PIE Tech

POLLACHI INSTITUTE OF ENGINEERING AND TECHNOLOGY

(Approved by **AICTE** and Affiliated to **Anna University**)

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Department of Mechanical Engineering

Regulation 2021

II Year – III Semester

ME3393- MANUFACTURING PROCESSES All Units

ME3393	MANUFACTURING PROCESSES	L	T	P	C
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COURSE OBJECTIVES:

1. To illustrate the working principles of various metal casting processes.
2. To learn and apply the working principles of various metal joining processes.
3. To analyse the working principles of bulk deformation of metals.
4. To learn the working principles of sheet metal forming process.
5. To study and practice the working principles of plastics molding.

UNIT – I METAL CASTING PROCESSES **9**

Sand Casting – Sand Mould – Type of patterns - Pattern Materials – Pattern allowances – Molding sand Properties and testing – Cores –Types and applications – Molding machines – Types and applications– Melting furnaces – Principle of special casting processes- Shell, investment – Ceramic mould – Pressure die casting – low pressure, gravity- Tilt pouring, high pressure die casting- Centrifugal Casting – CO_2 casting –- Defects in Sand casting process-remedies

UNIT II METAL JOINING PROCESSES **9**

Fusion welding processes – Oxy fuel welding – Filler and Flux materials-–Arc welding, Electrodes, Coating and specifications – Gas Tungsten arc welding –Gas metal arc welding - Submerged arc welding – Electro slag welding– Plasma arc welding — Resistance welding Processes -Electron beam welding –Laser beam Welding Friction welding – Friction stir welding – Diffusion welding – Thermit Welding, Weld defects – inspection &remedies – Brazing - soldering – Adhesive bonding.

UNIT III BULK DEFORMATION PROCESSES **9**

Hot working and cold working of metals – Forging processes – Open, impression and closed die forging – cold forging- Characteristics of the processes – Typical forging operations – rolling of metals – Types of Rolling – Flat strip rolling – shape rolling operations – Defects in rolled parts – Principle of rod and wire drawing – Tube drawing – Principles of Extrusion – Types – Hot and Cold extrusion. Introduction to shaping operations.

UNIT IV SHEET METAL PROCESSES **9**

Sheet metal characteristics – Typical shearing, bending and drawing operations – Stretch forming operations – Formability of sheet metal – Test methods –special forming processes - Working principle and applications – Hydro forming – Rubber pad forming – Metal spinning – Introduction of Explosive forming, magnetic pulse forming, peen forming, Super plastic forming – Micro forming – Incremental forming.

UNIT V MANUFACTURE OF PLASTIC COMPONENTS **9**

Types and characteristics of plastics – Molding of thermoplastics & Thermosetting polymers– working principles and typical applications – injection molding – Plunger and screw machines – Compression molding, Transfer Molding – Typical industrial applications – introduction to blow molding – Rotational molding – Film blowing – Extrusion – Thermoforming – Bonding of Thermoplastics- duff moulding.

TOTAL :45 PERIODS

OUTCOMES:

At the end of the course the students would be able to

1. Explain the principle of different metal casting processes.
2. Describe the various metal joining processes.
3. Illustrate the different bulk deformation processes.
4. Apply the various sheet metal forming process.
5. Apply suitable molding technique for manufacturing of plastics components.

TEXT BOOKS:

1. Kalpakjian. S, “Manufacturing Engineering and Technology”, Pearson Education India,4th Edition, 2013
2. P.N.Rao Manufacturing Technology Volume 1 Mc Grawhill Education 5th edition,2018.

REFERENCES:

1. Roy. A. Lindberg, Processes and materials of manufacture, PHI / Pearson education, 2006.
2. S. Gowri P. Hariharan, A.Suresh Babu, Manufacturing Technology I, Pearson Education, 2008.
3. Paul Degarma E, Black J.T and Ronald A. Kosher, Eligth Edition, Materials and Processes, in Manufacturing, Eight Edition, Prentice – Hall of India, 1997.
4. Hajra Chouldhary S.K and Hajra Choudhury. AK., Elements of workshop Technology, volume I and II, Media promoters and Publishers Private Limited, Mumbai, 1997
5. Sharma, P.C., A Text book of production Technology, S.Chand and Co. Ltd., 2004

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Low (1) ; Medium (2) ; High (3)															

UNIT - I

METAL CASTING PROCESS.

