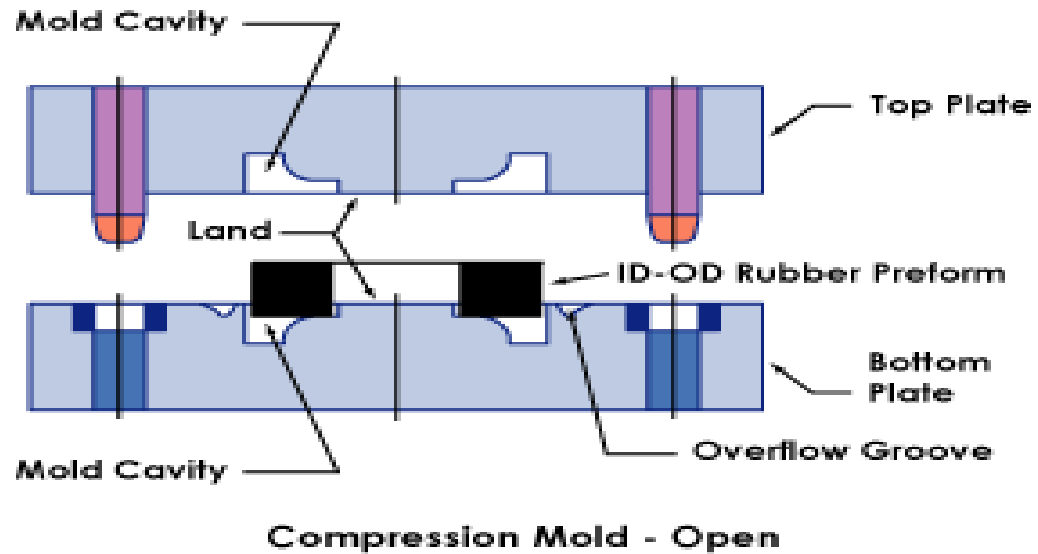
Heat for polymerization is supplied through the walls of the cavity by steam or electricity.

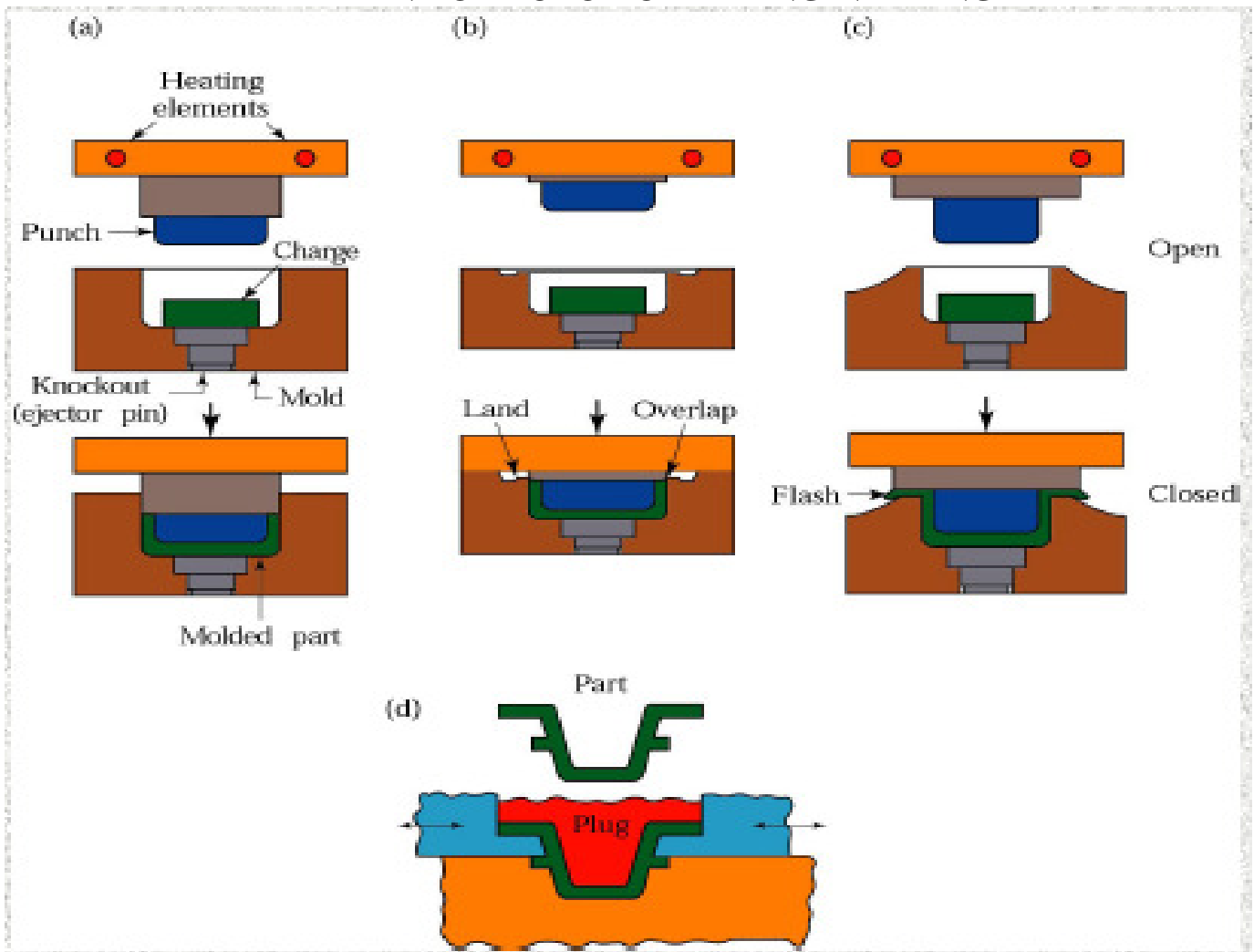
Moulding pressure : 0.35 kgf/mm² for polyester & epoxy,

1.4 to 4.2kgf/mm² for other thermosets.

Complete cycle take 10 sec for small parts under 2.5mm thick & 5 to 10 min for large, thicker part.

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Compression Molding





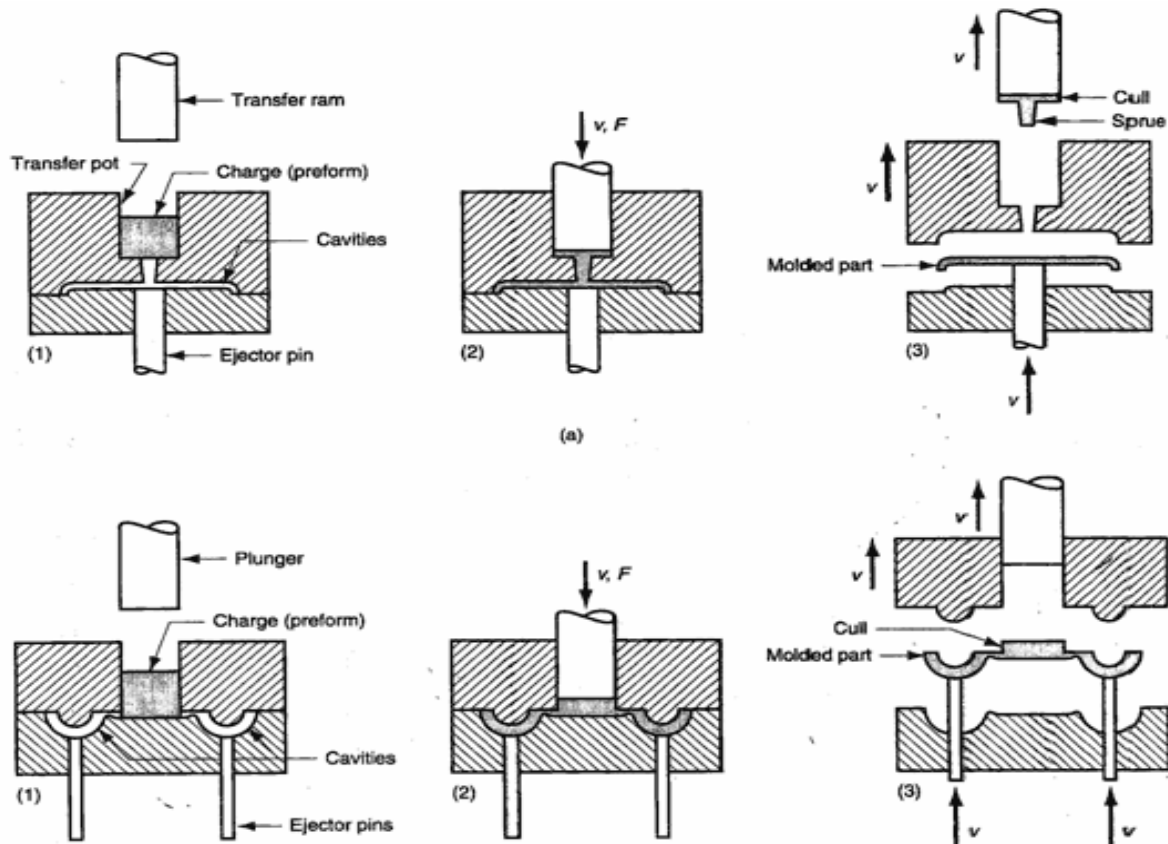
Transfer moulding:

Process of forming articles in a closed mould, where the fluid plastic material is converged into the mould cavity under pressure from outside of the mould.

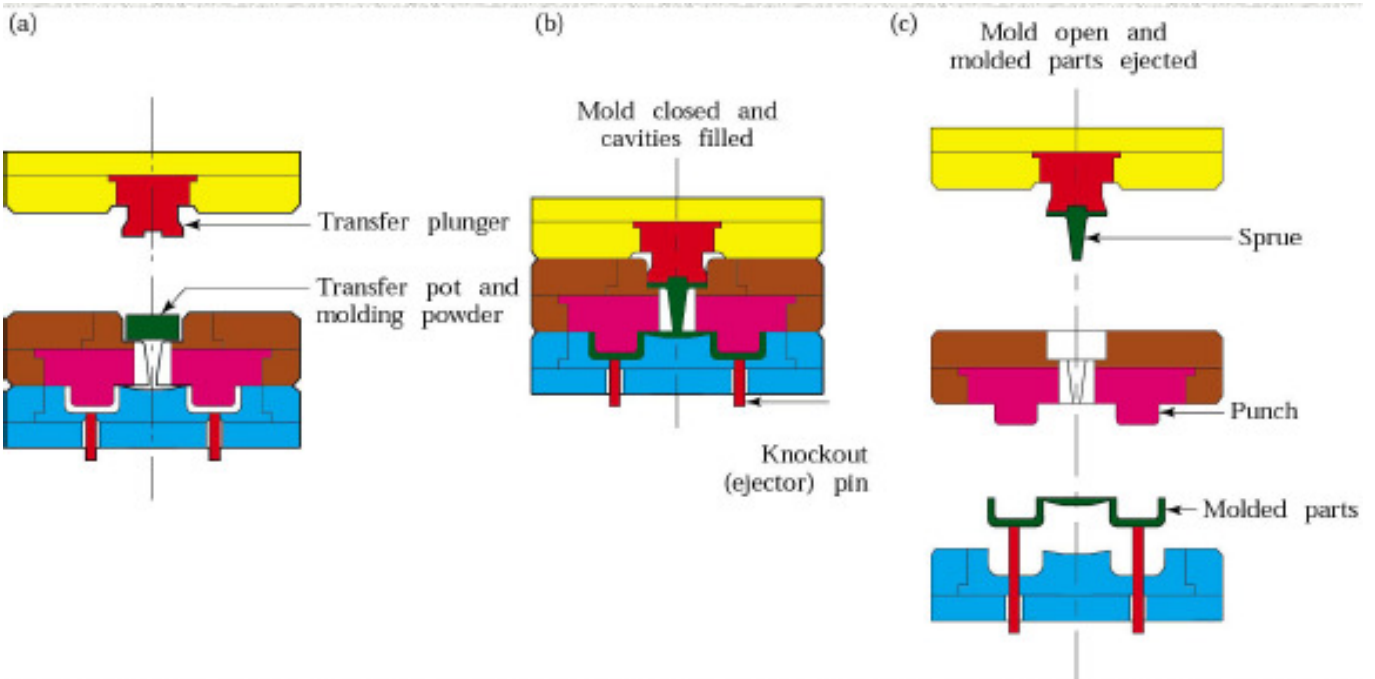
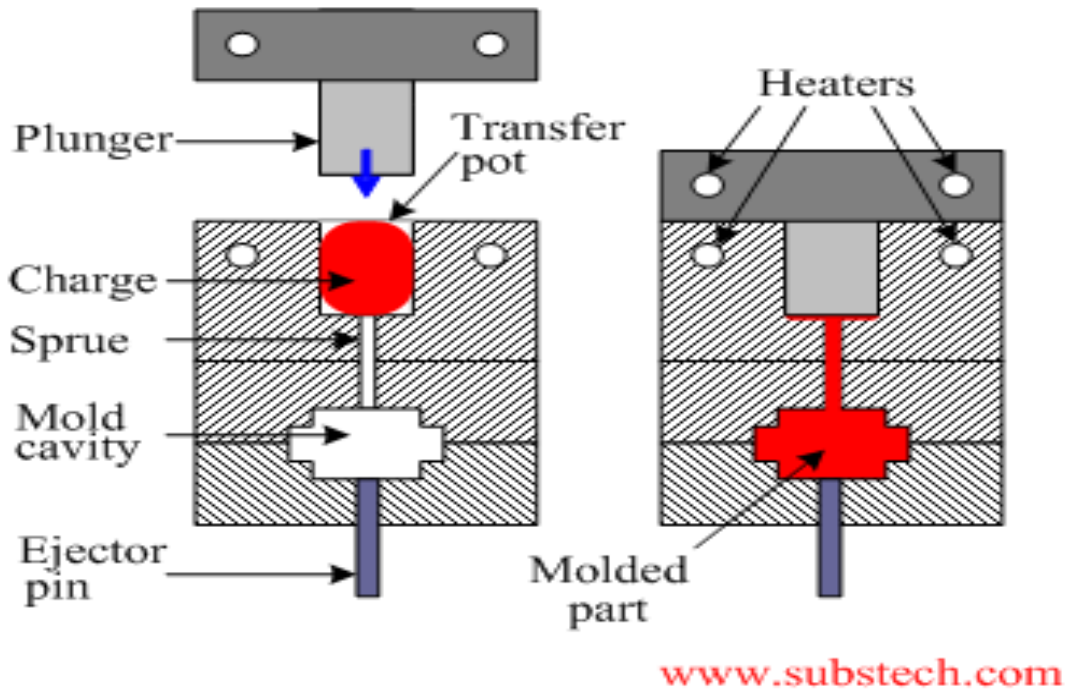
Material is placed in a hot transfer pot.

When the material is sufficiently softened, the plunger forces the fluid plastic through the orifice(sprue) into the closed mould.

Final curing takes place.



Transfer Molding





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Injection moulding

Most widely used method for producing parts of both

Thermoplastic & thermosetting resins.

Polymer (solid form, pellets or powder) is fed through a hopper to a injector screw.

Die-end is surrounded with heaters-gradually brings the polymer to the required temp.

Process starts with feeding plastic pellets into hopper.

Resins fall into the tube and pushed along the hot tube by reciprocating screw(feeder).

Sufficient volume of molten plastic is available at the injection nozzle end.

Entire screw is then plunged forward to force the material into the mould.

Ram is held under pressure for a few seconds for the moulded part to solidify.

It then retracts slightly and the mould opens.

Knock-out pins eject the moulded piece.

Later the sprue & runners are trimmed off.

10 sec to 6 min. Per run.

Each run may produce one or several parts.

300 to 400 runs/hrs in a fully automatic equipment is possible.

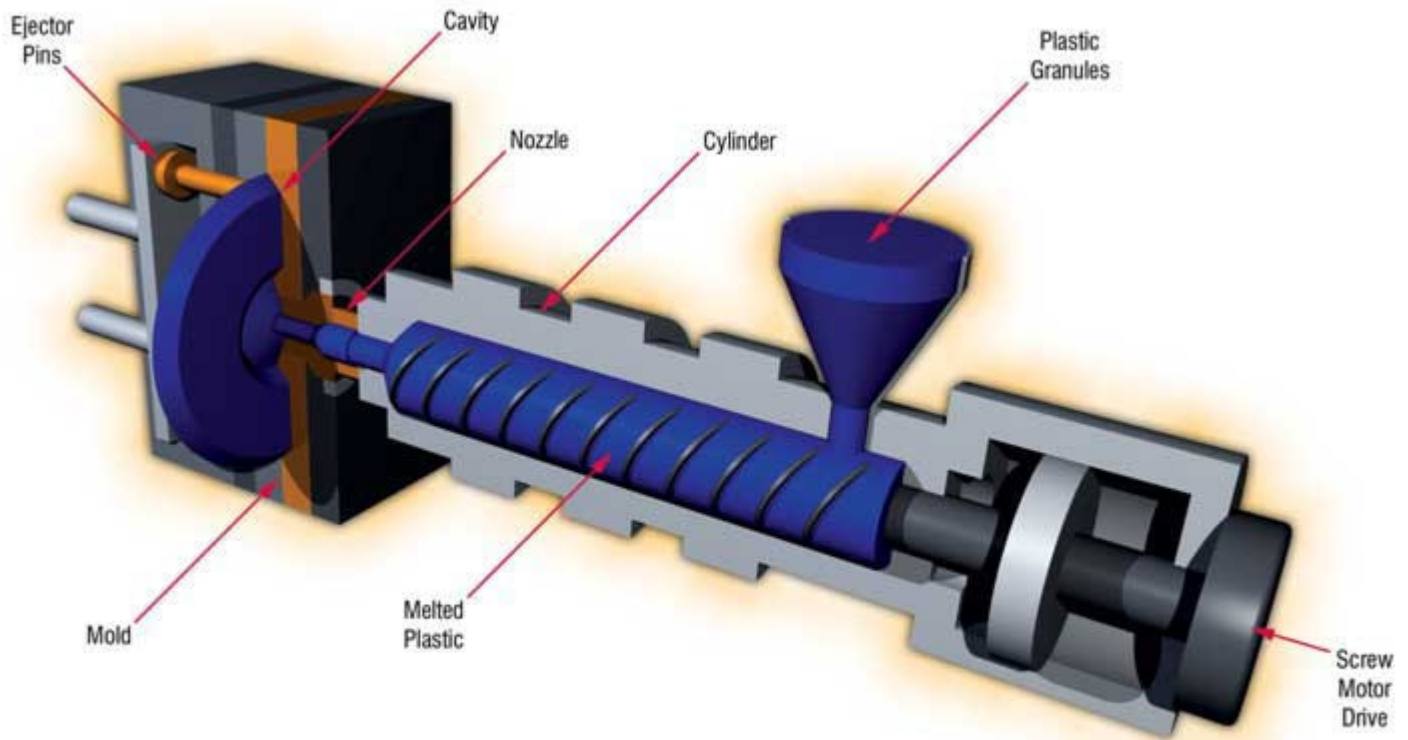
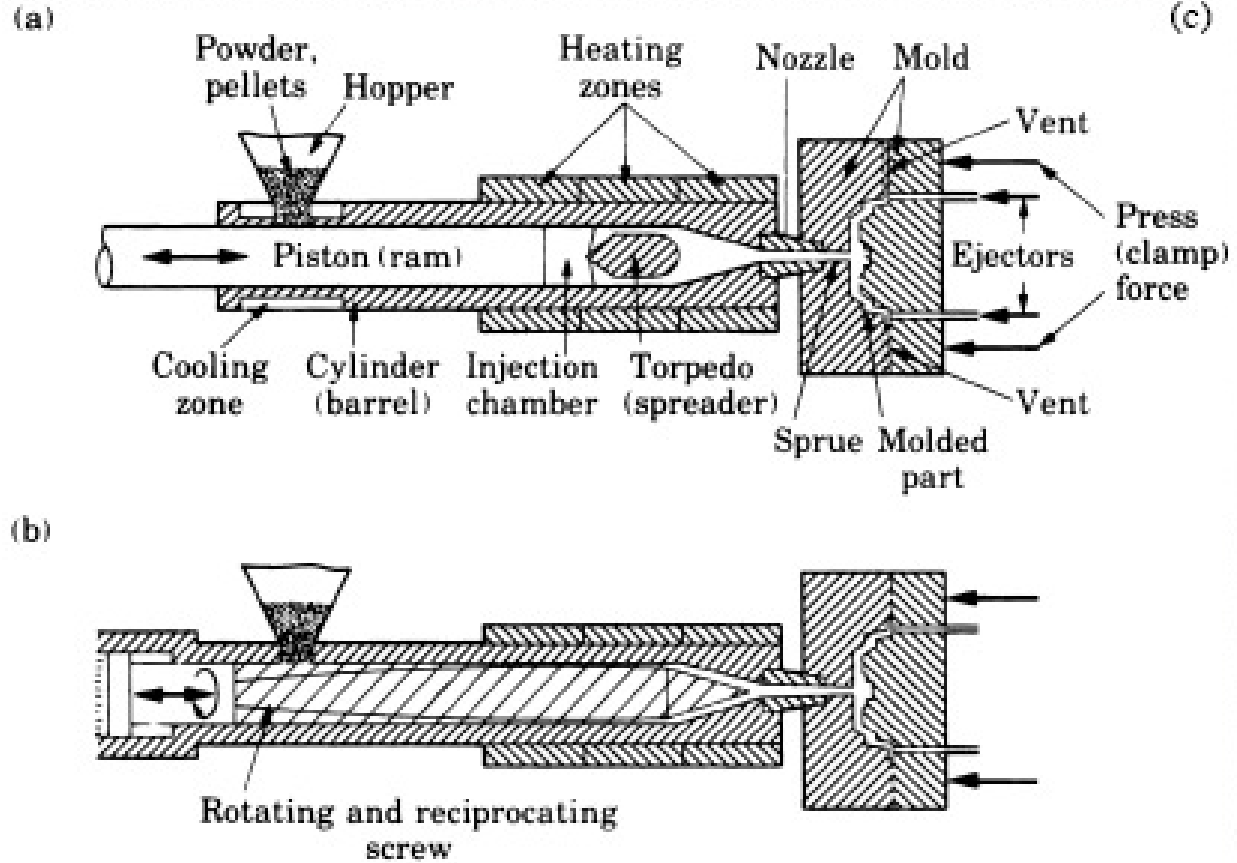
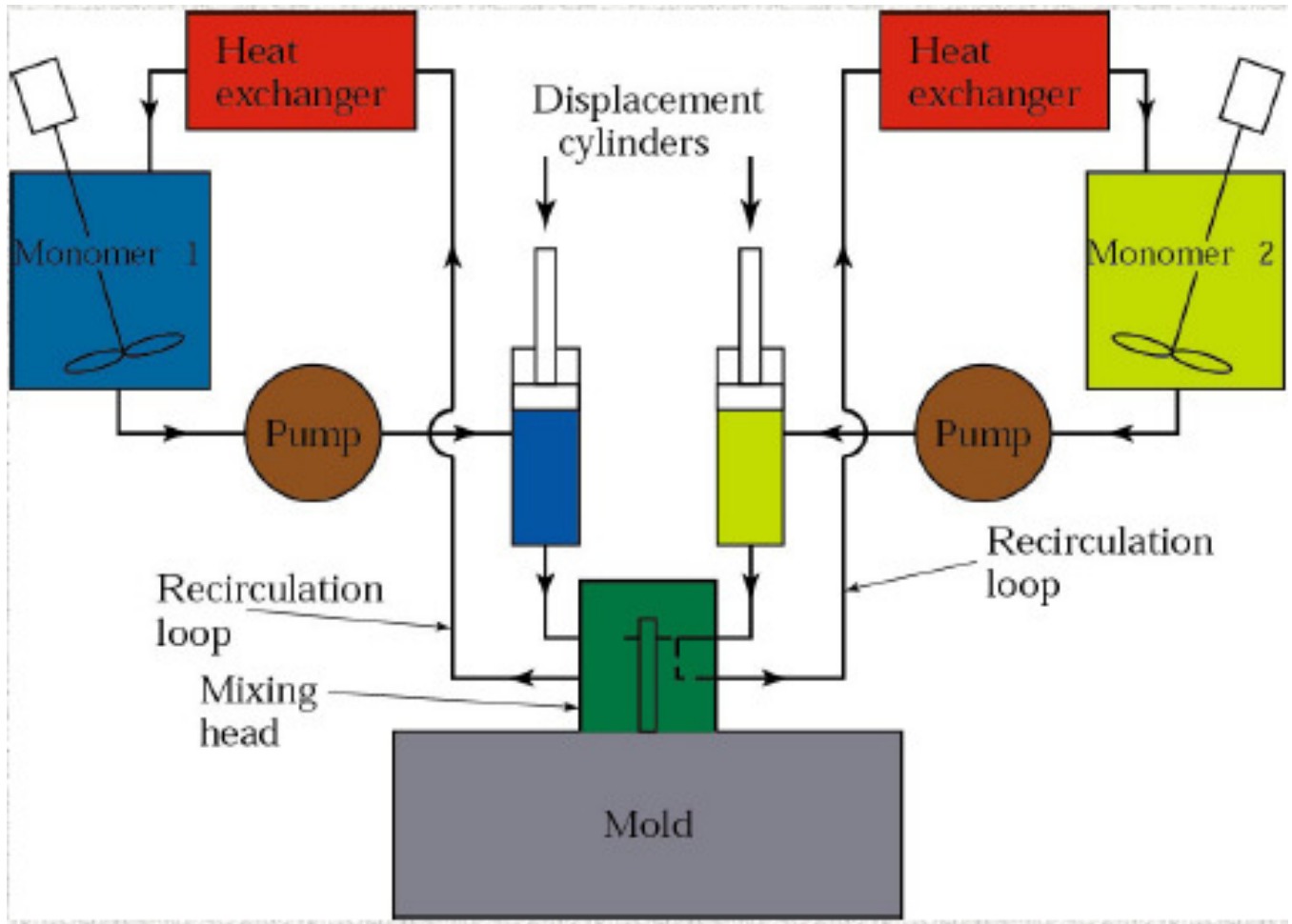


Figure 1. Cutaway View of the Injection Molding Process

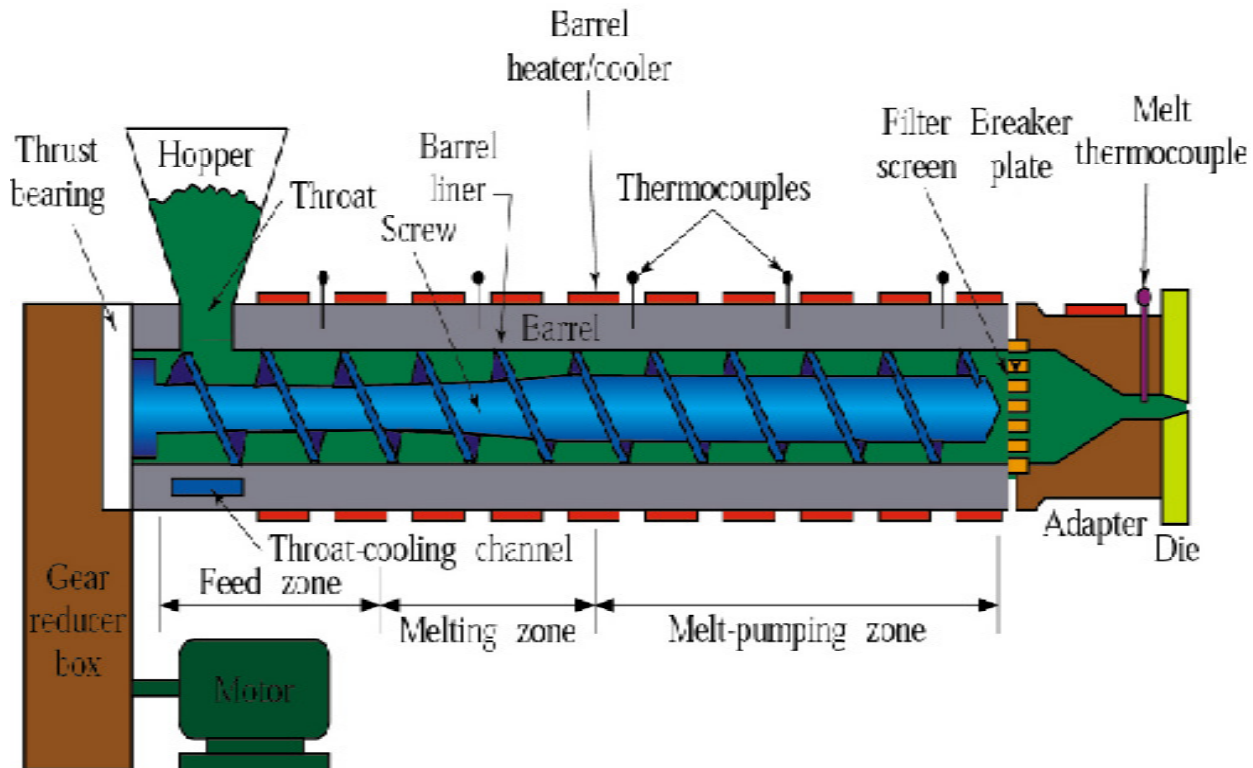


Reaction Injection Molding



Extrusion:

Rotating screw carries the hot plastic forward & forces it through heated die orifice of required shape. As it leaves the die, it is gradually cooled by carrying it through cooling media while resting on a conveyor. Wound into coil or cut into length



Calendering:

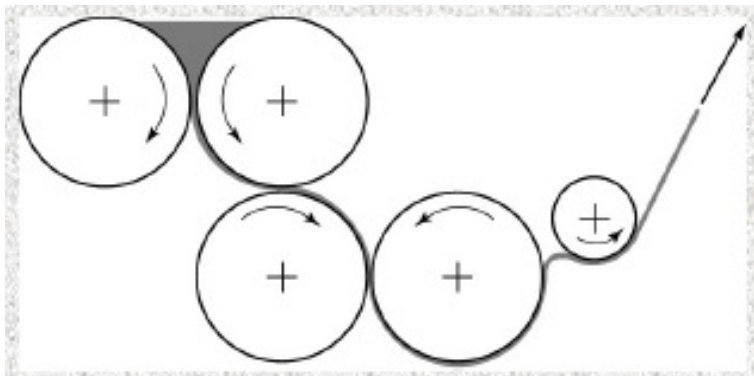
Method of making film & sheet.

Plastic compound (composed of resin, filler, plasticizer, color pigment etc.) is passed between heated rollers.

Material is squeezed into the film or sheet.

Finished product is cooled by passing through water cooled rolls.

Ex. vinyl floor tile, cellulose acetate sheet & film etc.



Thermoforming

Shaping of hot sheets or strips of thermoplastic material by mechanical or pneumatic methods.

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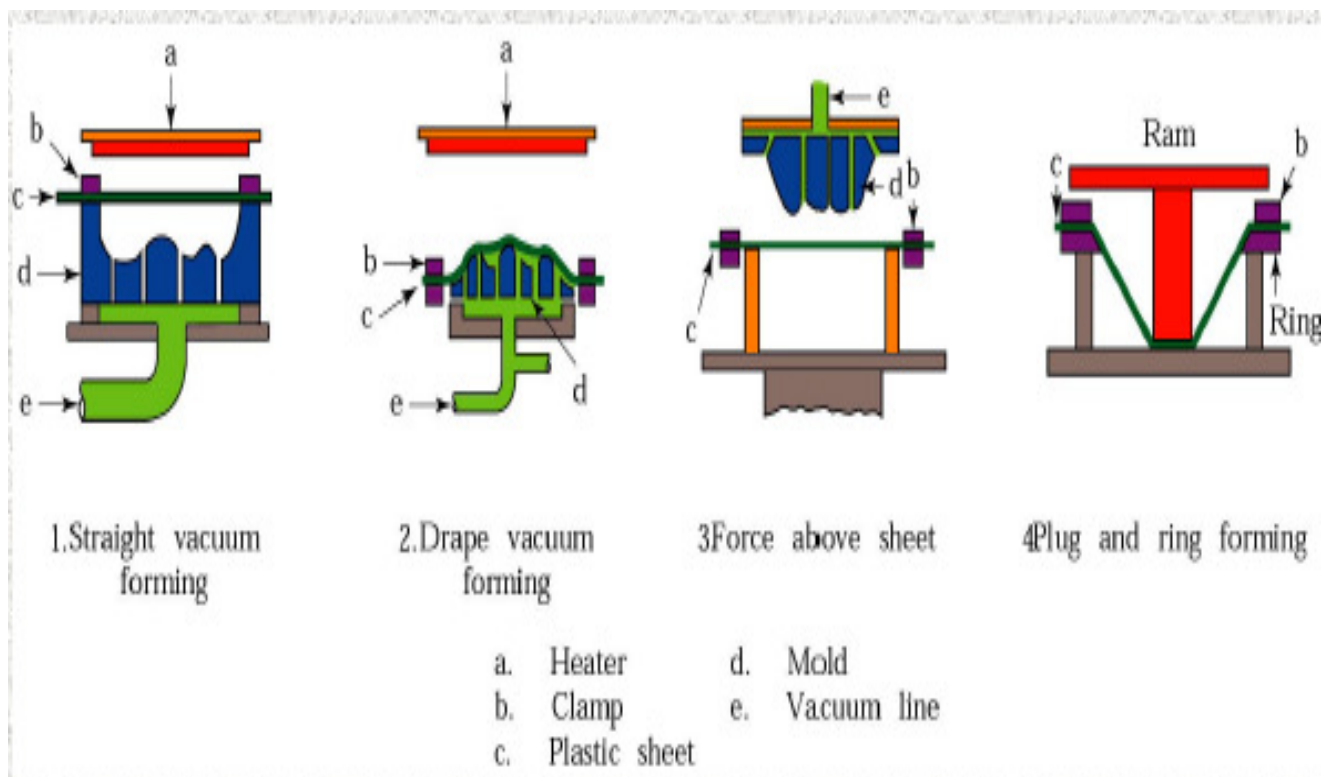
The sheets of plastic used in the thermoforming process are produced by either extrusion, calendaring or pressing.

A plastics sheet is clamped into a frame & heated until it sags.

Vacuum air or mechanical pressure is applied through small holes in mould & plastic is pulled against the mould.

The frame is raised & part is removed & trimmed in punch press.

It is also called as vacuum forming.

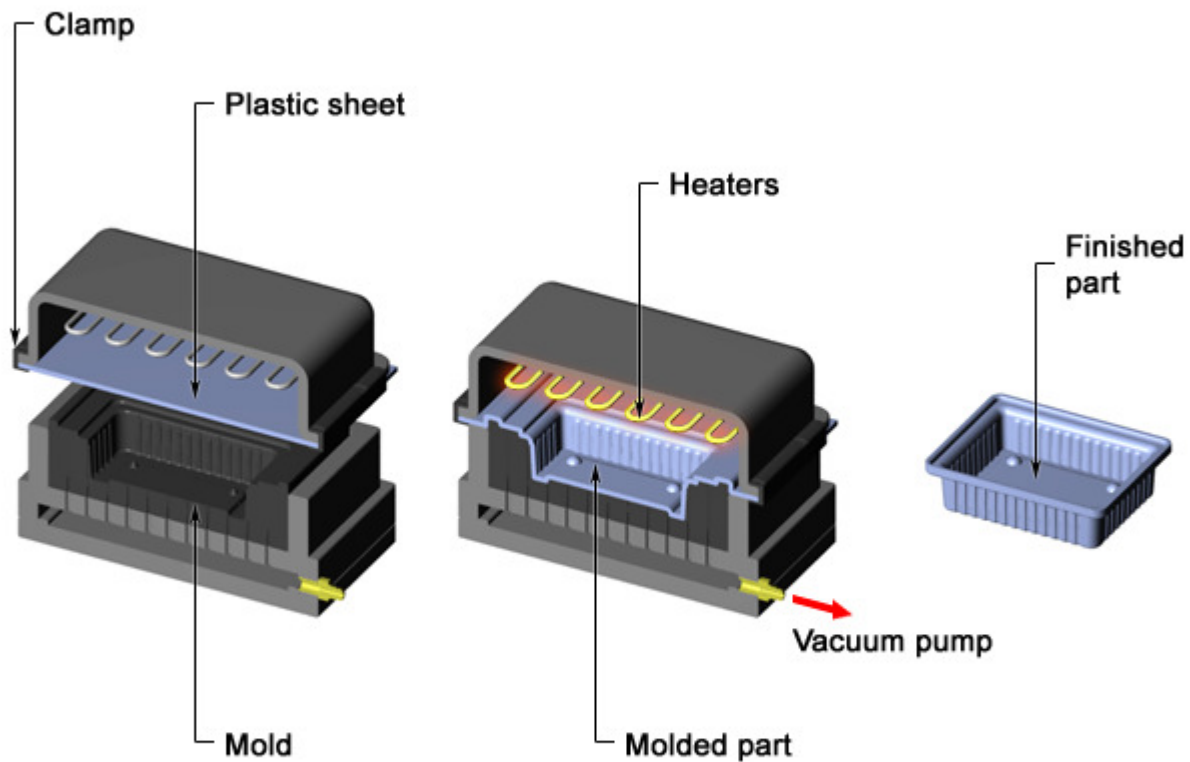




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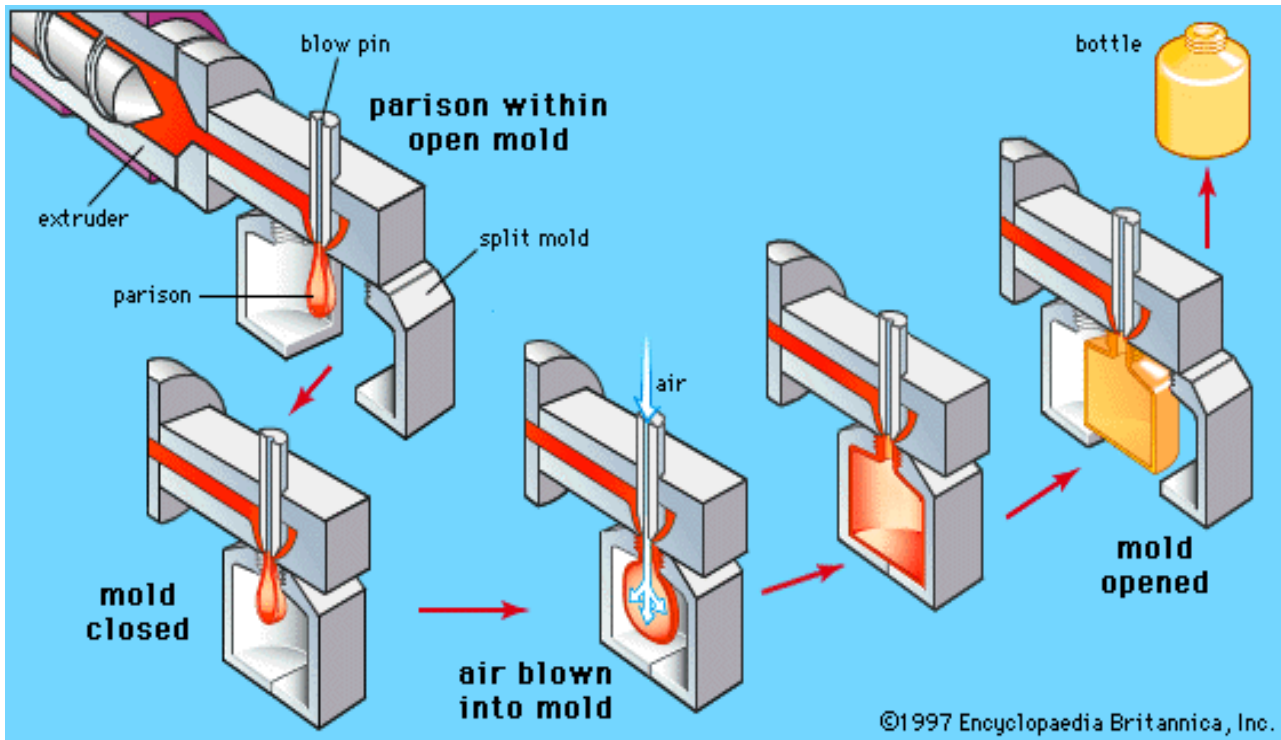




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Blow moulding

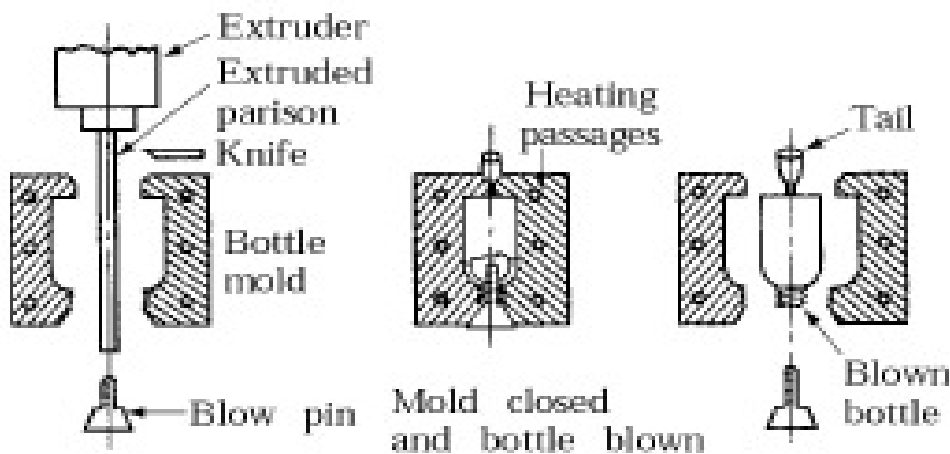
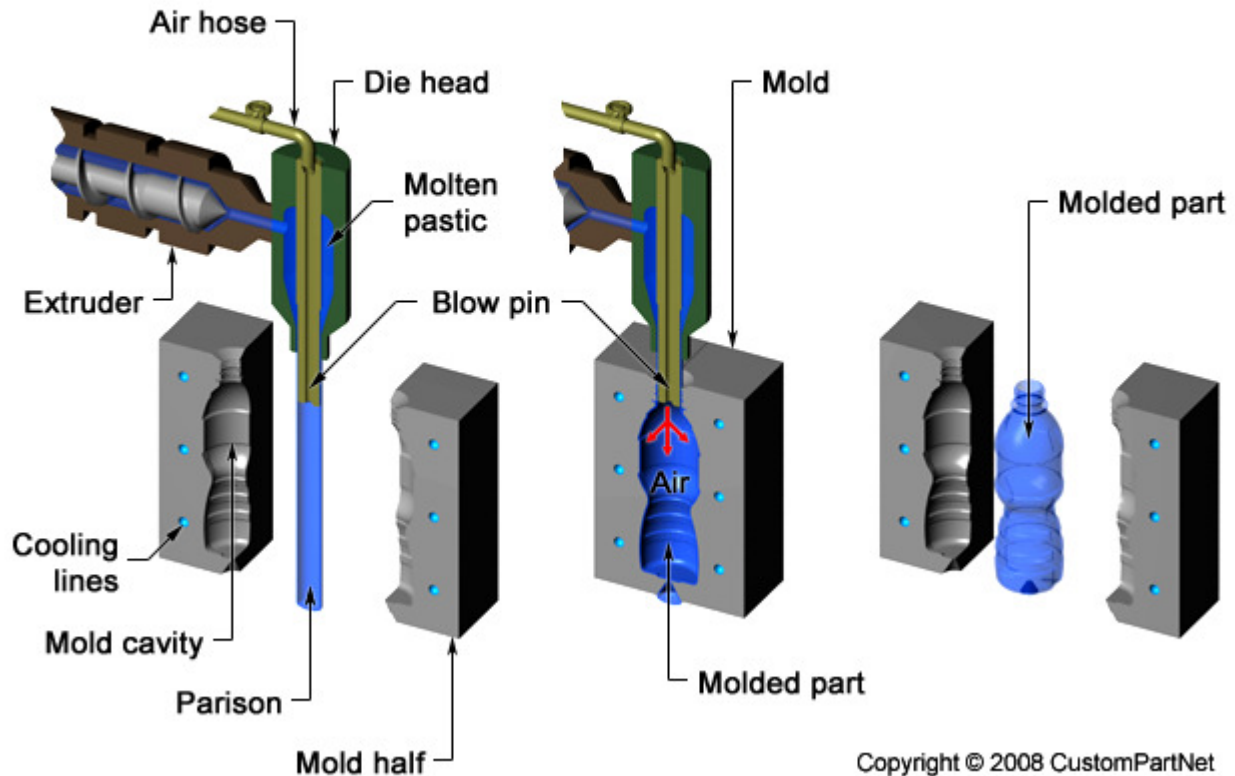
- Process of placing a softened thermoplastic closed-end tube (parison) & applying air pressure to inflate it.
- Blow moulded product includes bottles, floats, automobile heater ducts & similar articles.