Casting:

It is the process of producing metal or alloy components parts

Steps for casting:

- Pattern making
- Sand mixing
- Core making
- Melting
- Pouring
- Finishing
- Testing
- Heat treatment
- Re-testing

Advantages:

- Freedom of design
- uniform directional properties
- better damping capacity
- No need of metal joining process
- difficult parts easily manufactured

Application:

- Transportation vehicles
- Machine tool structures
- Turbine vanes and power generators
- Mill throwing
- Pump filter and valve
- Aircraft engine blades
- Agricultural parts
- Atomic energy applications.

Pattern making:

Pattern materials:

- Wood
- Metal
- plastic
- plaster
- wax

Pattern Allowances:

- Shrinkage or Contraction allowances
- Machining allowances
- Draft or taper allowances
- Distortion allowances
- Rapping or Shake allowance.

Tyxes of Pattems:

The type of patten to be used for a particular casting will depend on following factors

- Quantity of casting to be produced
- Type of moulding method
- size and shape of the casting
- design of casting

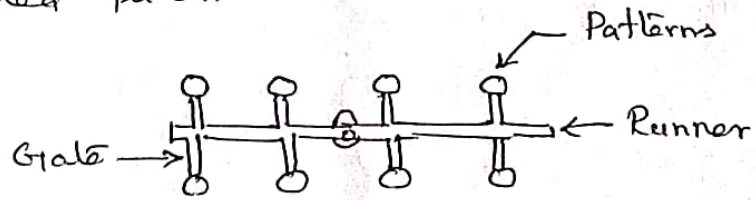
1. Single piece (or) solid pattern:

2. Two piece (or) split pattern

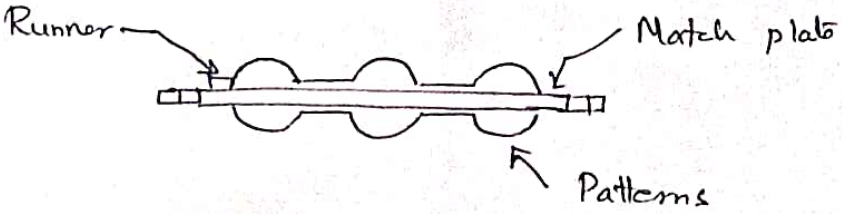
3. Loose piece pattern

4. Cope and drag pattern

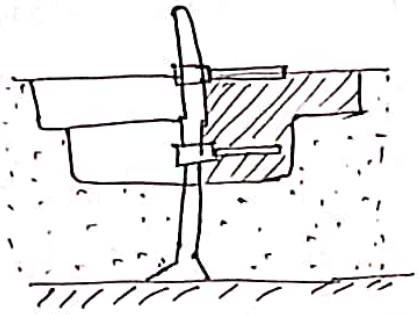
5. Gated patten



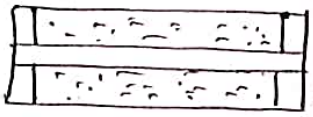
6. Match plate pattern:

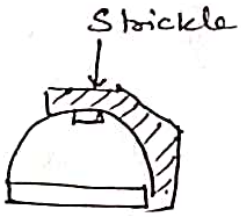


Sweep pattern:

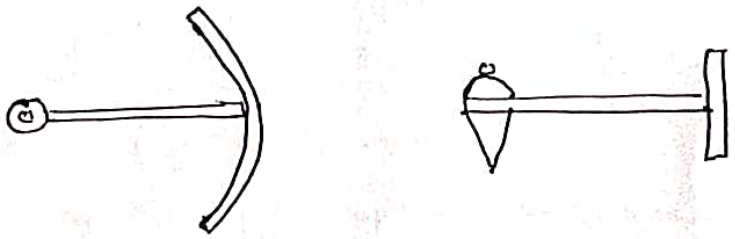


Skeleton pattern:

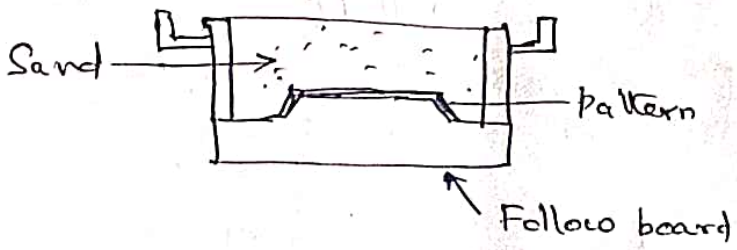




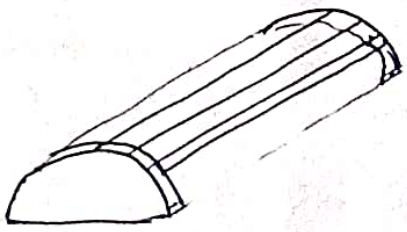
Segmental pattern:



Follow board pattern



Lagged up-pattern



Pattern colours:

- Red - Cast surfaces to be machined
- Black - Surface to be left unmachined
- Yellow - Core print seats
- Red strips on yellow base - Loose piece
- No colour - Parting surface
- Black strips - Supports or stop offs
  Yellow base
- Yellow strips on black - Core prints.

Mold Materials:

Selection of materials:

- Cost of the materials
- Quality of casting required
- Number of casting required
- Shape and size of the casting
- Accuracy of the casting
- Material to be cast

Moulding Sand:

Types of moulding Sand:

- Natural sand
- Synthetic sand
- Special sand

Special sand:

- Green Sand
- Loam sand
- core Sand
- Parting Sand
- Facing Sand
- Backing Sand

Characteristics of moulding Sand:

- Flowability or plasticity
- Green strength
- Dry Strength
- Permeability or porosity
- Refractoriness
- Adhesiveness
- Cohesives
- Thermal Stability
- Collapsibility

Constituents of moulding Sand:

- Sand
- Binder
- Additives
- Water

Binder

- Organic binders
  - linseed oil
  - Dextrin
  - Molasses
  - Pitch
- Inorganic binders
  - Sodium Silicate
  - portland cement
- clay binder
  - Bentonite
  - Fire clay
  - Limonite
  - Ball clay
  - kaolonite

Additives:

- Coal dust
- Sea coal
- Cornflour or cereals
- Silica flour
- Wood flour
- Pitch
- Fuel oil
- Dextrin and molashes.

Sand preparation and conditioning:

- Mixing of sand ingredients such as sand, binder, moisture and other additives.

Sand tempering: process by which adequate amount of moisture is added to the moulding sand to make it workable

Sand conditioning: consists of preparing of the moulding sand, so that it becomes suitable for moulding purposes.

Sand Preparation:

- to develop optimum properties in the moulding sand
- To obtain even distribution of sand grains throughout the bond
- To add suitable amount of water to activate clay binder
- To deliver sand at the suitable temperature
- To remove impurities from the moulding sand.

Sand Testing:

- Moisture content test
- Clay content test
- Permeability test
- Grain fineness test
- Mould hardness test
- Refractoriness test
- Compression Strength test

Core:

Core is a sand shape or form which makes the contour of a casting for which no provision has been made in the pattern for moulding.

Functions of core:

- Forming the main internal cavity for hollow casting
- External undercut feature
- deep recesses in the casting
- Increase the Strength of the mould
- Part of gating assembly
- Green sand mould and can also be used to improve the mould surface.

Core Sand and its Ingredients:

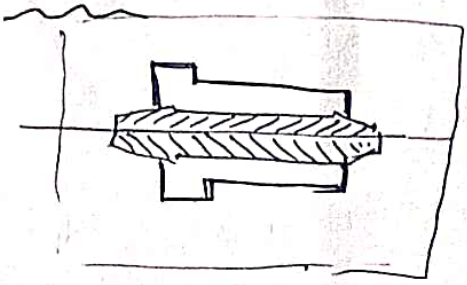
- Granular refractories
  - Dry silica sand
  - Carbon
  - Zircon
  - Olivin
  - Chamotte
- Core binders
  - Hold sand grains together
  - Give strength to cores
  - Make the cores erosion resistant
  - Impart adequate collapsibility to cores.
- Additives:

Core making:

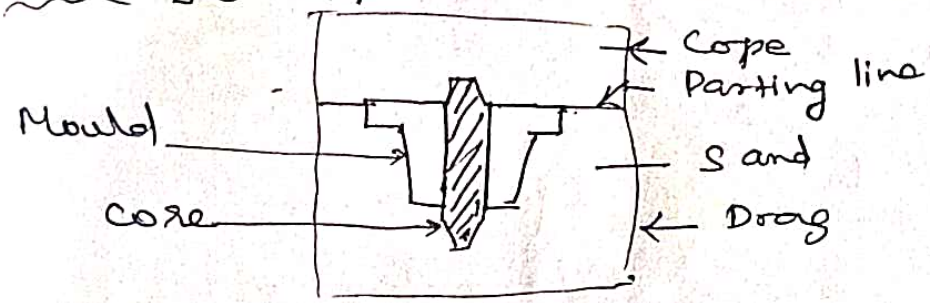
- core sand preparation
- Core making
- Core baking
- Core finishing or dressing
- Setting the cores.

Types of cores:

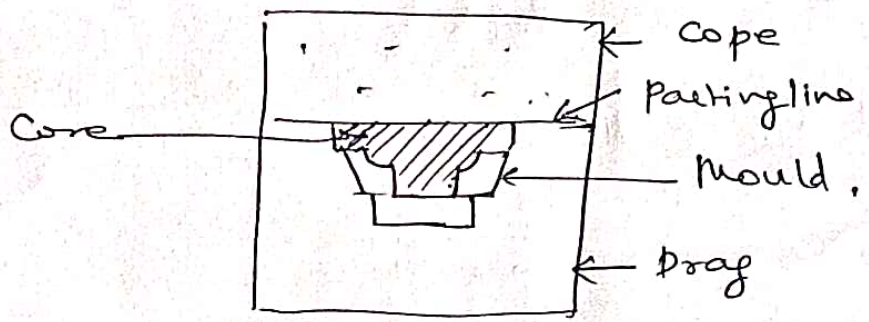
Horizontal core:



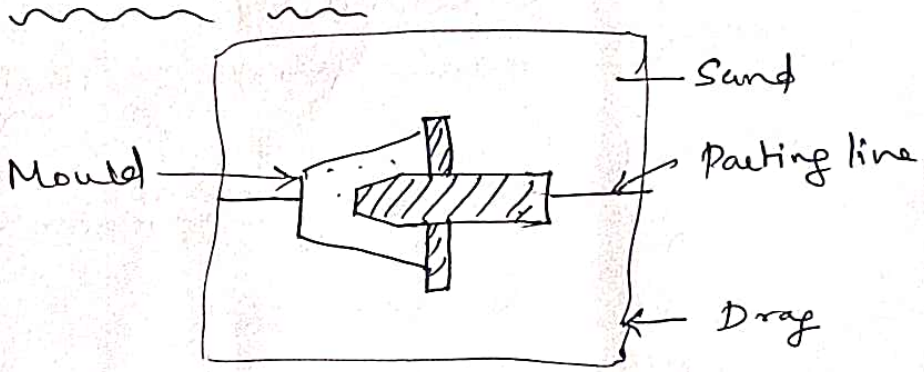
Vertical core:



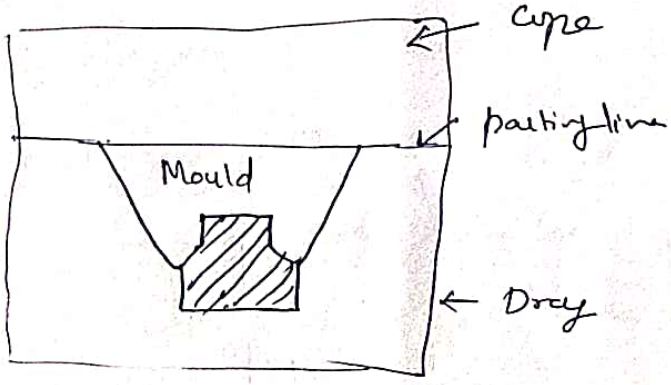
Hanging core:



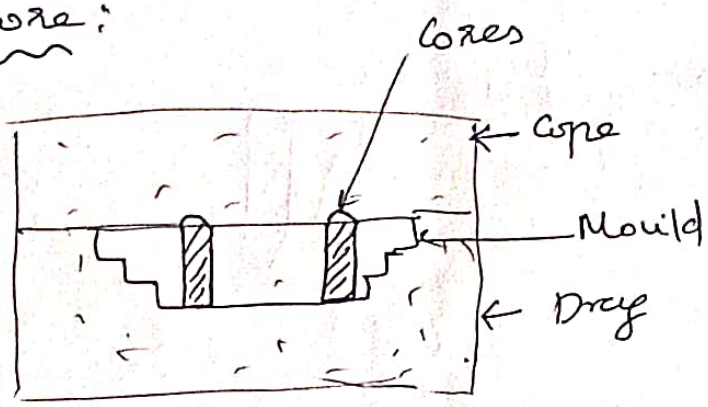
Balanced core:



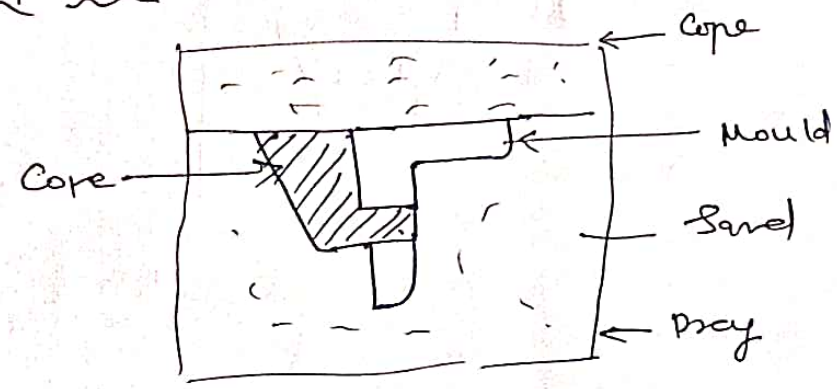
Ram-up core:



Kiss core:



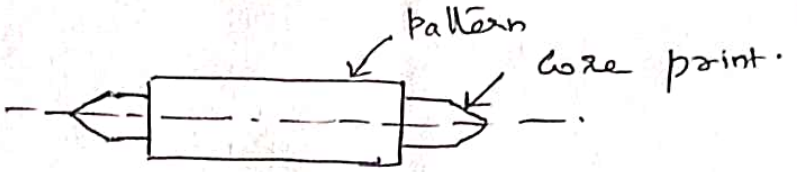
Drop core:



Core boxes:

- Half core box
- Dump core box
- Split core box
- Strickle core box
- Gang core box
- Loose piece core box
- Left and right core boxes.

Core Prints :



Extra projections provided on the pattern

Core prints ~~are~~ types

- Horizontal core prints
- Vertical core print
- Balanced core print
- Cover core prints
- Wing core print

chaplets :

- Radiator chaplets
- Stem chaplets
- Cast chaplets
- Sheet metal chaplets
- Double head chaplets.

Moulding Process:

- As per the method used
  - Floor moulding
  - Bench moulding
  - Pit moulding
  - Machine moulding.
- As per the moulding materials:
  (i) Sand moulding,
  - Green sand moulding
  - Dry sand moulding
  - Loam moulding
  - Shell moulding
  - Cement bonded sand moulding
  - Core sand moulding
  - Skin dried sand moulding
  - Carbon-dioxide moulding.

  (ii) Metallic moulding:
  - Floor moulding
  - Bench moulding
  - Pit moulding

UNIT - II

METAL JOINING PROCESS:

- Welding
- Soldering
- Brazing
- Adhesive bonding.

Welding:

Classification:

- Pressure welding
- Non pressure welding.

Gas Welding:

- Oxy-acetylene welding
- Oxy hydrogen welding
- Air acetylene welding
- Pressure gas welding.

Arc Welding:

- Carbon arc welding
- Flux cored arc welding
- Gas tungsten arc welding (TIG)
- Gas metal arc welding (MIG)
- Plasma arc welding
- Electro-slag welding
- Stud arc welding
- Shielded metal arc welding
- Submerged arc welding.

Resistance welding:

- Spot welding
- Seam welding
- Projection welding
- Percussion welding
- Flash butt welding
- Resistance butt welding

Solid State Welding:

- Cold welding
- Friction welding
- Ultrasonic welding
- Diffusion welding
- Explosive welding
- Roll welding
- Forge welding
- Hot pressure welding

Thermo-chemical welding process:

- Thermo welding
- Atomic hydrogen welding.