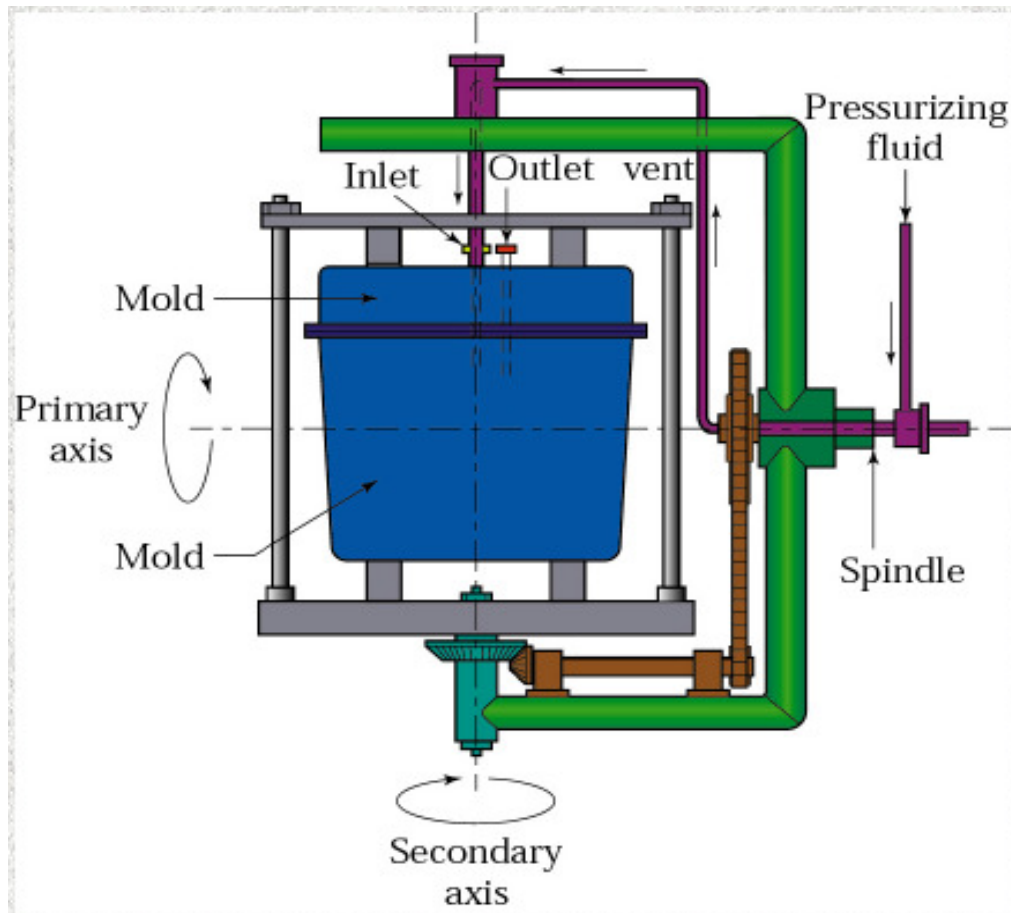
Parison Extrusion
(Cross-section)

Blow Molding
(Cross-section)

Part Formed



Rotational Molding



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

Composite Materials

Combination of two or more chemically distinct and insoluble phases

Composite materials are widely used in aircraft, space vehicles, piping, electronics, automobiles, boats sporting goods etc.

Three types:



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Polymer-matrix composites (PMC)

Metal-matrix composites (MMC)

Ceramic-matrix composites (CMC)

Polymer-matrix composites:

Mechanical properties of plastics can be improved by embedding reinforcements of various types viz. glass or graphite fibers to produce **reinforced plastics / fiber reinforced plastics**.

Contains fibers (discontinuous or dispersed phase) in a plastic matrix (continuous phase)

Commonly used fibers are glass, graphite, aramids and boron.

Glass fibers are most commonly used and less expensive.

Named as glass-fiber reinforced plastic (GFRP) and contains 30 % to 60% glass fiber by volume.

Glass fibers are made by drawing molten glass through small orifices in a platinum die.

Graphite fibers are more expensive than glass fibers and have a combination of low density, high strength and high stiffness.

Named as carbon-fiber reinforced plastic (CFRP)

Aramids are the toughest fibers and have very high specific strengths

A common aramids is marketed under the trade name **Kevlar**.

They undergo some plastic deformation before fracture and so they have higher toughness than brittle fibers.

Boron fibers consist of boron deposited (by chemical vapor-deposition techniques) onto tungsten fibers

Matrix materials includes thermosets and thermoplastics: commonly consists of epoxy, polyester, phenolic, fluorocarbon, polyethersulfone etc.

Matrix in reinforced plastics has three functions:

- to support the fibers in place and transfer the stresses to them, while they carry most of the load
- to protect the fibers against physical damage and the environment
- to reduce the propagation of cracks in the composite, by virtue of the greater ductility and toughness of the plastic matrix.

Reinforced plastics are typically used in military and commercial aircraft, rocket components, helicopter blades, automobile bodies, leaf springs, drive shafts, pipes, ladders, pressure vessels, sporting goods, helmets, boat hulls and various structures and components.

Metal-matrix composites (MMC)

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Advantages of a metal matrix over a polymer matrix are its higher elastic modulus, its resistance to elevated temperatures and its higher toughness and ductility.

Limitations are higher density and greater difficulty in processing.

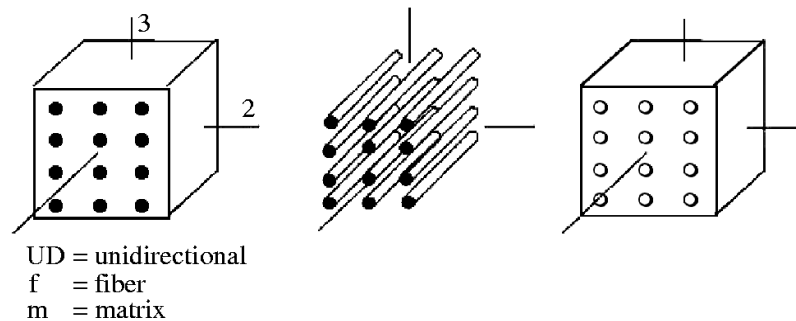
Matrix materials includes aluminum, aluminum-lithium, magnesium, copper, titanium and super alloys.

Fiber materials can be graphite, aluminum oxide, silicon carbide, boron, molybdenum and tungsten.

Boron fibers in an aluminum matrix have been used for structural tubular support in space shuttle orbiter.

Silicon carbide fibers in titanium matrix are used for beams, stiffeners and frames of hypersonic aircraft.

UD-COMPOSITE (UD) = FIBERS (f) + MATRIX (m)



Ceramic-matrix composites (CMC)

Composites with a ceramic matrix have good resistance to high temperatures and corrosive environment. Matrix materials that can retain their strength up to 1700 deg.c are silicon carbide, silicon nitride and aluminum oxide.

Fiber materials are usually carbon and aluminum oxide.

Applications are in jet and automotive engines, deep-sea mining equipment, pressure vessels, structural components, cutting tools and dies for extrusion and drawing of metals.

Processing Reinforced Plastics

In order to obtain good bonding between the reinforcing fibers and the polymer matrix, fibers are surface treated: Impregnation

After impregnation the resulting partially cured sheets are called in various names such as Prepregs, Sheet-molding compound (SMC), Bulk-molding compound (BMC) and Thick-mold compound (TMC).

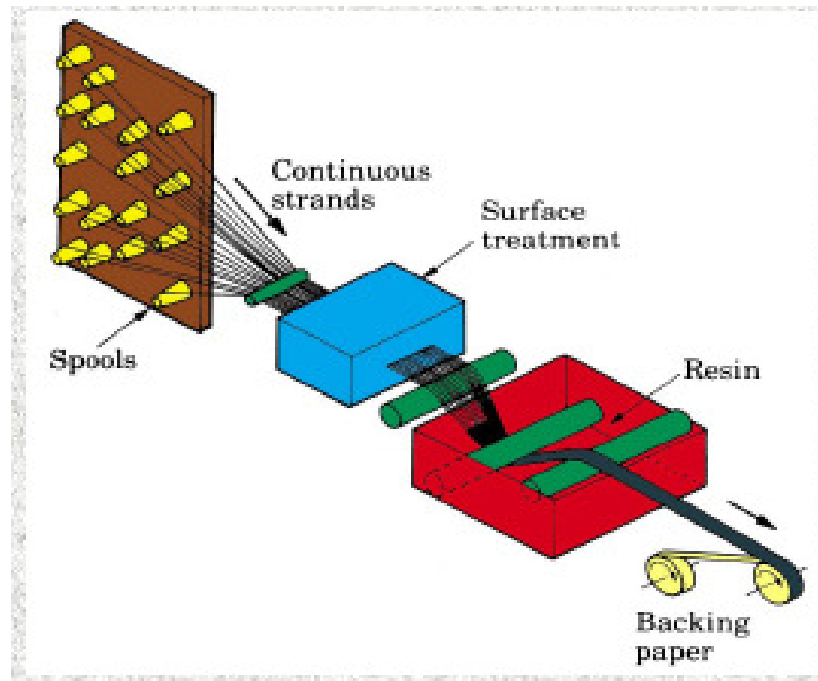
a) Prepregs:

Continuous fibers are first aligned and subjected to surface treatment to enhance adhesion to the polymer matrix.

Coated by dipping them in a resin bath and finally made into a sheet or tape.

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Individual pieces of the sheet are then assembled into laminated structures.

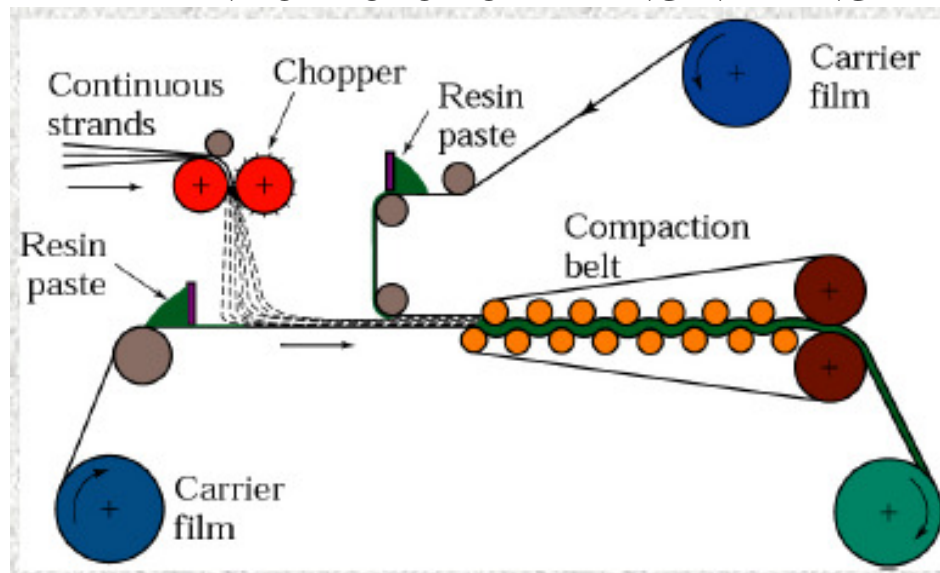


b) Sheet-molding compound (SMC):

Continuous strands of reinforcing fiber are first chopped into short fibers and then deposited in random directions over a layer of resin paste

A second layer of resin paste is deposited on top and the sheet is pressed between rollers

Product is gathered into rolls or placed into containers in layers and stored



c) Bulk-molding compound (BMC):

These compounds are in the shape of billets, up to 50mm in diameter produced by the use of extrusion process to obtain a bulk form

d) Thick-molding compound (TMC):

Usually injection molded, using chopped fibers of various lengths and possess higher strength.

Molding

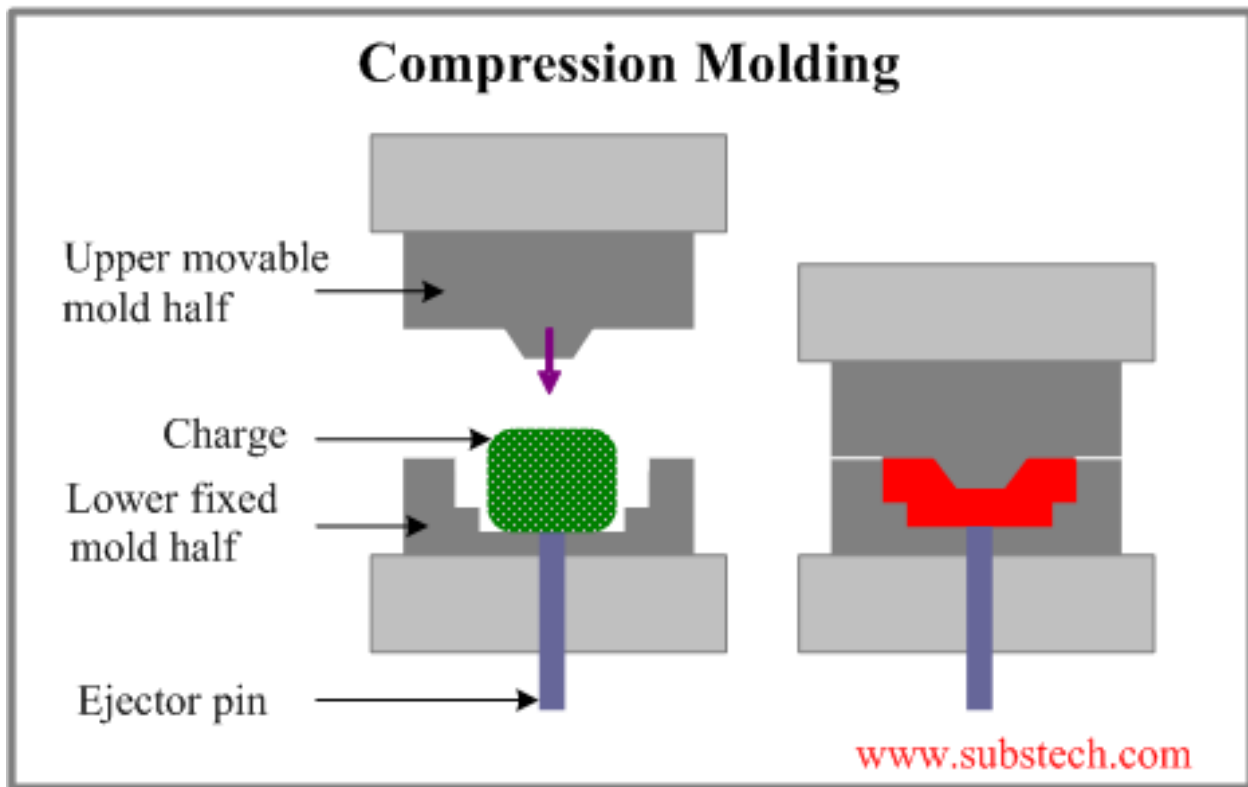
a) Compression molding:

Material is placed between two molds and pressure is applied.

Depending on the material, the molds may be either at room temp. or heated to accelerate hardening

Material may be in bulk form (BMC, which is viscous, sticky mixture of polymers, fibers and additives)

Sheet-molding compounds can also be used in molding



b) Vacuum-bag molding & Pressure-bag forming:

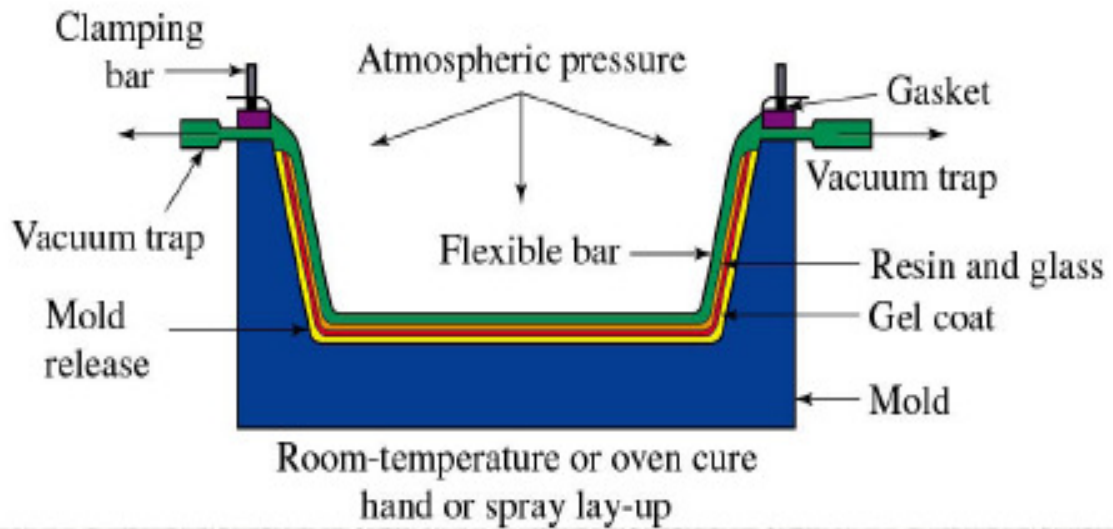
Prepregs are laid in a mold to form the desired shape

Pressure required to shape the product and develop good bonding is obtained by covering the lay-up with a plastic bag and creating a vacuum.

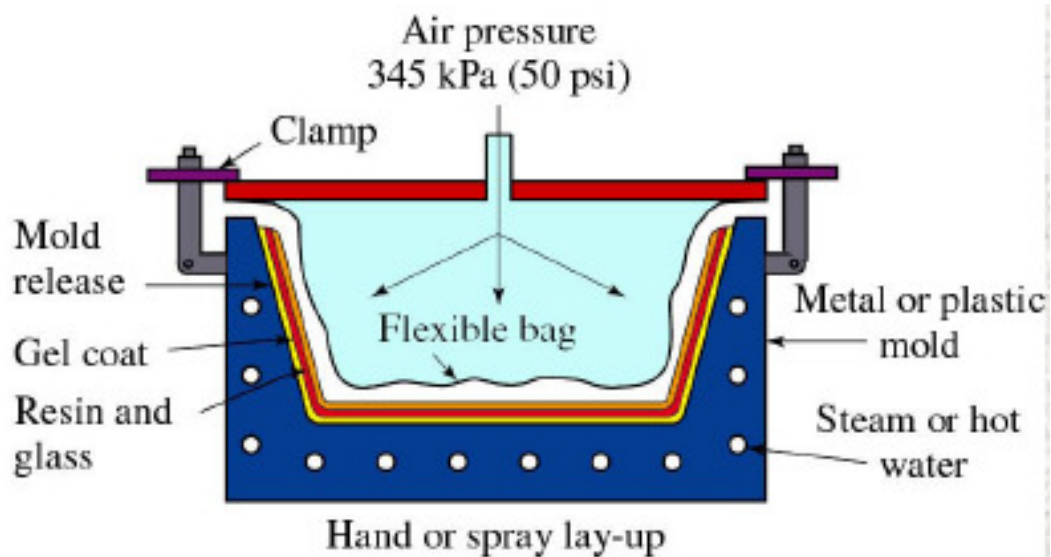
If additional heat and pressure are desired, the entire assembly is put into an autoclave.

In facilitate order to prevent the resin from sticking to the vacuum bag and to removal of excess resin, a gel coat can be provided on both sides of the prepreg

Vacuum bag molding



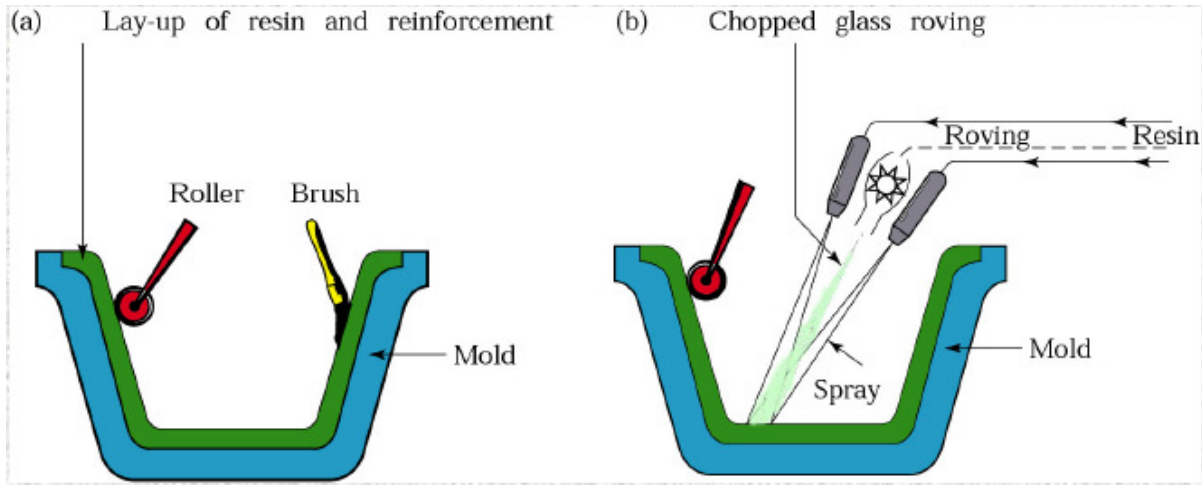
Pressure bag forming



c) Contact Molding:

Use a mold made of materials such as reinforced plastics, wood or plaster
Wet method, in which the reinforcement is impregnated with the resin at the time of molding.
Simplest method is called hand lay-up: materials are placed and shaped in the mold by hand and the squeezing action expels any trapped air and compacts the part.

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Molding may also be done by spraying

Processes are relatively slow and labor costs are high, simple and tooling is inexpensive.

Only the mold-side surface of the parts needs to be smooth

Many types of boats are made by this process.

d) Resin transfer molding:

Resin is mixed with a catalyst and is forced by a piston – type positive displacement pump into the mold cavity that is filled with fiber reinforcement.



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METAL FORMING AND POWDER METALLURGY

Powder Metallurgy → the name given to the process by which fine powdered materials are blended, pressed into a desired shape (*compacted*), and then heated (*sintered*) in a controlled atmosphere to bond the contacting surfaces of the particles and establish the desired properties.

→ it is commonly designated as **P/M**

→ it readily lends itself to the mass production of small, intricate parts of high precision, often eliminating the need for additional machining or finishing.

→ has a little material waste; unusual materials or mixtures can be utilized; and controlled degrees of porosity or permeability can be produce.

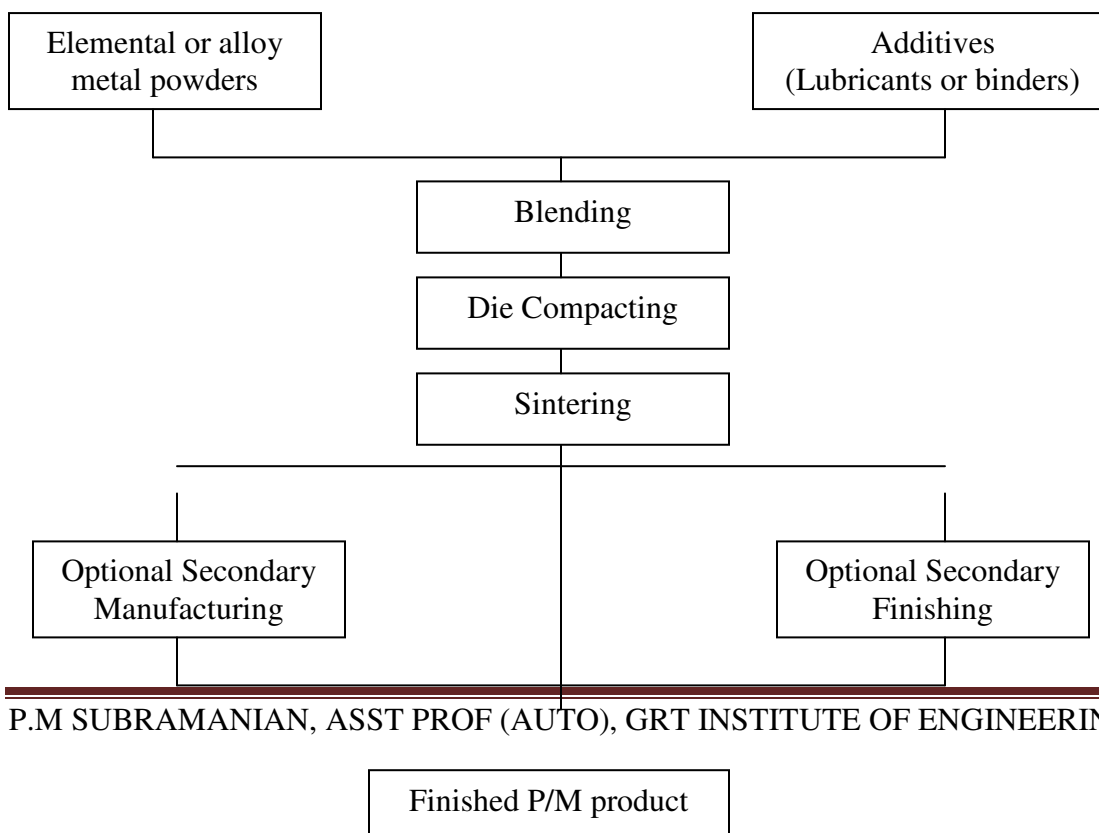
- Major areas of application tend to be those for which the P/M process has strong economical advantage or where the desired properties and characteristics would be difficult to obtain by any other method.

Basic Steps of Powder Metallurgy:

1. Powder Manufacture
2. Mixing or Blending
3. Compacting
4. Sintering

- Optional secondary processing often follows to obtain special properties or enhanced precision.

Flowchart of the Powder Metallurgy Process:

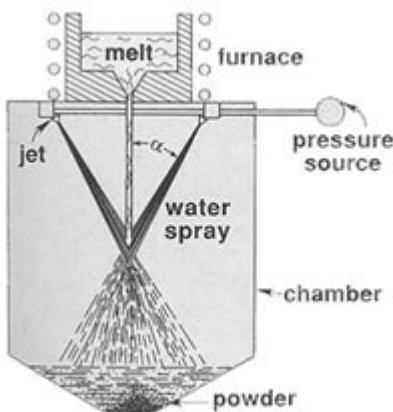


Important Properties and Characteristics of the metal or material powders that are used:

- Chemistry
- Purity
- Particle size
- Size distribution
- Particle shape
- Surface texture of the particles

2 Methods for Producing Metal Powders:

1. **Melt Atomization** → produced 80% of all the commercial powder
 - it is a process where a liquid is fragmented into molten droplets which then solidify into particles, and various forms of energy are used to form the droplets
 - a molten metal is atomized by a stream of impinging gas or liquid as it emerges from an orifice
 - an extremely useful means of producing pre-alloyed powders
2. **Atomization from a Rotating Consumable Electrode** → an electric arc impinges on a rapidly rotating electrode (*all contained within a chamber purged with inert gas*), with centrifugal force causing the molten droplets to fly from the surface of the electrode



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Figure 2-1: Water Atomization Process: Source "Powder Metallurgy Science" Second Edition, R.M. German, MPIF.

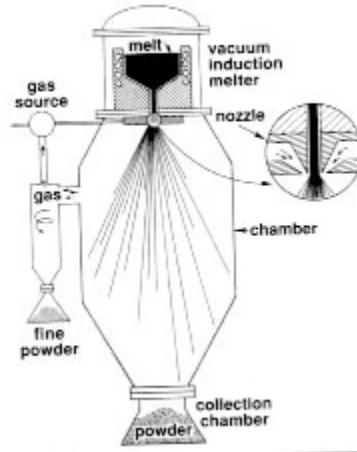


Figure 2-2: Vertical Gas Atomizer: Source "Powder Metallurgy Science" Second Edition, R.M. German, MPIF.

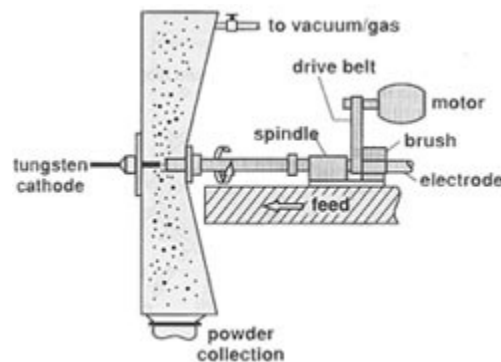


Figure 2-3: Centrifugal Atomization by the Rotating Electrode Process: Source "Powder Metallurgy Science" Second Edition, R.M. German, MPIF.

Commercial Powder that are produced :

- Aluminum alloys
- Copper alloys
- Stainless steel
- Nickel-based alloys (*such as Monel*)
- Titanium alloys

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- Cobalt-based alloys
- Other low-alloy steels

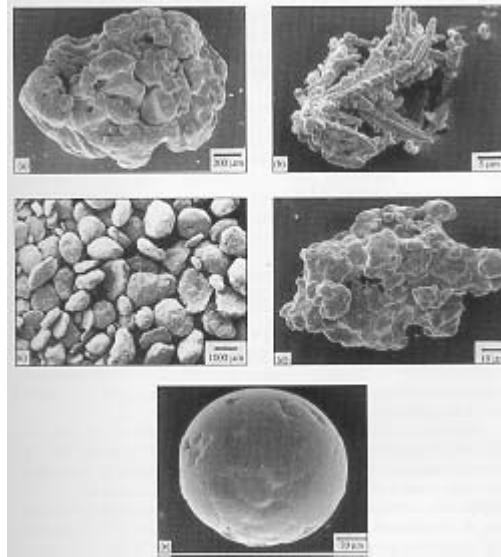


Figure 5: Representative Metal Powders: (a) Chemical; Sponge Iron-Reduced Ore; (b) Electrolytic: Copper; (c) Mechanical: Milled Aluminum Powder Containing Disperoids (17); (d) Water Atomization : Iron; (e) Gas Atomization: Nickel-Base Hardfacing Alloy.: Source "Atomization - The Production Of Metal Powders" A. Lawley, MPIF.

Process features of the powder particles that size and shape can varied and depend on :

- Velocity and media of the atomizing jets or the speed of electrode rotation
- Starting temperature of the liquid (*which affects the time that surface tension can act on the individual droplets prior to solidification*)
- Environmental provided for cooling

When cooling is slow (*such as in gas atomization*) and surface tension is high, spherical shapes can form before solidification.

Irregular shapes are produced due to more rapid cooling, such as water atomization.

Other methods of Powder Manufacture :

- Chemical reduction of particulate compounds (generally crushed oxides or ores)



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- Electrolytic deposition from solutions of fused salts
- Pulverization or grinding of brittle materials (comminution)
- Thermal decomposition of hydrides or carbonyls
- Precipitation from solution
- Condensation of metal vapors

Almost any metal, metal alloy, or nonmetal like ceramic, polymer or wax or graphite lubricant can be converted into powder form by any of the methods.

Some methods can produce only elemental powder, often of high purity. While others can produce pre-alloyed particles.

Operations such as drying or heat treatment may be required prior to further processing.

Rapidly solidified power (microcrystalline and amorphous)

Increasing the cooling rate of liquid material can result in the formation of an ultrafine or microcrystalline grain size. In these materials, a large percentage of the atoms are located in grain boundary regions, giving unusual properties, expanded alloy possibilities, and good formability. If the cooling rate approaches or exceeds 10^6 °C/sec, metals can solidify without becoming crystalline.

Production of amorphous material, however, requires immensely high cooling rates. Atomization with rapid cooling and the “splat quenching” of a metal stream onto a cool surface to produce a continuous ribbon are two prominent methods. Since much of the ribbon material is further fragmented into powder, powder metallurgy thus becomes the primary means of fabricating useful products.

Powder testing and evaluation

Flow rate is a measure of the ease by which powder can be fed and distributed into a die. Poor flow characteristics can result in nonuniform die filling and in nonuniform density and properties in a product.

Associated with the flow characteristics is the apparent density, a measure of the powder's ability to fill available space without the application of external pressure. Compressibility tests evaluate the effectiveness of applied pressure in raising the density of the powder, and green strength is used to describe the strength and fracture of resistance.

Powder mixing and blending

It is rare that a single powder will possess all of the characteristics desired in a given process and product. Most likely, a starting material will be a mixture of various grades or sizes of powder, or powders of different compositions, with additions of lubricants or binders.

Some powders, such as graphite, can even play a dual role, serving as lubricant steel. Lubricants improve the flow characteristics and compressibility at the expense of reduced green strength.

Blending or mixing operations can be done either dry or wet, where water or other solvent is used to improve mixing, reduce dusting, and lessen explosion hazards.



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Compacting – one of the most critical steps in the P/M process.

Green compact – loose powder is compressed and densified into shape, usually at room temperature.

- * *Most compacting is done with mechanical presses and rigid tools, but hydraulic and hybrid presses can also be used.*
- * *Compacting pressures generally range between 3 and 120 tons/in² (40 to 1650 MPa) depending on material and application with 10 to 30 tons/in² (140 to 415 MPa) being the most common.*
- * *Most P/M presses have total capacities of less than 100 tons ($9 \times 10^5 \text{ N}$)*
- * *Increasing numbers are being purchased with high capacity; as a result, powder metallurgy products are often limited to cross sections of less than 3 in² (2000mm²).*
- * *With increased press capacity, sections up to 10 in² (6500mm²) have become more common.*
- * *Metal-forming processes, such as rolling, forging, extrusion, and swagging, have also been adapted to compact powders.*

Typical Compaction Sequence for a Mechanical Press:

With the feed bottom punch in its fully raised position, a feed shoe moves up into position over the die. The feed shoe is an inverted container filled with powder, connected to the powder supply by a flexible tube. With the feed shoe in position, the bottom punch descends to a preset fill depth, and the shoe retracts, leveling the powder. The upper punch retracts and the bottom punch rises to eject the green compact. As the die shoe advances for the next cycle, its forward edge clears the compact from the press, and the cycle repeats.

During compacting, the powder particles move primarily in the direction of the applied force. The opposing force is probably a combination of:

1. Resistance by the bottom punch
2. Friction between the particles and the die surfaces

Compaction with a Single Punch:

* *When pressure is applied at one punch, maximum density occurs below the punch and decreases as one moves down the column.*

Double-action Press:

-more uniform density can be obtained and thicker products can be compacted.

* *Since sidewall friction is a key factor in compaction, the resulting density is strong function of both the thickness and width of the part being compressed. For good, uniform compaction, the ratio of thickness/width should be kept below 2.0 whenever possible.*

Effect of Compacting Pressure on Green Density:

* *The average density of the compact depends on the amount of the pressure that is applied.*



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Two-thickness Part with only One Punch:

- shows that a single displacement will produce different degrees compaction in different thickness of powder.
- therefore, it is impossible for a single punch to produce uniform density in multi-thickness part.

Two Methods of Compacting Two Thickness Parts to Near Uniform Density:

- by providing different amounts of motion to the various punches and synchronizing these movements to provide simultaneous compaction, a uniformly compacted product can be produced.

*Isostatic Compaction – when extremely complex shapes are desired, the powder is generally encapsulated in a flexible mold and immersed in a pressurized gas or liquid.
- production rates in this process are extremely low, but parts up to several hundred pounds can be compacted effectively.

Compaction Tooling (Punches and Dies)

- compaction tools are usually made off harden tool steel.
- die surfaces should be highly polished and the dies should be heavy enough to withstand the high pressing pressures.
- lubricants are also used to reduce die wear.

P/M Injection Molding

- small, complex-shaped components have been fabricated from plastic for many years by means of injection molding.
- recently developed alternative to conventional powder metallurgy compaction.
- while the powdered material does not flow like a fluid: complex shapes can be produced by mixing ultrafine (usually less than 10 um) metal, ceramic, or carbide powder with a thermoplastic/wax material (up to 50% by volume).
- *A water-soluble methylcellulose binder is one attractive alternative to the thermoplastics.

Sintering

The word sinter comes from the Middle High German Sinter, a cognate of English cinder. In the sintering operation, the pressed- powder compacts are heated in a controlled – atmosphere environment to a temperature below the melting point but high enough to permit the solid-state diffusion and held for sufficient time to permit bonding of the particles. Most sintering operations involve three stage and many sintering furnaces employ three corresponding zones. The first operation, the burn-off or purge, is designed to combust any air, volatilize and remove lubricants or binders that would interfere with good bonding and slowly raise the temperature of the compacts in a controlled manner. The second or the high- temperature stage is where the desired solid – state diffusion and bonding between the powder particles take place. Finally, a cooling period is required to lower the temperature of the products while maintaining them in a controlled atmosphere. These three stages must be conducted in a protective atmosphere. This is critical since the compacted shapes have



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residual porosity and internal voids that are connected to exposed surfaces. Reducing atmospheres, commonly based on hydrogen, dissociated ammonia, or cracked hydrocarbons, are preferred since they can reduce any oxide already present on the particle surfaces and combust harmful gases that are liberated during sintering. During the sintering operation, a number of changes occur in compact. Metallurgical bonds form between the powder particles as a result of solid-state diffusion and strength, ductility, toughness, and electrical and thermal conductivity all increase. Diffusion may also promote when different chemistry were blended.

Other techniques to produce high density P/M products

High – density P/M parts can also be produced by using high temperature forming process. Sheets of sintered powder reduced in thickness and further densified by rolling. The Ceracon process is another method of raising conventional pressed –and- sintered P/M products to full density without the need for encapsulation or canning. Another means of producing a high density shape from fine particles is in-situ compaction or spray forming.

Secondary operations

- P/M parts are ready to use after they have emerged from the sintering furnace but many products utilize one or more secondary operations to provide enhanced precision, improved properties, or special characteristics.
- ⇒ Secondary operations are performed to improve:
 1. Density
 2. Strength
 3. Shape
 4. Corrosion Resistance
 5. Tolerances
- Any powder metallurgy process creates some porosity. MIM minimizes total porosity and typically limits interconnected porosity (that porosity connected to a free surface) to less than 0.2%, regardless of the product's percent of full density. This means standard coloring and plating techniques can be used without resin impregnation. Oil impregnation and copper infiltration are not used with MIM. When heat treated, parts can be case hardened to closely control case depths equivalent to wrought material. Other metalworking techniques such as drilling, tapping, turning, grinding, and broaching work well with MIM. All parts are barrel finished unless otherwise specified. These guidelines are not absolute, and are influenced by a number of factors related to part design.
- A wide range of additional operations or treatments can be carried out on the parts after they have been sintered.
 1. Heat Treatment:-Sintered parts may be heat treated to increase strength and also hardness for improved wear resistance.
 2. Oil Impregnation:-The controlled porosity of P/M parts permits their impregnation with oil and resin. This operation is used to give the part self lubricating properties.
 3. Resin Impregnation :-Used to improve machinability, seal parts gas or liquid tight, or prepare the surface for plating.
 4. Machining :-All normal machining operations can be carried out on sintered components.



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5. Drilling:-Usually used for holes not in the direction of the pressing.
6. Burr Removal:-Barrelling is used to remove burrs and sharp corners.
7. Corrosion Resistance:-Various types of surface treatment are available to increase corrosion resistance to withstand the most demanding of environments.
8. Finishing:-Includes, deburring, burnishing, coating oil dip, plating, welding, and mechanical surface treatments.

Properties of P/M Products

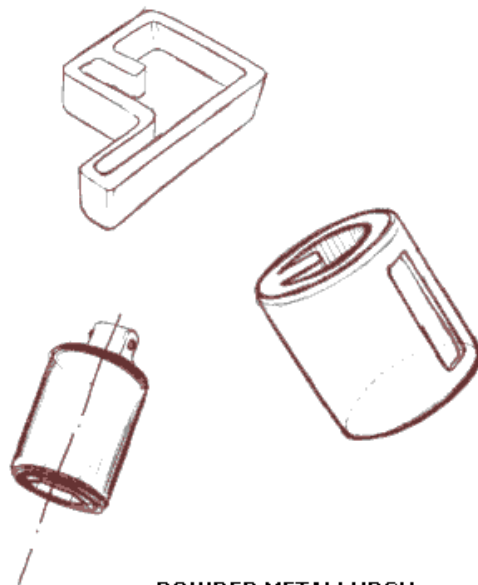
- Mechanical properties show a strong dependence on product density, with the fracture-limited properties of toughness, ductility and fatigue life being more sensitive than strength and hardness.
 - ❖ The voids in the P/M part act as stress concentrators and assist in starting and propagating fractures.
 - ❖ The yield strength of P/M products made from weaker metals is often equivalent to the same material in wrought form.
 - ❖ If higher strength materials are used or the fracture-related tensile strength is specified, the P/M properties tend to fall below those of wrought equivalents by varying but usually substantial amounts.
 - ❖ When larger presses or processes such as P/M forging or HIP are employed to produce higher density, the strength of the P/M products approaches that of the wrought material. With full density and fine grain size.
 - ❖ With full density and fine grain size. P/M parts often have properties that exceed their wrought or cast equivalents.
 - ❖ Since mechanical properties of powder metallurgy products are so dependent upon density, it is important that P/M products be designed and materials selected so that the final properties will be achieved with the anticipated amount of final porosity.
 - Physical Properties can also be affected by porosity
 - ❖ Corrosion resistance tends to be reduced due to the presence of entrapment pockets and fissures.
 - Electrical, thermal, and magnetic properties all vary with density.
- Porosity actually promotes good sound and vibration damping, and many P/M parts are designed to take advantage of this feature.

Design of Powder Metallurgy Parts

- P/M is a special manufacturing process and provision should be made for a number of unique factors. Products that are converted from other manufacturing processes without modification in design rarely perform as well as parts designed specifically for manufacture by power metallurgy.
 - Basic rules for the design of P/M parts:
 1. The shape of the part must permit ejection from the die. Perpendicular sidewalls are preferred, and holes or recesses should be uniform in size and parallel to the axis of punch travel.
 2. The Shape of the part should be such that powder is not required to flow into small cavities such as thin walls, narrow splines, or sharp corners.
 3. The shape of the part should permit the construction of strong tooling.

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4. the shape of the part should be within the thickness range for which P/M parts can be adequately compacted
 5. Parts can be design with as few changes in section thickness as possible.
 6. Parts can be designed to take advantage of the fact that certain forms and properties can be produced by P/M which are impossible, impractical, or uneconomical to obtain by any other method.
 7. If necessary, the design should be consistent with available equipment. Pressing areas should match press capability, and the number of thicknesses should be consistent with the number of available press actions.
 8. Consideration should also be made for product tolerances. Higher precision and repeatability is observed for dimensions in the radial direction (set by the die) than for those in the axial or pressing direction (set by punch movement)
 9. Finally, design should consider and compensate for the dimensional changes that will occur after pressing, such as the shrinkage that occurs during sintering.
- ❖ The ideal metallurgy part has a uniform cross section and a single thickness that is small compared to the cross-sectional width or diameter.
 - ❖ Complex shapes are possible but it should be remember that uniform strength and properties require uniform density.
 - ❖ Designs can easily accommodate holes that are parallel to the direction of pressing.
 - ❖ Holes at angles to this direction must be made by secondary processing.
 - ❖ Abrupt changes in section, narrow deep flutes, and internal angles without generous fillets should be avoided.
 - ❖ Punches should be designed to eliminate sharp points or thin sections that could easily wear a fracture.



**POWDER METALLURGY
(EXAMPLES)**



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Powder Metallurgy Products

Products that are commonly produced by powder metallurgy can generally be classified into five groups.

1. Porous or permeable products
 - Oil-impregnated bearings made from either iron or copper alloys, constitute a large volume of Powder Metallurgy products. They are widely used in home appliance, and automotive applications since they require no lubrication or maintenance during their service life. Unlike many alternative filters, they can withstand conditions of elevated temperature, high applied stress, and corrosive environments.
2. Products of complex shapes that would require considerable machining when made by other processes
 - Because of the accuracy and fine finish characteristic of the Powder Metallurgy process, many parts require no further processing and others require only a small amount of finish machining. Large numbers of small gears are made by the powder metallurgy process. Other complex shapes such as pawls, cams, and small activating levers, can be made quite economically.
3. Products made from materials that are difficult to machine or with high melting points
 - Some of the first modern uses of powder metallurgy were the production of tungsten lamp filaments and tungsten carbide cutting tools.
4. Products where the combined properties of two or more metals (or both metals and nonmetals) are desired.
 - The unique capability of the powder metallurgy process is applied to a number of products. In the electrical industry, copper and graphite are frequently combined in such applications as motor or generator brushes, copper providing the current carrying capacity, with graphite providing lubrication. Similarly, bearings have been made of graphite combined with iron or copper or of mixtures of two metals, such as tin and copper, where the softer metal is placed in a harder metal matrix. Electrical contacts often combine copper or silver with tungsten, nickel or molybdenum. The copper or silver provides high conductivity, while the material with high melting temperature provides resistance to fusion during the conditions of arcing and subsequent closure.
5. Products here the powder metallurgy process produces clearly superior properties
 - The development process that produce full density has resulted in powder metallurgy products that are clearly superior to those produced by competing techniques. In areas of critical importance such as aerospace applications, the additional cost of the processing may be justified by the enhanced properties of the product. In the production of powder metallurgy products magnets, a magnetic field can be used to align the particles prior to sintering, thereby producing a high flux density in the product.