Radiant energy Welding process:

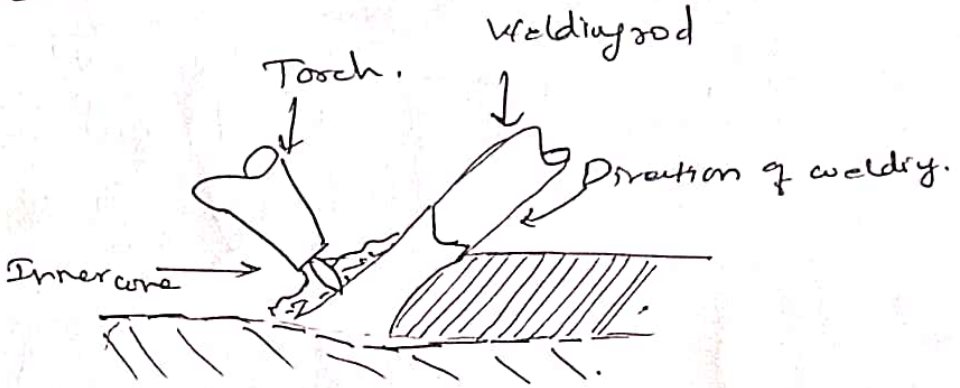
- Electron Beam welding
- Laser Beam welding.

Applications of Welding :

1. Aircraft construction
   - Welding of engine parts
   - Turbine frames for jet engine
   - Ducts, fittings etc
2. Automobile construction
   - Arc welding alloy wheels
   - Rear axle housing
   - Automobile frame
3. Buildings
   - Column base plates, trusses etc
   - Erection of structures.
4. Pressure vessels and tanks
   - Shell construction
   - joining of nozzle to the shell
   - Oil, gas and water
5. Rail road equipment
   - Front and rear hoods
   - Air receiver and engine
6. Pipe and pipelines
   - Open pipe joints
   - oil and gas pipe lines.
7. Ships
   - Steel frame
8. Trucks, trailers, etc
9. Machine tool frames, cutting tools etc
10. Fabrication of jigs, fixtures, clamps etc.

Gas welding Process:

Oxy-acetylene welding:



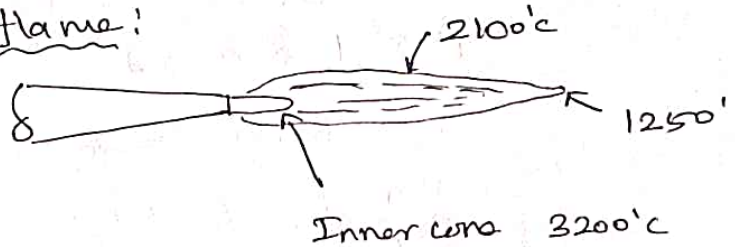
Stage 1:

$$2C_2H_2 + 2O_2 \rightarrow 4CO + 2H_2$$

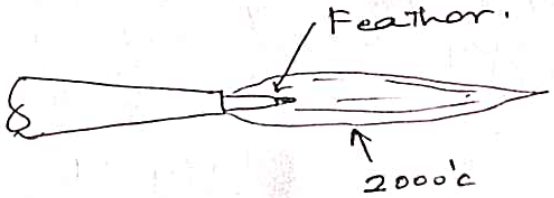
Stage 2:

$$2CO + 2H_2 + 3O_2 \rightarrow 4CO_2 + 2H_2O$$

Neutral flame:



Oxidising flame:



Reducing flame:

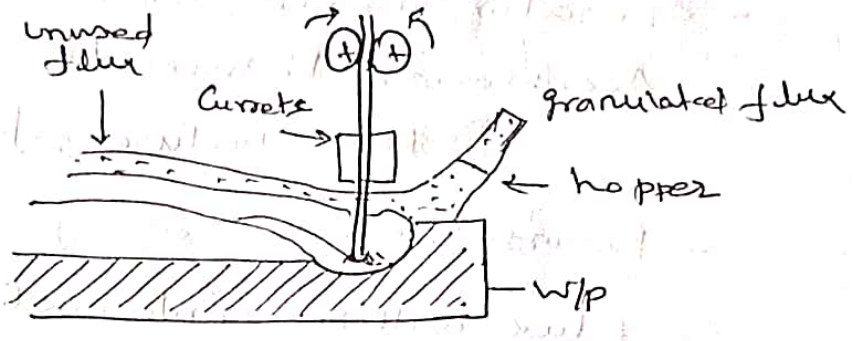
Gas welding Techniques:

- Leftward or fore hand welding method
- Rightward or back hand welding method
- Vertical welding method

Gas Welding Equipments:

1. Oxygen gas cylinder
2. Acetylene gas cylinder
3. Oxygen and acetylene for regulators,
4. Oxygen and acetylene gas hoses
5. Welding torch
6. Gas welding filler rods
7. Goggles and gloves
8. Spark lighter.