Advantages and Disadvantages of Powder Metallurgy

Advantages:

1. Elimination or reduction of machining
2. High Production Rates
3. Complex Shapes to be Produced
4. Wide Variations in Compositions are Possible
5. Wide Variation in Properties are Available

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6. Scrap is Eliminated or Reduced

Disadvantages:

1. Inferior Strength Properties
2. Relatively High Die Cost
3. High Material Cost
4. Design Limitations
5. Density Variations Produce Property Variations
6. Health and Safety Hazards

Powder metallurgy (P/M):

Metal parts are made by compacting fine metal powders in suitable dies and sintering (heating without melting)

Powder metallurgy process basically consists of the following operations in sequence:

Powder production, Blending, Compaction, Sintering, Finishing operations

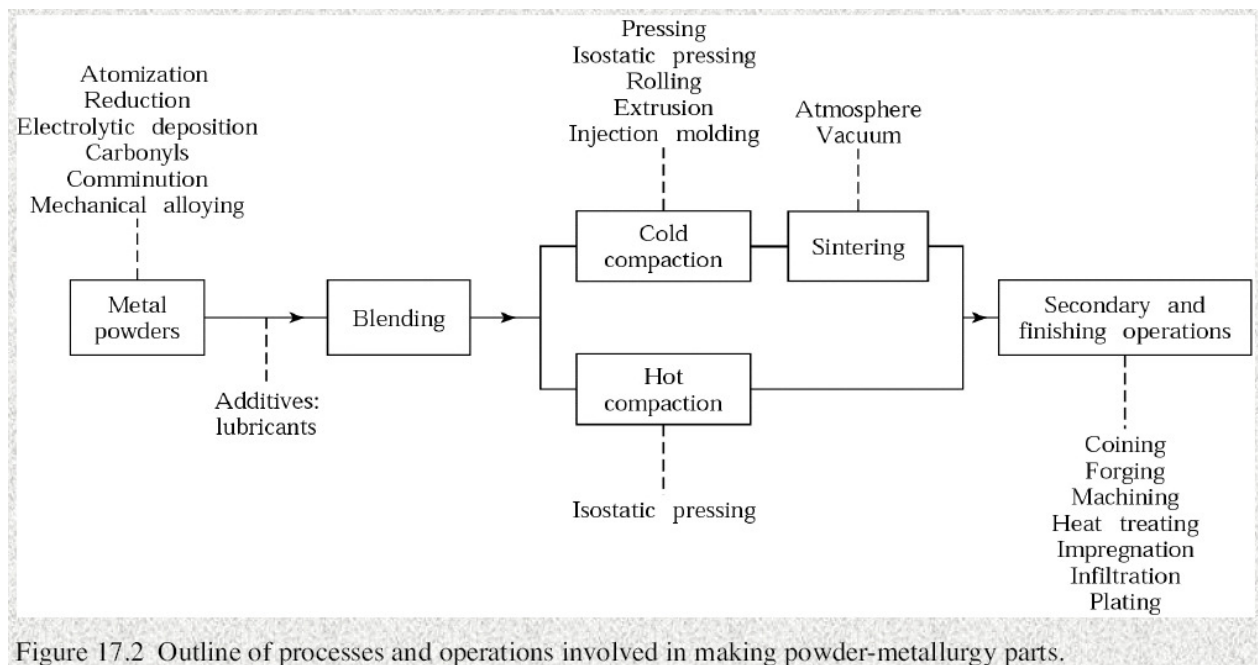


Figure 17.2 Outline of processes and operations involved in making powder-metallurgy parts.

Powder production:

a) Atomization:

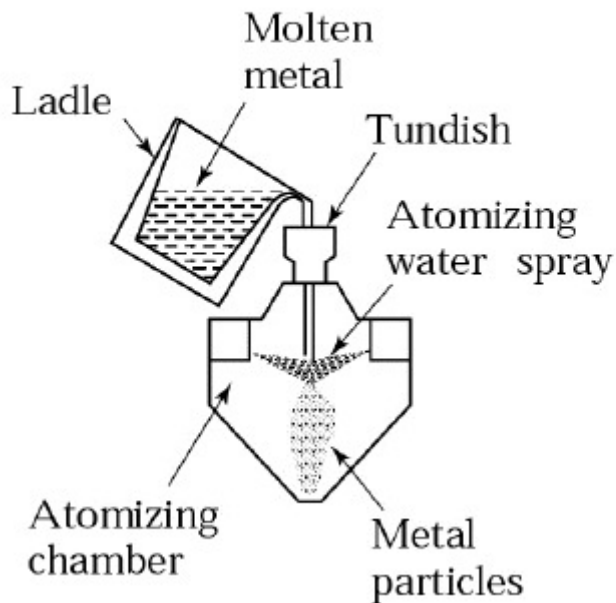
Produces a liquid-metal stream by injecting molten metal through a small orifice

Stream is broken up by jets of inert gas, air or water

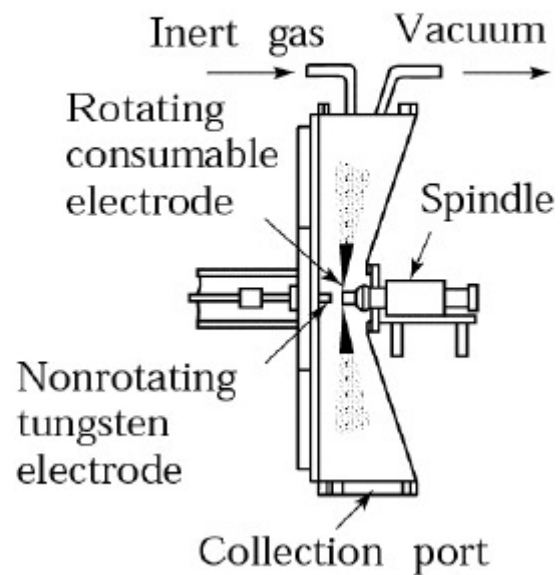
Size of the particles formed depends on temperature of the metal, rate of flow, nozzle size and jet characteristics

Atomization: Melt atomization & Atomization by consumable electrode

(a)



(b)

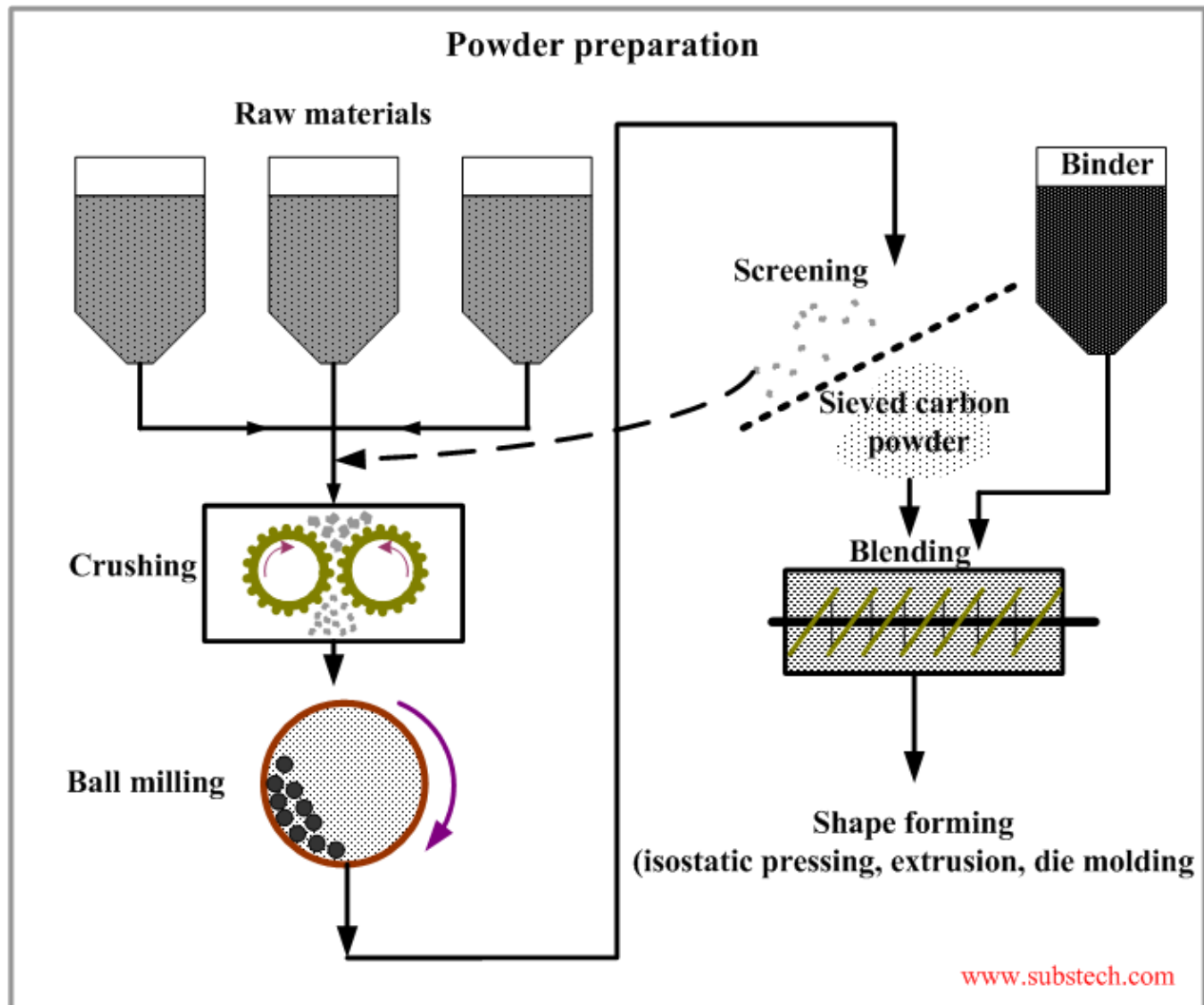


b) Reduction:

Reduction of metal oxides (removal of oxygen) uses gases, such as hydrogen and carbon monoxide as reducing agents

Very fine metallic oxides are reduced to the metallic state

Powders produced by this method are spongy and porous and have uniform shape



C) Electrolytic deposition:

Utilizes either aqueous solutions or fused salts

Powders produced are the purest available.

D) Carbonyls:

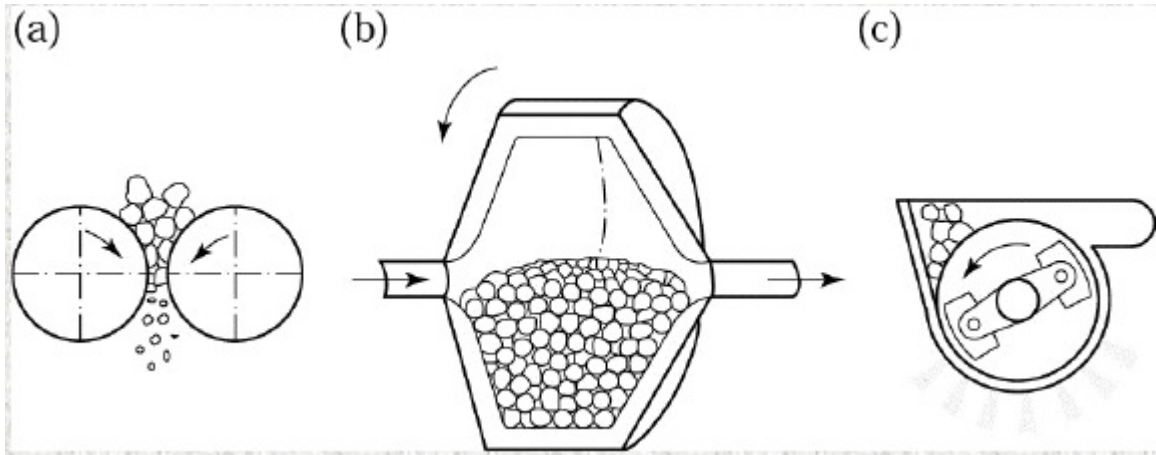
Metal carbonyls: iron carbonyl ($\text{Fe}(\text{CO})_5$) and nickel carbonyl ($\text{Ni}(\text{CO})_4$) are formed by letting iron / nickel react with carbon monoxide.

Reaction products are then decomposed into iron and nickel as small, dense, uniformly spherical particles of high purity.

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E) Comminution:

Mechanical Comminution (pulverization) involves crushing, milling in a ball mill or grinding brittle or less ductile metals into small particles



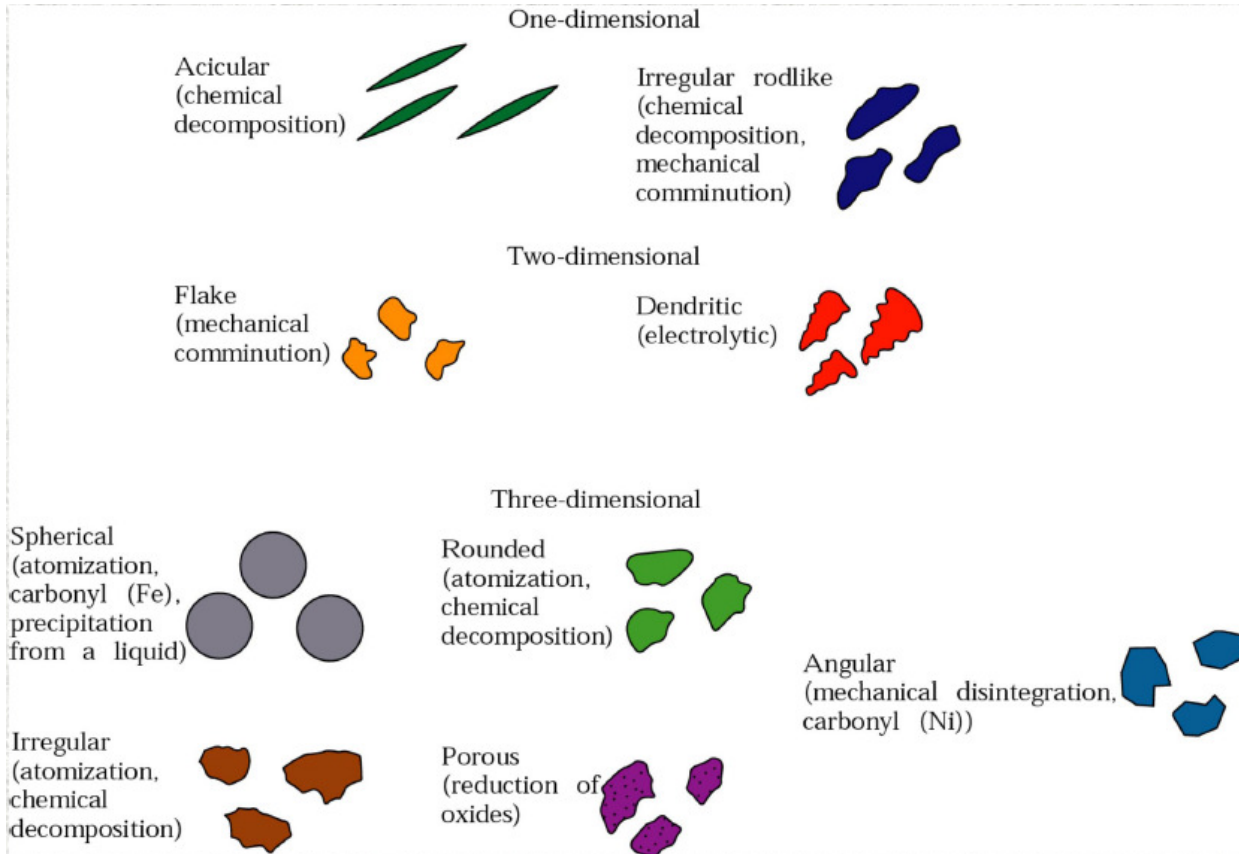
Methods of comminution: Roll crushing, Ball mill & hammer milling

F) Mechanical alloying:

Powders of two or more pure metals are mixed in a ball mill

Under the impact of the hard balls, the powders fracture and join together by diffusion, forming alloy powders

Particle shape of metal powder



Blending

Blending is the second step in powder metallurgy where mixing of powders take place

Blending is done for the following purposes:

Powders made by various processes have different sizes and shapes, are to be mixed to obtain uniformity (ideal mix is one where all particles of each material are distributed uniformly)

Powders of different metals and other materials can be mixed in order to impart special physical and mechanical properties and characteristics of the P/M product

Lubricants may be mixed with powder to improve their flow characteristics. Lubricants are stearic acid or zinc stearate in a proportion of 0.25% to 5% by weight



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Powder mixing must be carried out under controlled conditions to avoid contamination or deterioration

Deterioration is caused by excessive mixing, which may alter the shape of the particles and harden them

Powders can be mixed in air, in inert atmospheres, in liquids and make the mix uniform

Compaction of Metal Powders:

Compaction: Blended powders are pressed into shapes in dies

Presses are actuated either hydraulically / mechanically

Purpose of compaction is to obtain the required shape, density, particle – to – particle contact and to make the part sufficiently strong to be further processed.

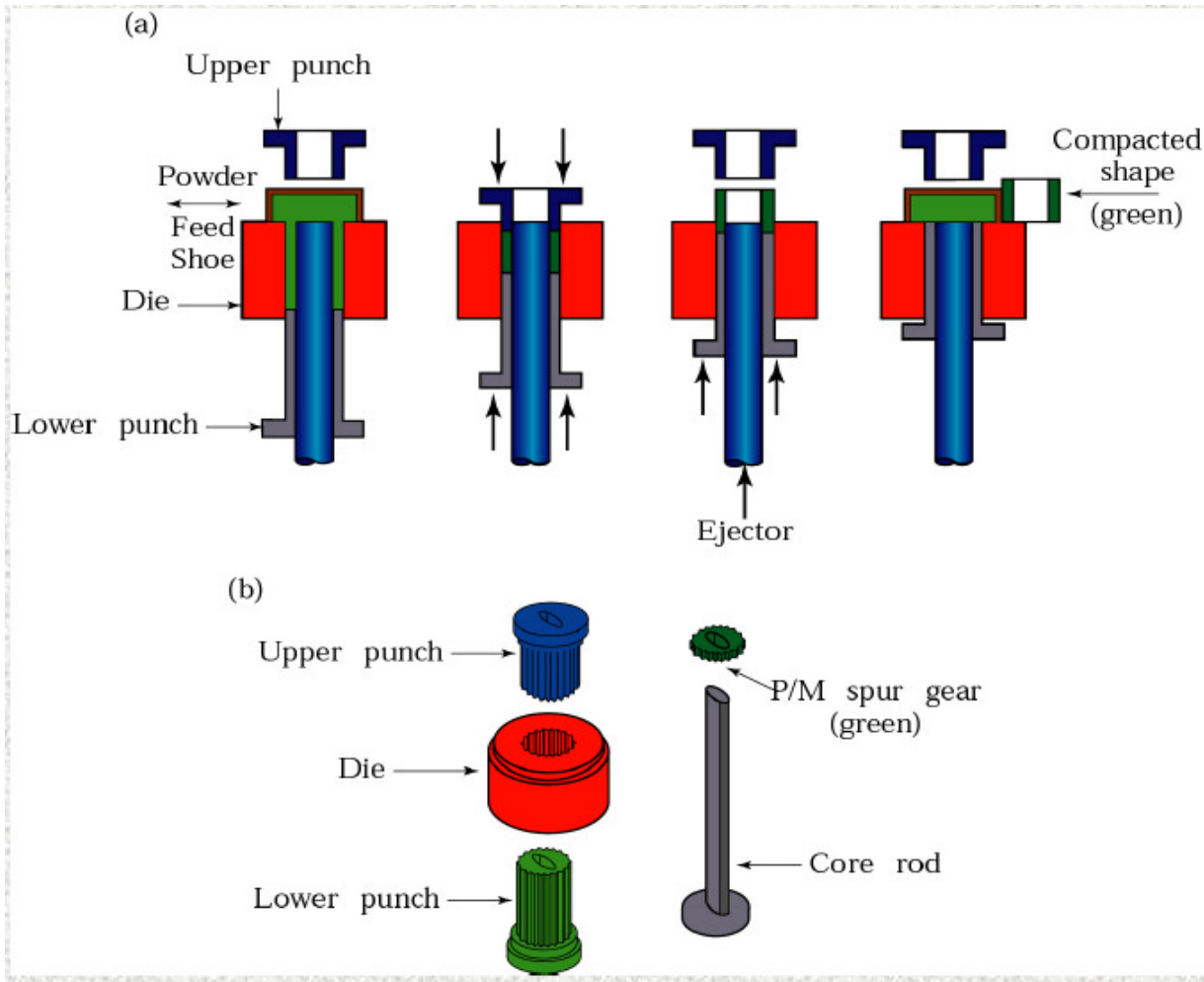
Pressed powder is known as **green compact**

Density of green compact depends on pressure applied

Higher the density, the higher the strength and the elastic modulus of the part

Pressure required for pressing metal powders ranges from 70 MPa for aluminum to 800 MPa for high density iron parts

Compacting pressure required depends on the characteristics and shape of the particles, method of blending and the lubricant.



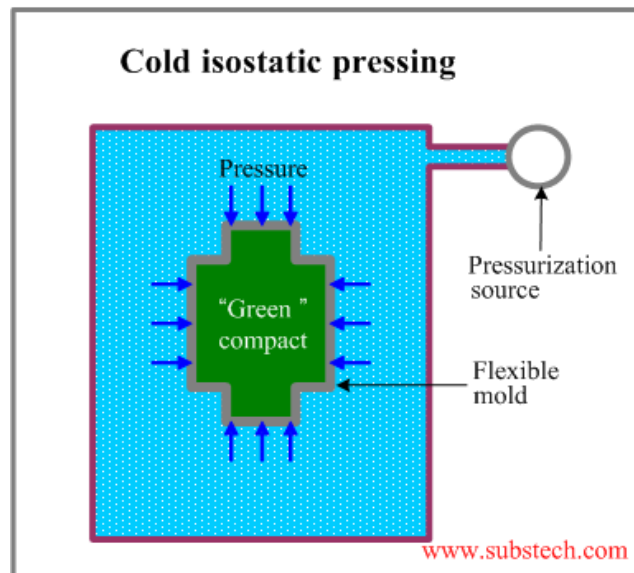
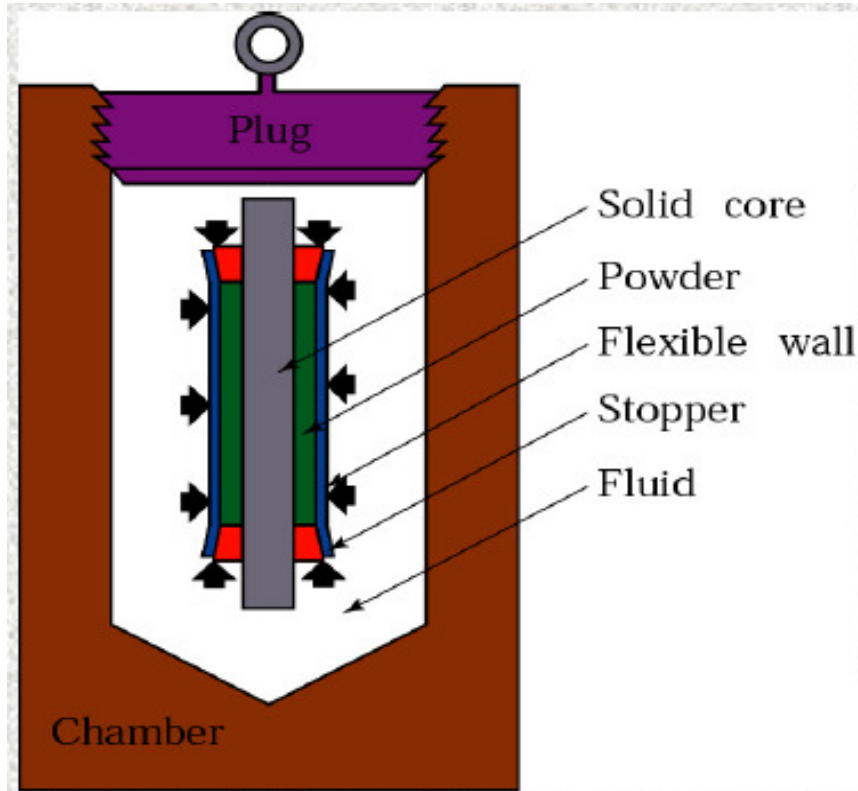
Isostatic Pressing

Compaction can be carried out or improved by additional processing such as isostatic pressing, rolling and forging.

Cold isostatic pressing

Metal powder is placed in a flexible rubber mold made of neoprene rubber, urethane, PVC or any other elastomer.

Assembly is pressurized hydrostatically in a chamber, usually by water at a pressure of about 400 MPa to 1000 MPa



Hot isostatic pressing

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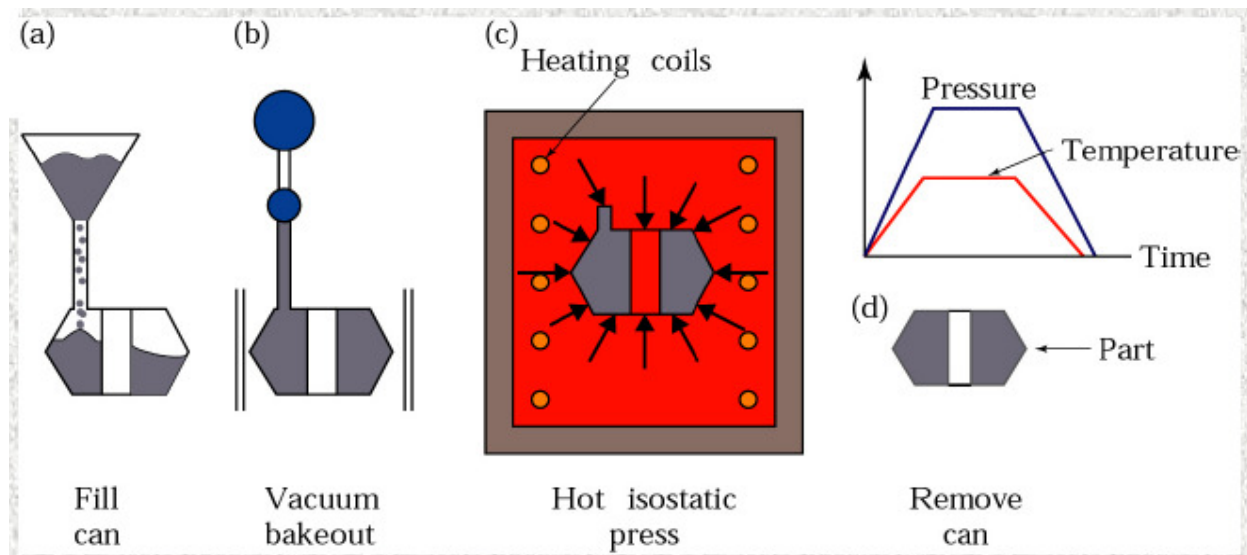
The container is usually made of a high-melting point sheet metal and the pressurizing medium is inert gas or a vitreous (glasslike) fluid

Common conditions for HIP are 100 MPa at 1100 deg.C.

Main advantage of HIP is its ability to produce compacts having almost 100% density, good metallurgical bonding of the particles and good mechanical properties

HIP process is used mainly in making superalloy components for aircraft and aerospace industries, military medical and chemical applications

Process is also used to close internal porosity and to improve properties in superalloy and titanium alloy castings for aerospace industry



Advantages of isostatic pressing:

Because of the uniformity of pressure from all directions and the absence of die-wall friction, it produces fully-dense compacts of practically uniform grain structure and density

Parts with high length-to-diameter ratios have been produced with very uniform density, strength and toughness and good surface detail.

Other compacting and shaping processes

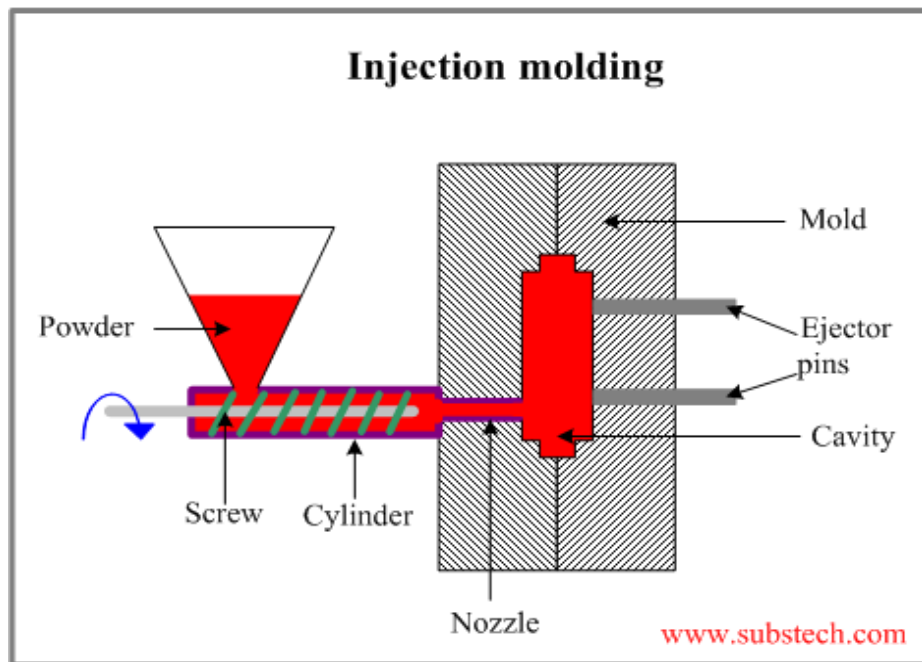
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Metal injection molding: Very fine metal powders (<10 microns) are blended with either a polymer or a wax based binder and injected into a mold

Molded green parts are placed in a low temperature oven to burn off the plastic or binder may be removed by solvent extraction

Metals suitable for metal-injection molding are carbon and stainless steels, tool steels, copper, bronze and titanium.

Typical parts made are components of watches, small caliber gun barrels and surgical knives



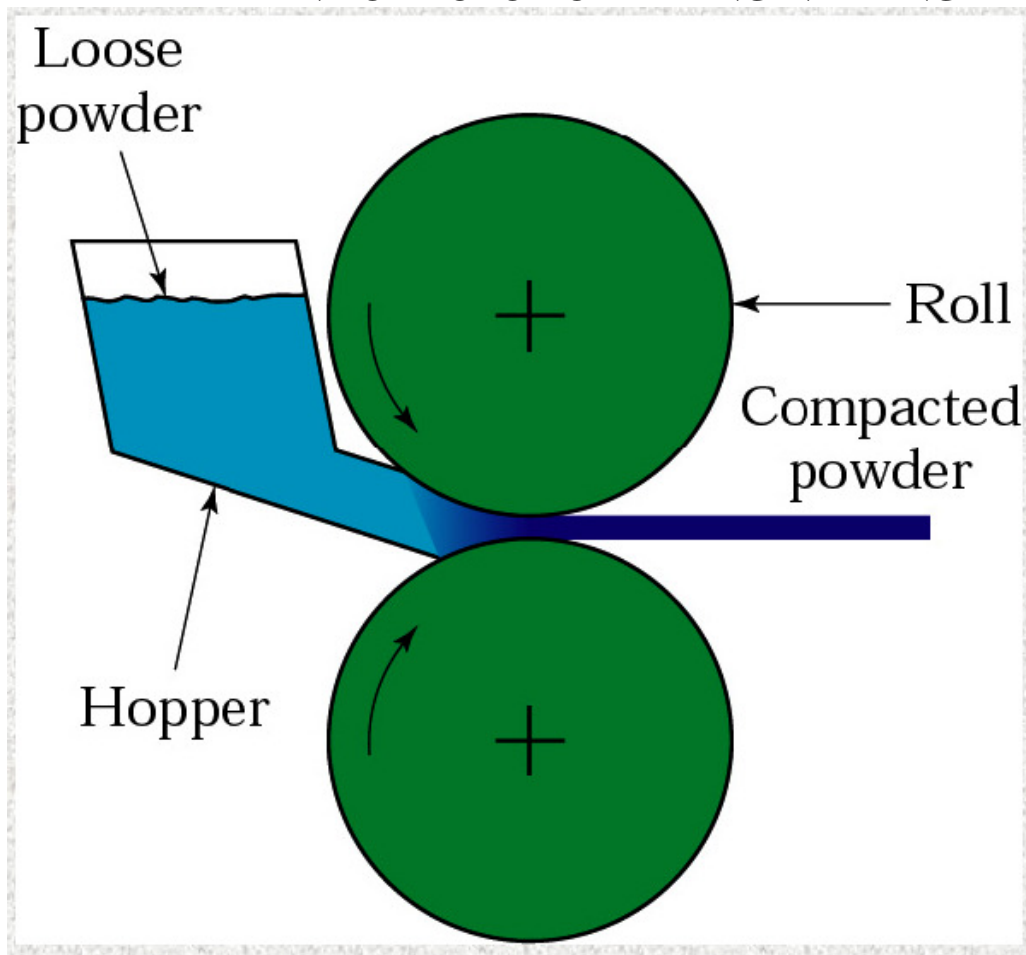
Advantages:

Complex shapes having wall thickness as small as 5mm can be molded, Dimensional tolerances are good and High production rates can be achieved by use of multicavity dies.

Rolling: In powder rolling (Roll compaction) the powder is fed to the roll gap in a two-roll rolling mill and is compacted into a continuous strip

Process can be carried out room or at elevated temperature

Sheet metal for electrical and electronics components and for coins are made by this process



Sintering

Process in which green compacts are heated in a controlled-atmosphere furnace to a temperature below the melting point but sufficiently high to allow bonding (fusion) of individual particles

Principal variables in sintering are temperature, time and the furnace atmosphere

Sintering temperatures are generally within 70 to 90% of the melting point of the metal or alloy

Sintering time range from a minimum of 10 minutes for iron and copper alloys to 8 hours for tungsten and tantalum

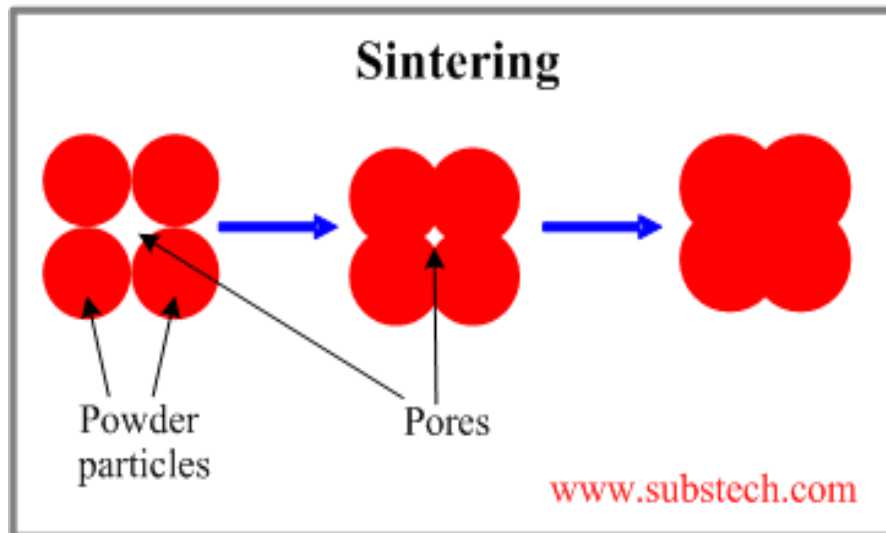
Continuos sintering-furnaces have three chambers

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- a) A burn-off chamber for volatilizing the lubricants in the green compact, in order to improve bond strength and prevent cracking
- b) A high-temperature chamber for sintering
- c) A cooling chamber

To obtain optimum properties

- a) Proper control of the furnace atmosphere for successful sintering
- b) An oxygen-free atmosphere is essential, to control the carburization and decarburization of iron and iron based compacts and to prevent oxidation of powders.
- c) Vacuum is generally used for sintering refractory metal alloys and stainless steels



Sintering Mechanisms:

Complex, depend on the composition of the metal particles and on the processing parameters.

Solid-state bonding

Vapor-phase transport

Liquid-phase sintering

Spark sintering

- a) Solid-state bonding

As temperature increases, two adjacent particles begin to form a bond by a diffusion mechanism

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As a result, the strength, density, ductility, thermal and electrical conductivities of the compact increase.

b) Vapor-phase transport

As the material is heated to very close to its melting temperature, metal atoms will release to the vapor phase from the particles

At convergent geometries the melting temperature is locally higher and the vapor phase resolidifies

Thus the interface grows and strengthens

c) Liquid-phase sintering

If two adjacent particles are of different metals, alloying can take place at the interface of two particles

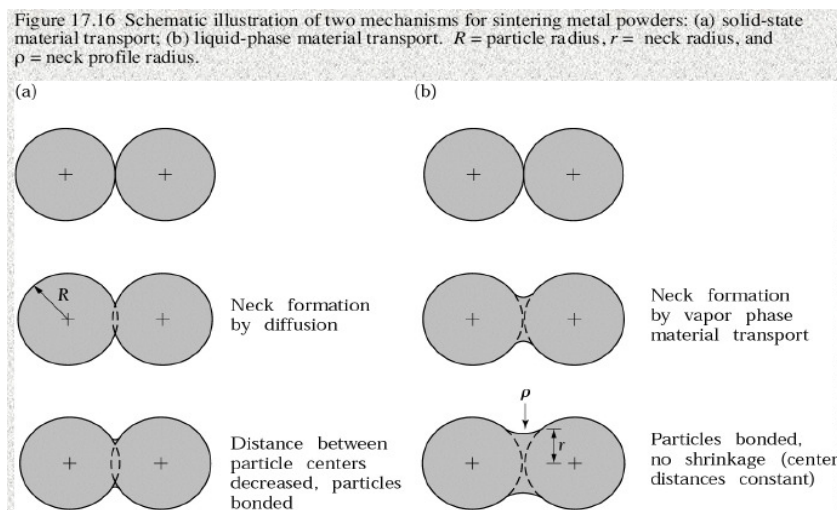
One of the particle may have a lower melting point than the other, which will melt and due to surface tension it will surround the particle that has not melted.

Stronger and denser parts can be obtained

d) Spark sintering

Loose metal powders are placed in a graphite mold, heated by an electric current, subjected to a high-energy discharge and compacted in one step.

The rapid discharge strips contaminants from the surfaces of the particles and thus encourages good bonding during compaction at elevated temperatures.



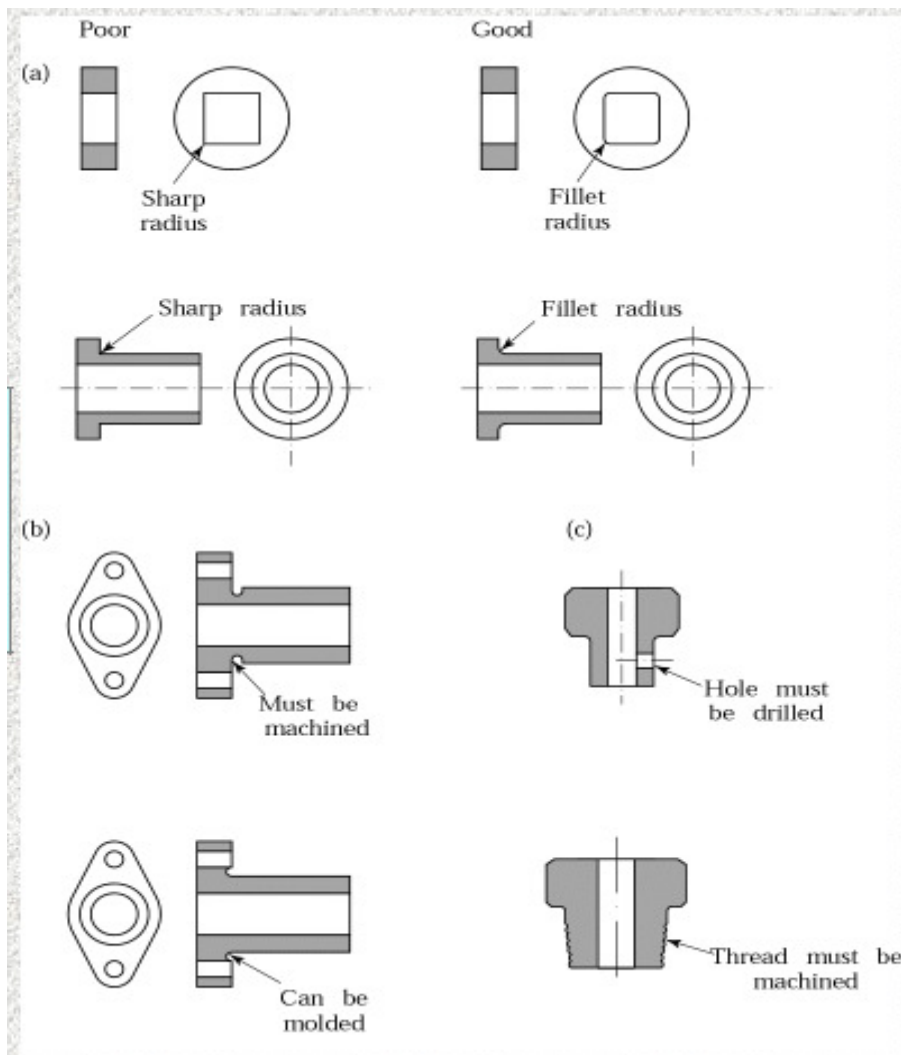
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Design considerations for powder metallurgy:

Shape of the compact must be as simple and uniform as possible. Sharp changes in contour, thin sections, variations in thickness and high length-to-diameter ratios should be avoided

Provision must be made for ejecting the green compact from the die without damaging the compact

Parts must be designed with the widest dimensional tolerances that are consistent with their intended applications ($\pm 0.05 - 0.1$ mm)



Process capabilities:

- a) technique for making parts from high-melting point refractory metals, parts which may be difficult or uneconomical to produce by other methods



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- b) Offers high production rates on relatively complex parts
- c) Offers good dimensional control : eliminates machining and finishing operations
- d) Wide range of compositions makes it possible to obtain special mechanical and physical properties
- e) Offers capability for impregnation and infiltration for special applications

MECHANICAL WORKING → PLASTIC DEFORMATION
(MECHANICAL PRESSURE)



**DIMENSIONAL CHANGES
PROPERTIES**

SURFACE CONDITIONS

MECHANICAL WORKING → HOT WORKING

COLD WORKING

HOT WORKING:

Deforming metal above recrystallisation temperature and below melting point (new grains are formed)

- FORGING
- ROLLING
- EXTRUSION
- DRAWING
- PIERCING

FORGING :

Process of reducing a metal billet between flat dies or in a closed impression die to obtain a part of a predetermined size and shape.

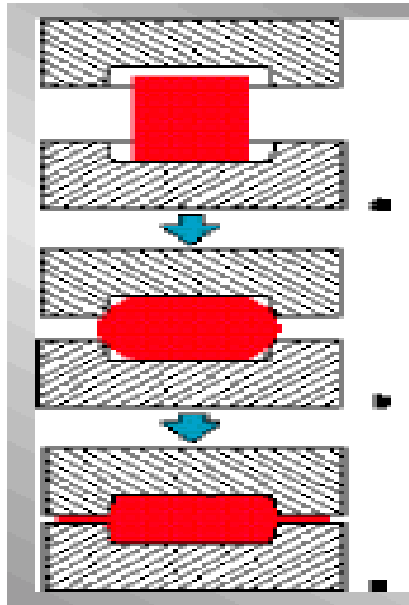
SMITH DIE (FLAT DIE / OPEN DIE): HAND FORGING & POWER FORGING
(HAMMER & PRESS)

IMPRESSION DIES FORGING: DROP, PRESS & MACHINE FORGING



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HAMMER: Machine which work on forgings by blow

PRESS : Machine which work on forgings by pressure

PRESSES:

HYDRAULIC
MECHANICAL
SCREW
HAMMER

HAMMERS:

GRAVITY DROP HAMMER
POWER DROP HAMMER
COUNTER BLOW

SPEED RANGE OF FORGING EQUIPMENT

Hydraulic press	:	0.06 – 0.30 m/s
Mechanical press	:	0.06 – 1.5 m/s
Screw press	:	0.0 – 1.2 m/s
Gravity drop hammer	:	3.6 – 4.8 m/s
Power drop hammer	:	3.0 – 9.0 m/s
Counter blow hammer	:	4.5 – 9.0 m/s

HYDRAULIC PRESS:

Operate at constant speed

Load limited / load restricted (Press stops if the load required exceeds its capacity)

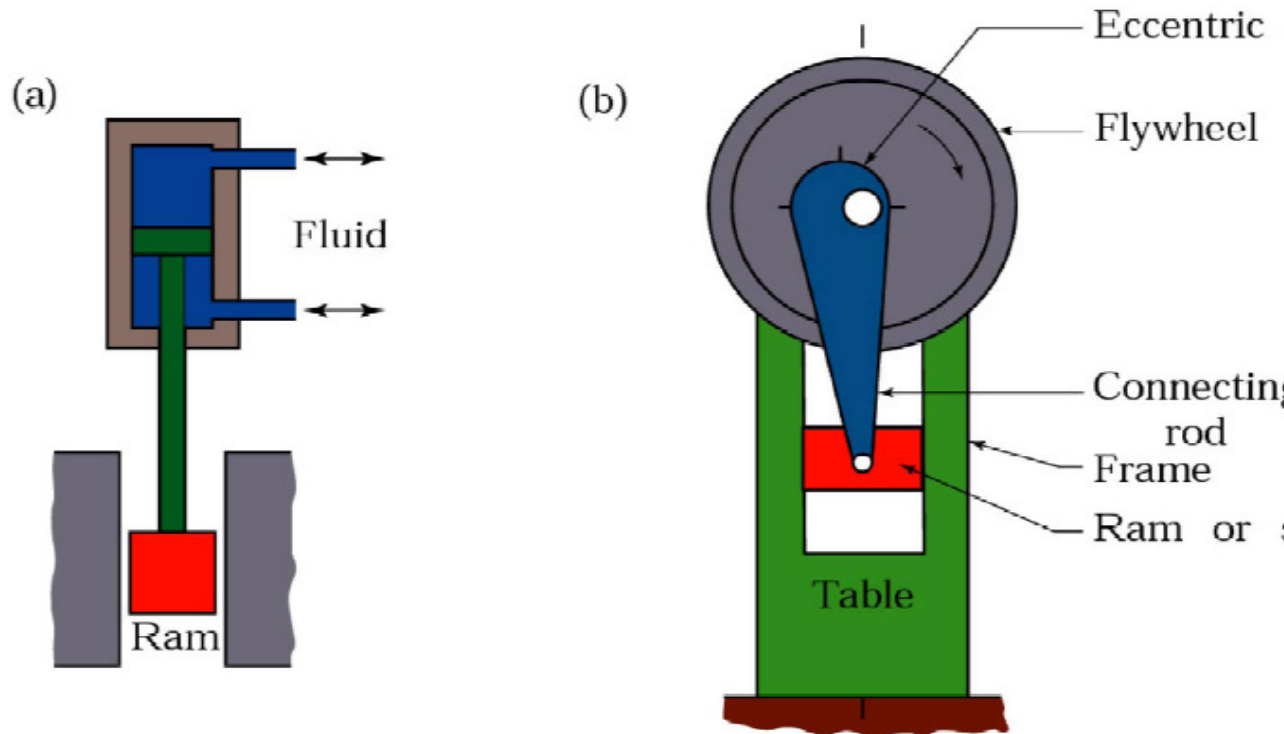
Large amount of energy transmitted to work piece by constant load throughout the stroke

Slower & involves higher initial cost but require less maintenance

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Press capacity range up to 14,000 tons for open die forging, 82,000 tons for closed die forging.

(Ex.) Main landing gear support beam for Boeing 747 aircraft is forged in a 50,000 tons hydraulic press (Closed die forging) Titanium alloy – weighs 1350 kgs.



Schematic illustration of the principles of various forging machines.

(a) Hydraulic press. (b) Mechanical press with an eccentric drive; the eccentric shaft can be replaced by a crankshaft to give the up-and-down motion to the ram.

MECHANICAL PRESS:

Stroke limited (Speed varies from a max at the center of the stroke to zero at the bottom of the stroke)

Energy is generated by a large flywheel powered by an electric motor.

A clutch engages the flywheel to an eccentric shaft

A connecting rod translates the rotary motion into a reciprocating linear motion.

Force available in a mechanical press depends on the stroke position

Extremely high at the BDC, Have high production rates

Easy to automate & requires less operator skill

Capacity range from 300 tons to 12,000 tons.

SCREW PRESS:

Presses derive their energy from a flywheel

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Forging load is transmitted thru. a vertical screw

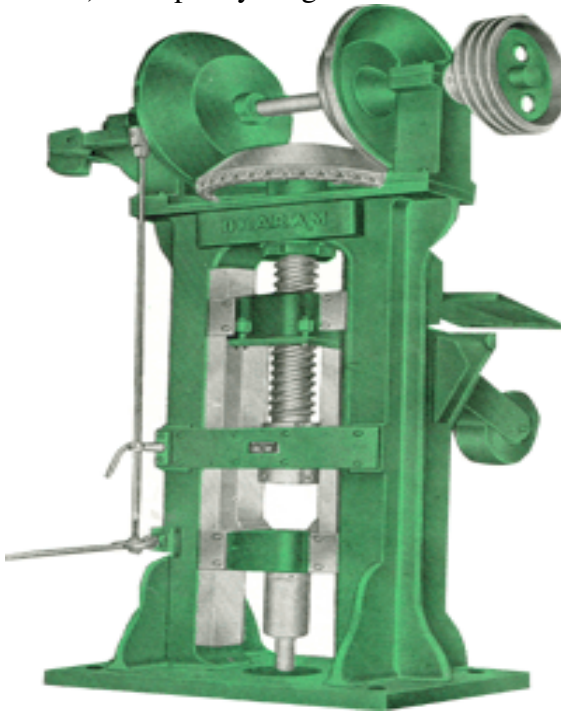
Ram comes to a stop when the flywheel energy is dissipated

Hence screw presses are energy limited

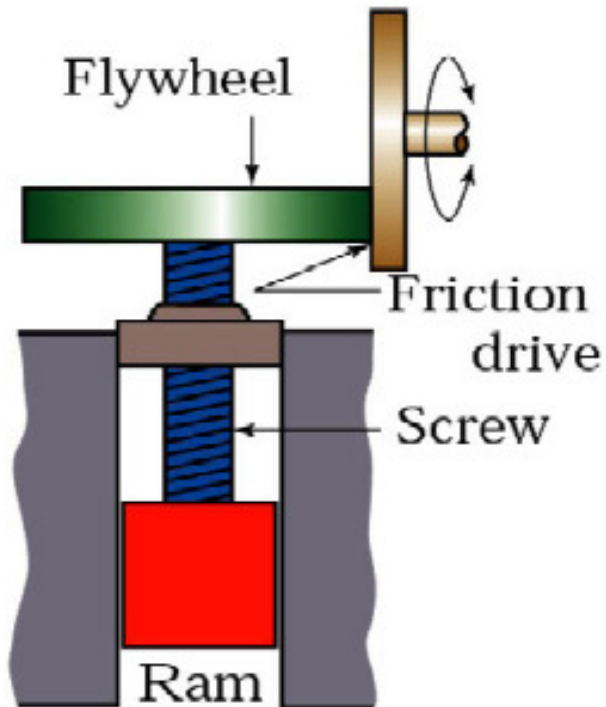
If the dies do not close at the end of the cycle, the operation is repeated until the forging is completed

Used for various open die and closed die forging

Suitable for small production quantities and precision parts (turbine blades) & Capacity range from 160 tons to 31,500 tons



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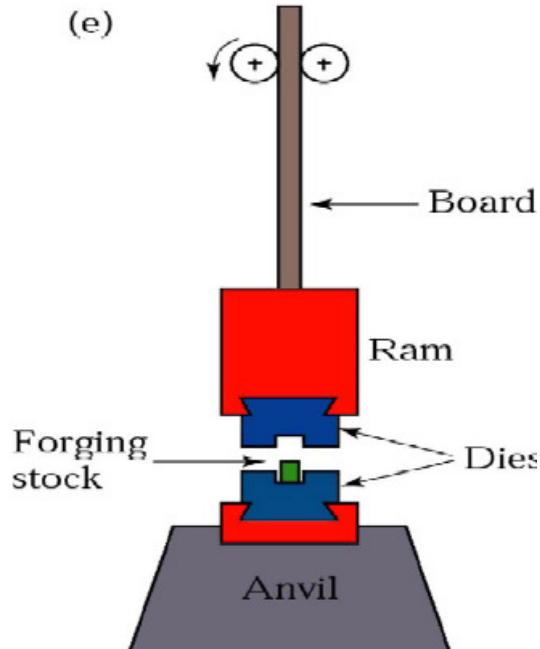
GRAVITY DROP HAMMER (DROP FORGING)

Energy is derived from the free falling ram

Available energy of the hammer is the product of the ram's weight and the height of the drop

Ram wt. range from 180 kg to 4500 kg.

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POWER DROP HAMMER

Ram's down stroke is accelerated by steam, air or hydraulic pressure at about 750 kpa

Ram wt. range from 225 kg to 22500 kg

Pneumatic Power Hammer

COUNTER BLOW HAMMER

Has two rams that simultaneously approach each other horizontally or vertically to forge the parts

Operates at high speeds and transmits less vibration

ROLLING

Method of forming metal into desired shape by plastic deformation between rolls

Crystals are elongated in the direction of rolling

Start to reform after leaving the zone of stress

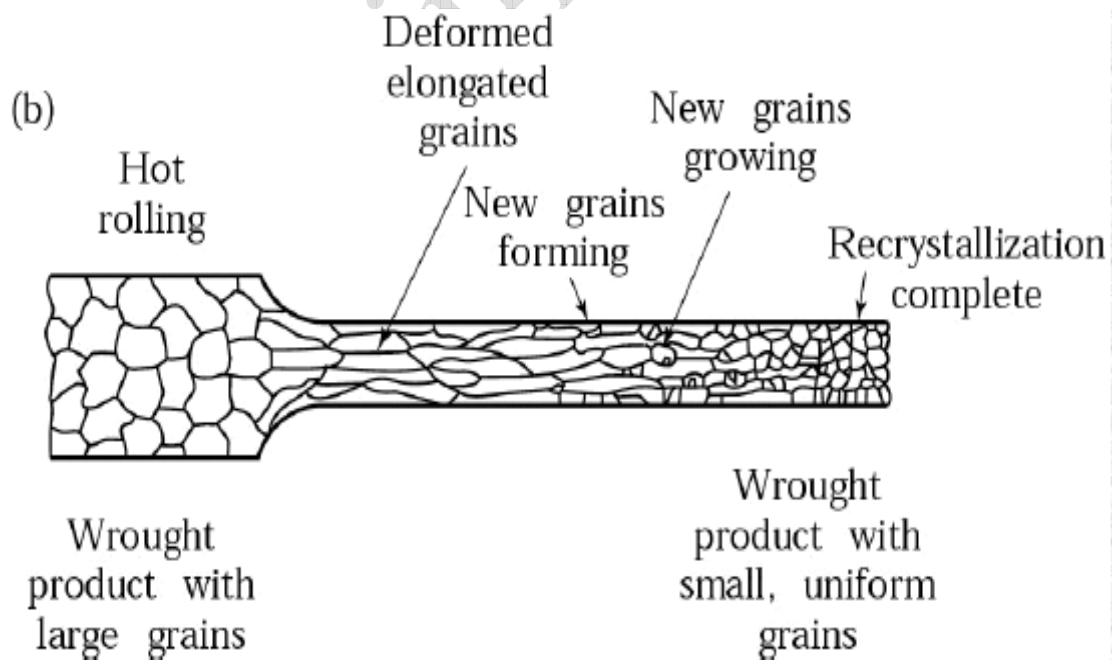
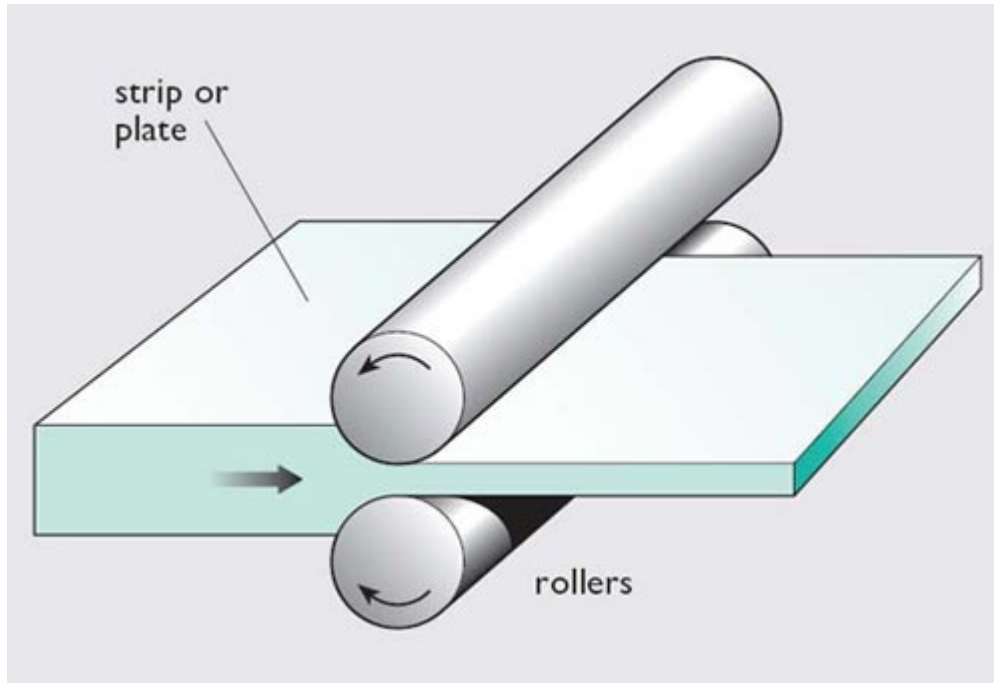
Work is subjected to high compressive stresses and surface shear stresses.

Metal in a hot plastic state is passed between 2 rolls revolving at the same speed but in opposite direction

Metal is reduced in thickness and increased in length

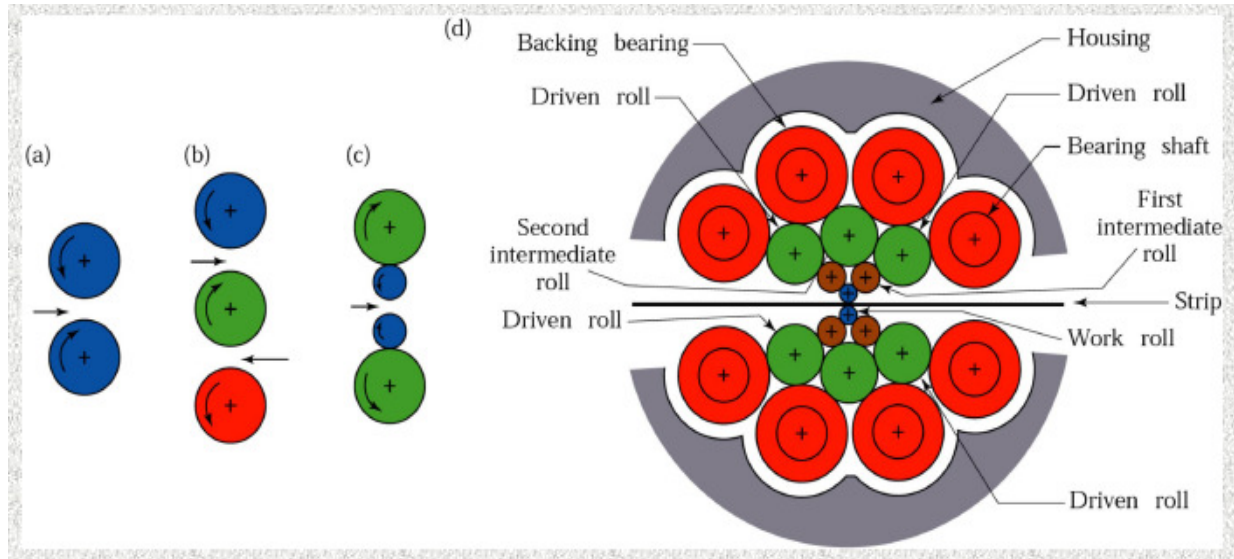
Application: Bars, Plates, Sheets, Rails & Structural Sections

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Backing Roll Arrangements

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RING ROLLING

A thick ring is expanded into a large diameter ring with a reduced c.s.

Ring is placed between two rolls (one is driven)

Thickness is reduced by bringing the rollers closer together as they rotate

Volume of ring remains constant during deformation, the reduction in thk. Is compensated by an increase in the ring's diameter.

Ring shaped blank is produced by

cutting from the plate

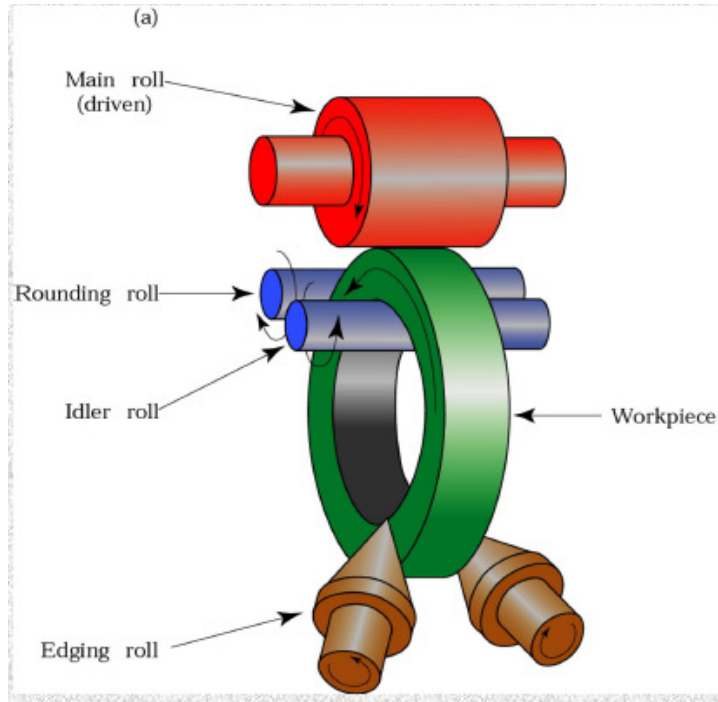
piercing

cutting a thick walled pipe

Various shapes can be ring rolled by the use of shaped rolls

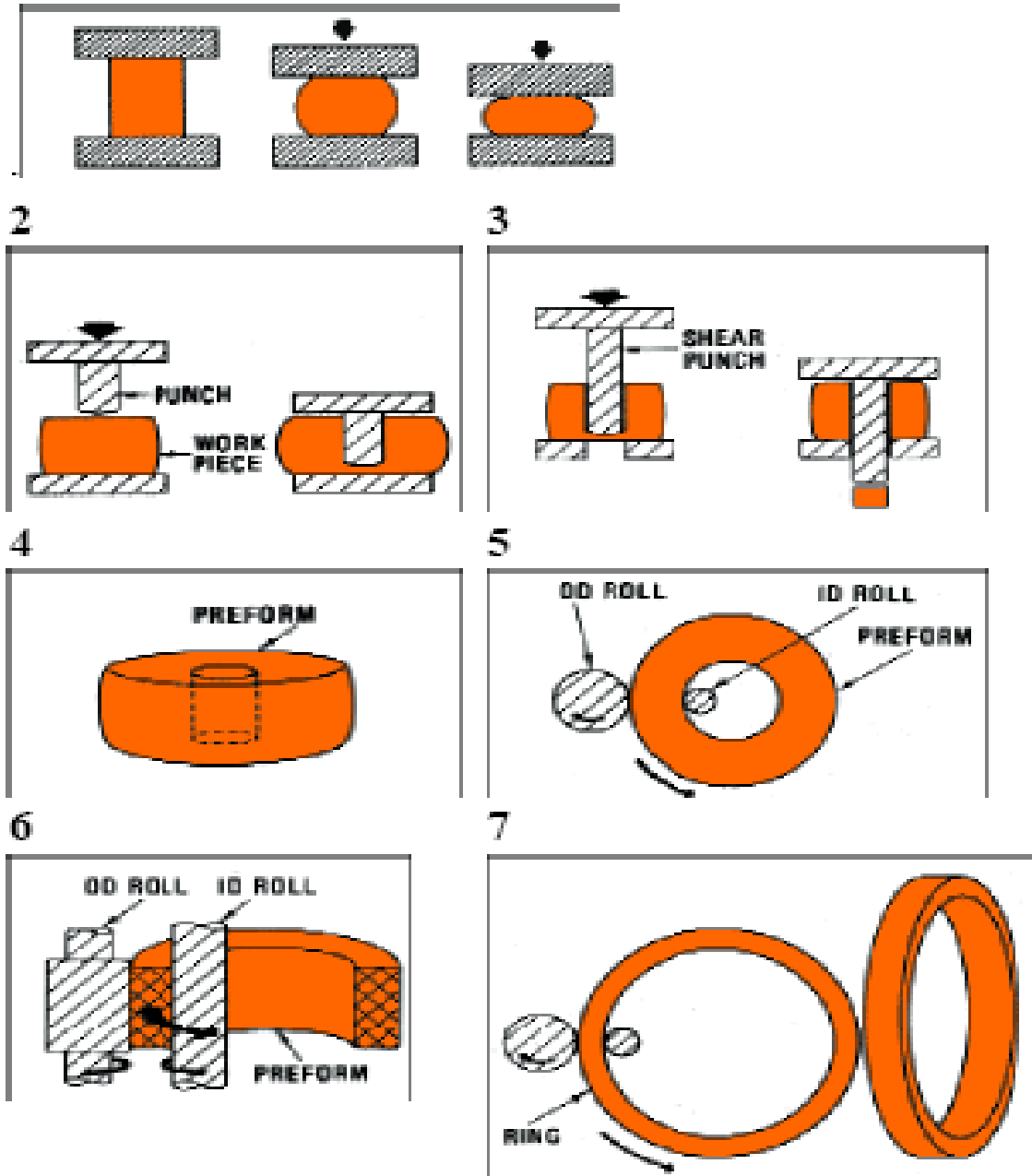
can be carried out at room / elevated temp depending upon the size, strength and ductility of w / p

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Stages in the Ring Rolling Process



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Application of ring rolling
large rings for rockets & turbines
gearwheel rims
ball bearing & roller bearing races
flanges
reinforcing rings for pipes
Advantages
short production time
no material wastage
close dimensional tolerances
Favorable grain flow.

THREAD ROLLING

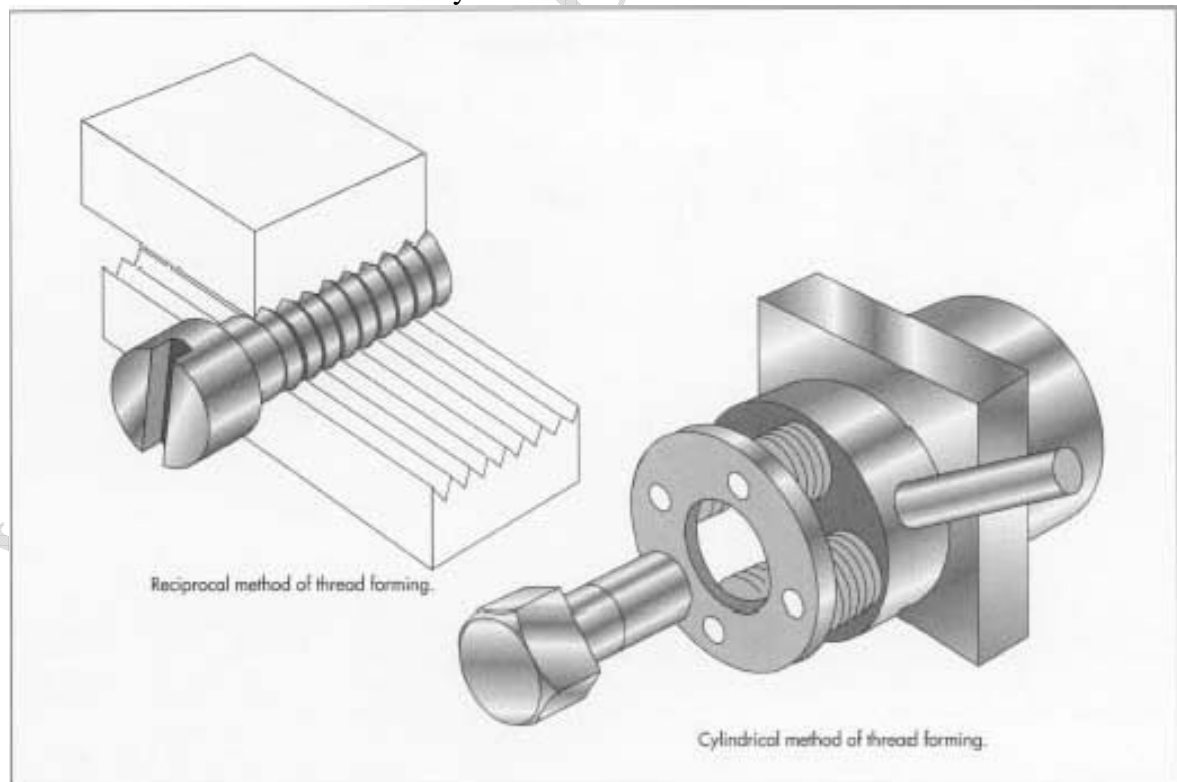
Cold forming process: St / Tapered threads are formed on round rods by pressing them between dies

Threads are formed on w/ p with each stroke of a pair of flat reciprocating dies.

Process is capable of generating similar shapes such as grooves, gear forms etc.

Almost all threaded fasteners at high production rates are formed

Threads are also formed with rotary dies.



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Advantages

generating threads involve no wastage of material

Good strength (due to cold working)

Surface finish is very smooth

Induces compressive residual stress results in improving fatigue life

EXTRUSION

Billet is forced through a die

Any solid / hollow c.s. can be produced

Extruded part have a constant c.s. because the die geometry remains constant

Types : Direct / Forward, Indirect / Reverse, Hydraulic & Lateral Extrusion

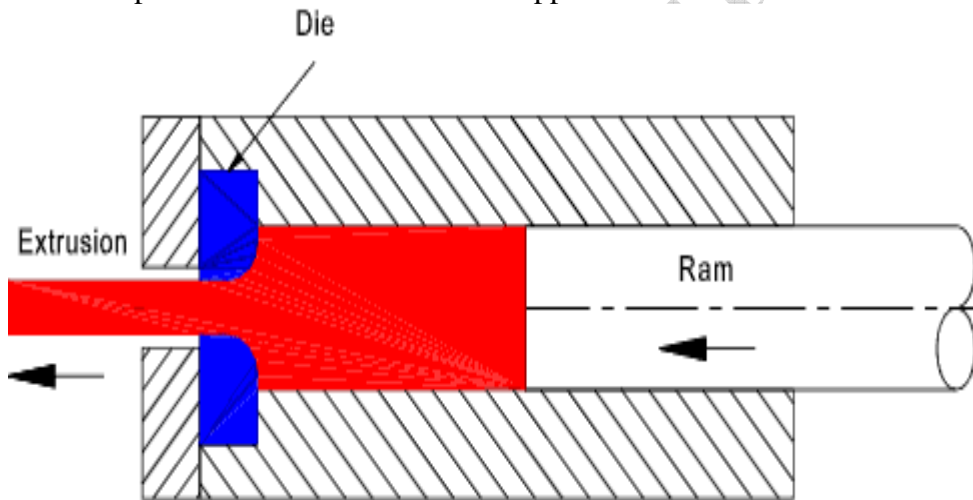
Direct Extrusion:

A round billet is placed in a chamber

Forced thru. a die opening by a hydraulically – driven ram / pressing stem

Die opening may be round or can have any shapes.

Extruded part moves in the direction of application of force



Direct Extrusion

Indirect extrusion:

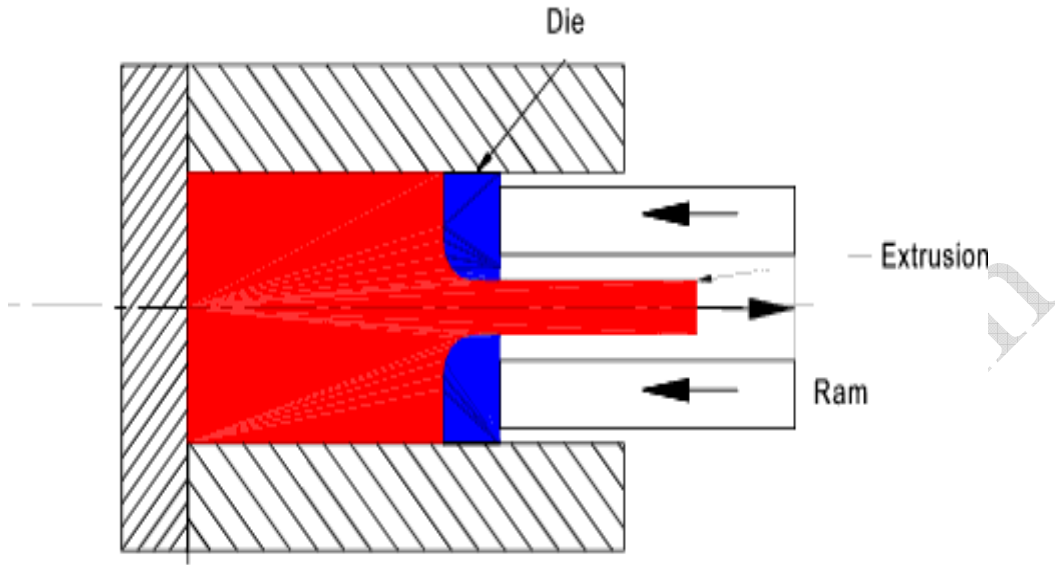
Die moves towards the billet.

Extruded part moves in the direction opposite to the direction of application of force.

Force is applied thru. the tool stem

At the end of the chamber backing disc is provided.

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Indirect Extrusion

Hydrostatic extrusion:

The billet is smaller in volume than the chamber.

Chamber is filled with fluid and the pressure is transmitted to the billet by the ram

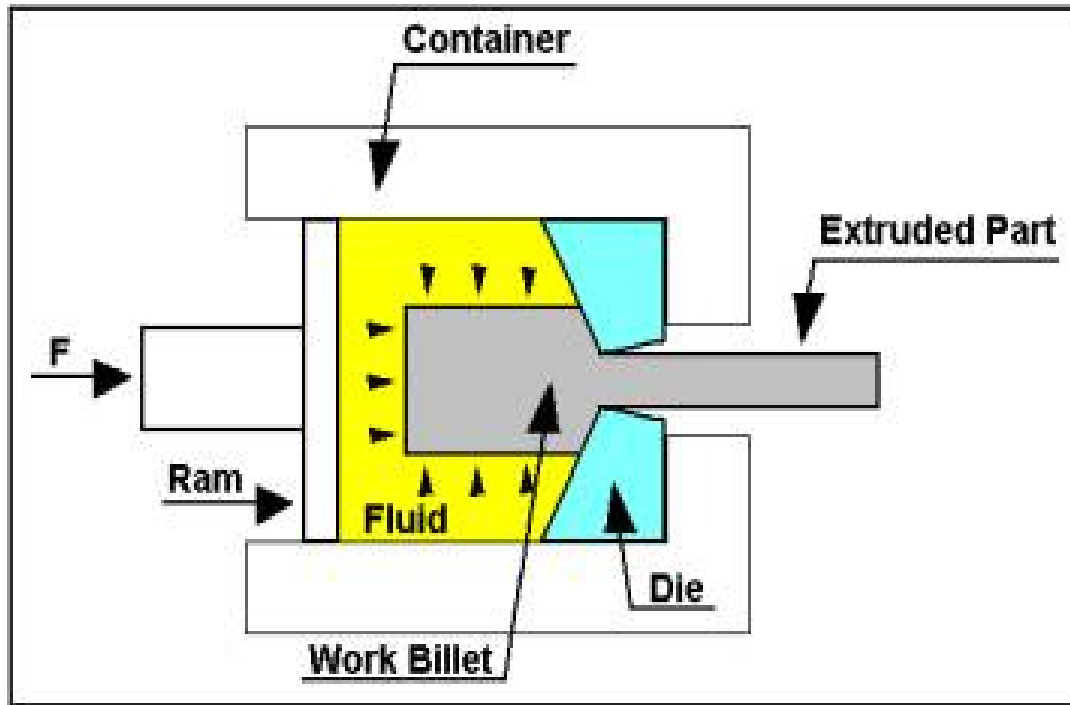
No friction is there to overcome along the chamber walls.

Extruded part moves in the direction of application of pressure

Carried out at room temperature using vegetable oil as the fluid (Castor oil)

For elevated temp. extrusion Wax, Polymers and glass were used as fluids.

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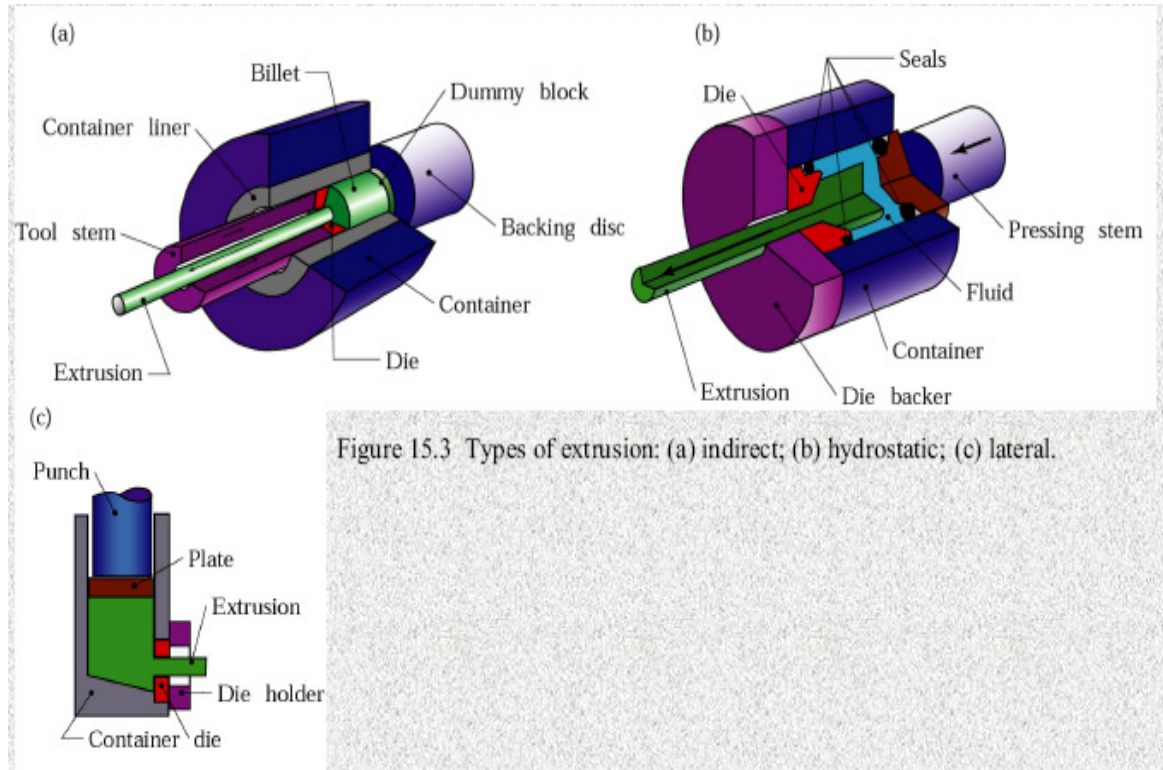
Lateral Extrusion:

Extruded part moves out in the direction perpendicular to the direction of application of force.

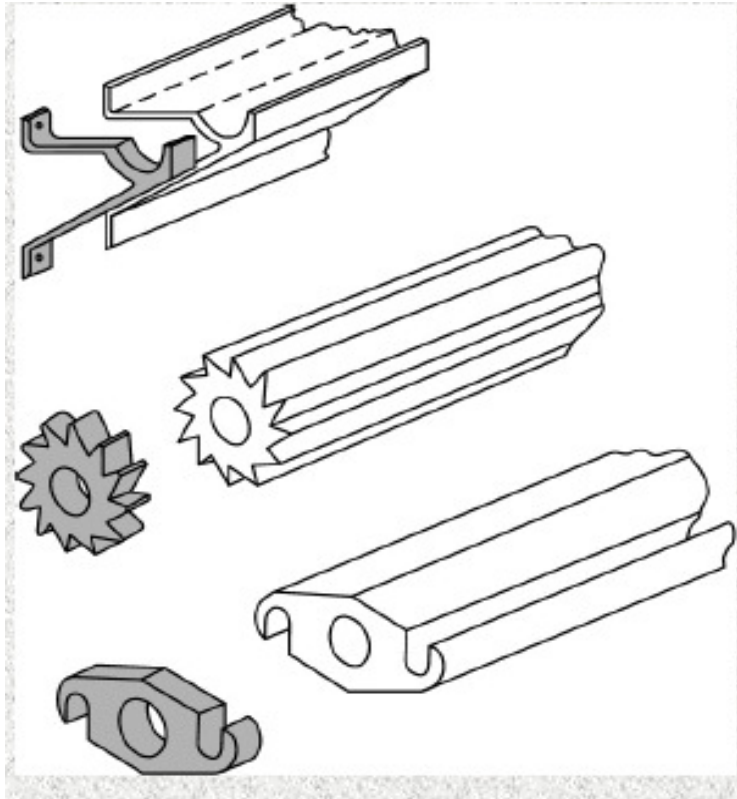
Commonly extruded materials are Al., Cu., Steel, plastics, lead pipes etc.

Typical products includes railings for sliding doors, tubes of various c.s., Structural & architectural shapes, door & window frames etc.

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Extrusion defects:

Surface cracking: If the temp., friction or speed is high surface temp. increases significantly and may result in surface cracks.

Occur especially in Al., Mg., and Zn. Alloys.

Pipe: During metal flow it tends to draw surface oxides & impurities toward the center of the billet like a funnel, called as pipe defect.

Internal cracking: Center of the extruded part can develop cracks due to the higher die angle, impurities etc.

DRAWING PROCESS

C.S. of a round rod or wire is typically reduced / changed by pulling it thru. a die.

Major variables in drawing:

Reduction in c.s. area

Die angle

Friction along the die - w/p interfaces

Drawing speed

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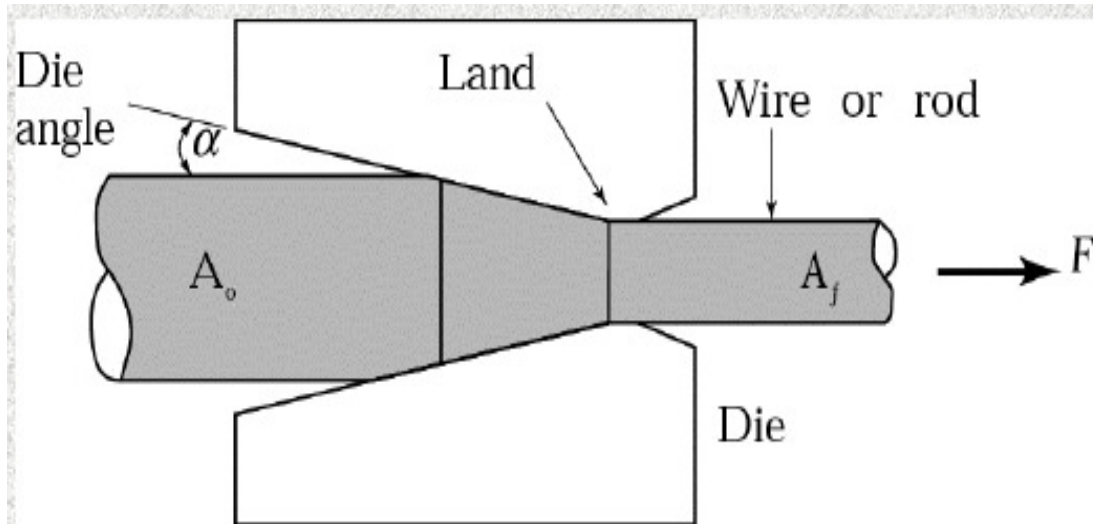


Figure 15.18 Process variables in wire drawing. The die angle, the reduction in cross-sectional area per pass, the speed of drawing, the temperature, and the lubrication all affect the drawing force, F .

Die angle influences the drawing force and the quality of the drawn product
As more work has to be done to overcome friction, force increases with increasing friction

As reduction increases, the drawing force increases

Magnitude of the force is to be limited (when the tensile stress due to drawing force reaches the yield stress of the metal, the w/p will simply yield and eventually break)

Max.reduction in c.s. area per pass is 63% (ie) 10 mm dia rod can be reduced to a dia of 6.1 mm in one pass without failure.

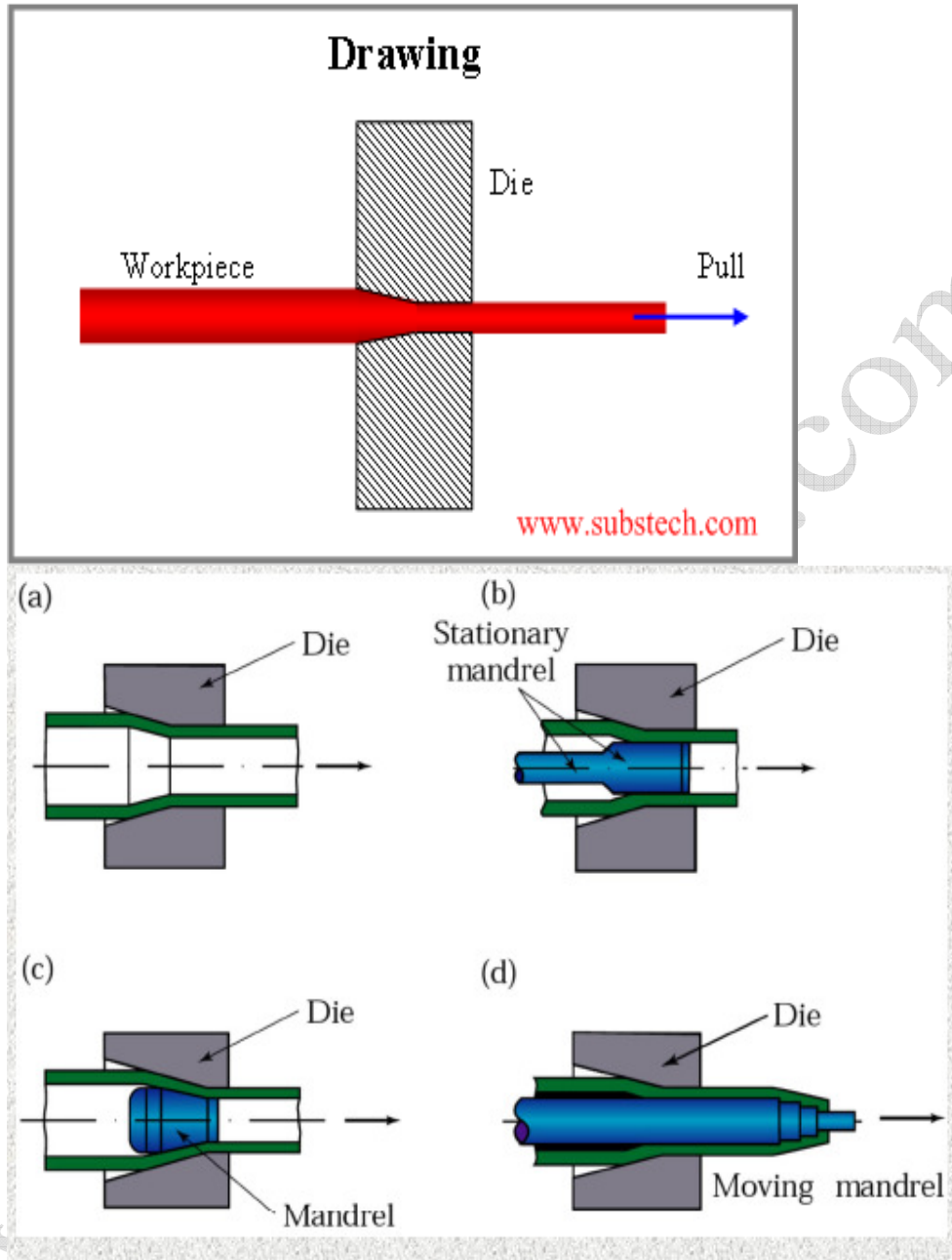
Various solid c.s. can be produced by drawing thru. dies with different profiles

Tubes as large as 300 mm in dia can be drawn

Drawing speeds depend on the material and on the reduction in c.s. area.

Range from 1 m/s to 2.5 m/s for heavy sections and upto 50 m/s for very fine wire

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Die Materials

Usually tool steels and carbides : diamond dies are used for fine wire

For improved wear resistance, steel dies may be chromium plated and carbide dies may be coated with titanium nitride.

Mandrels for tube drawing are made of hardened tool steels / carbides.

Diamond dies are used for drawing fine wire with dia ranging from 2 μ m to 1.5 mm.

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May be made of single crystal diamond / polycrystalline form with diamond particles in a metal matrix.

Due to lack of tensile strength and toughness, carbide and diamond dies are used as inserts, supported in a steel casing

For hot drawing, cast steel dies are used due to their high resistance to wear at elevated temp.

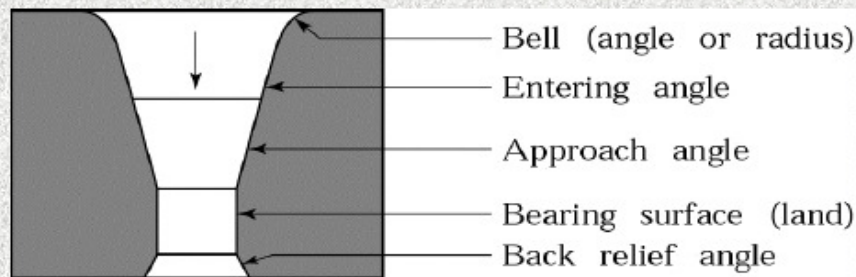
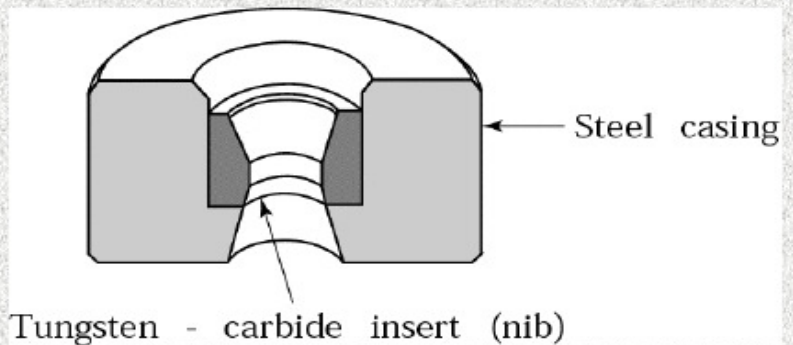


Figure 15.20 Terminology of a typical die used for drawing round rod or wire.

Figure 15.21 Tungsten- carbide die insert in a steel casing. Diamond dies, used in drawing thin wire, are encased in a similar manner.



Lubrication:

Proper lubrication is essential in order to

- improve die life
- reduce drawing forces
- reduce temp.
- improve surface finish

Basic types:

Wet drawing: The dies and the rod are completely immersed in the lubricant (oils & emulsions containing fatty or chlorinated additives)

Dry drawing: Surface of the rod to be drawn is coated with a lubricant (soap) by passing it through a box filled with the lubricant.

Coating: Rod is coated with a soft metal, which acts as a solid lubricant. Copper / Tin can be chemically deposited on the surface of the metal.