Sub merged arc welding :



- Produced electric arc, heating
- hidden arc
- fed bare metal electrode
- Flux covered electrode,
- granular flux
- process is semi automatic
- Flux made up of Silica, metal oxide

Advantages :

- higher welding speed is used
- weld distortion very less
- without spark, smoke, flash.
- Smooth weld shapes can be obtained
- materials under 12mm thick welded.

GAS

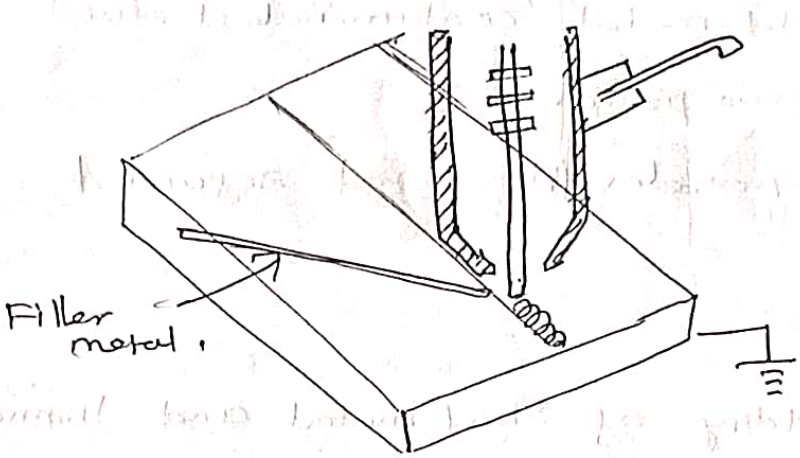
Disadvantages:

- Operator can not see
- Accessories Required
  - Jigs, Fixtures, focussing device.
- Process requires edge preparation
- Flux will be contaminated
- cast Iron, Al alloys, Mg alloys, Pb can not be welded.

Applications:

- Fabications of
  - pipes, penstocles.
  - Pressure vessels, boilers
  - Railroad and earth moving equipments
  - Ship building
  - cranes
  - Nuclear power Industry.

Gas Tungsten Arc Welding:



- Also called as TIG Welding
- heating the work piece with ~~electrode~~ electric arc.
- To avoid atomic contamination - shielding gas used
- Filler metal may be added.
- Electrode reaches 2 to 3 mm from w/p

Advantages:

- No flux is used.
- Better control of operator
- produce smooth and sound welds
- No welding cleaning required
- high Quality welds in non ferrous metals.

Electro

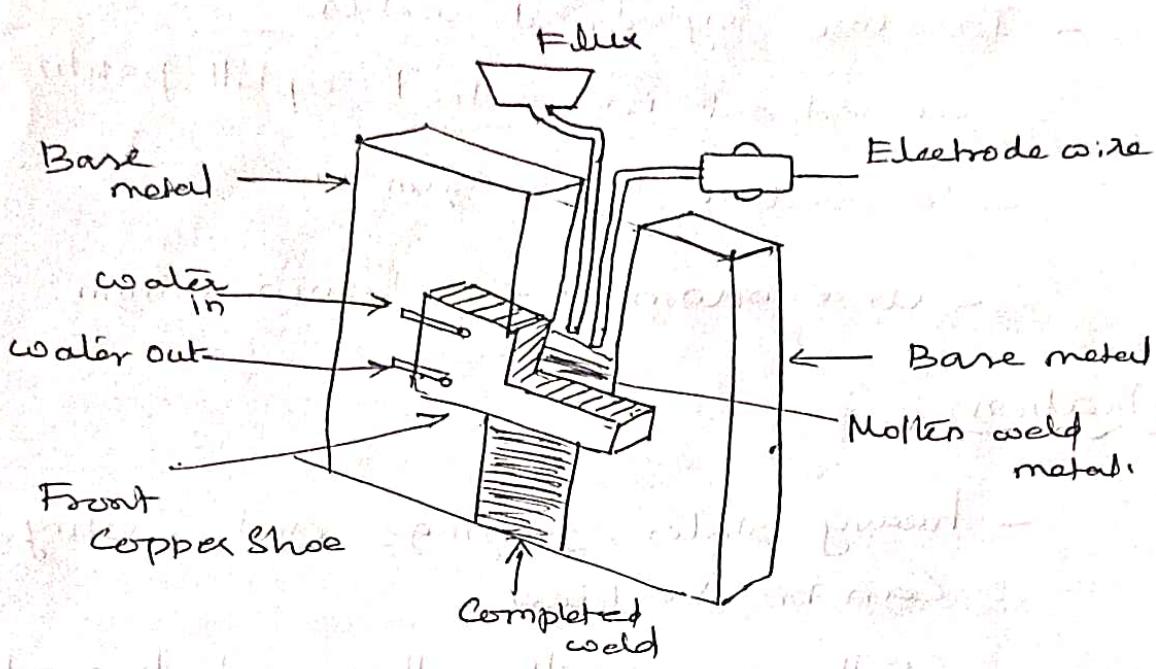
Disadvantages:

- Cost of Equipment very high
- Weld metal contamination due to gas
- Slow process
- Separate filler rod required

Applications:

- Welding of Sheet metal and thinner sections
- Precision welding in aircraft
- Welding of
  - expansion bellows
  - Instrumental diaphragms
  - Transistor cases
- Welding of Al, Mg, Cu, Ni

Electro Slag Welding:



- Coalescence is produced by molten slag
- melts filler materials
- Filler metal / electrode
- This Arc heats flux and melts - it to produce slag
- The temparature 1700°C to 1900°C
- Progressive process of melting and Solidification from the bottom upward

Advantages:

- Provides high deposition rates
- Residual Stresses are low
- Flux consumption is very low
- No are exits
- upto 450mm to be welded.

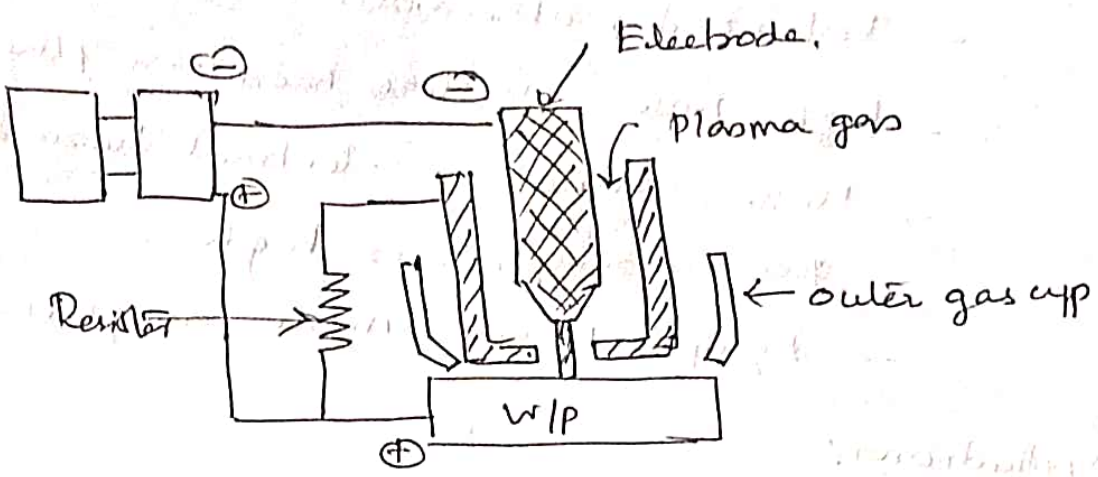
Dis advantages:

- To close cylindrical welds
- carried out in vertical uphill positn
- To produce larger grain size.
- Un economical for below 6mm.

Applications:

- heavy plates, forgings and casting can be welded
- Following are the alloys which can be welded
  - Low carbon and medium carbon steels
  - high Strength alloy steels
  - High Strength Structural Steels.

Plasma Arc Welding:



- heat produced by tungsten electrode
- Two inert gases
- No pr required.
- Plasma jet energy depends on electrical power.
- Temparature 50,000 F
- Types
  - Transferred arc procss
  - Non transfered arc procss.

Advantages:

- It employs constricted arc
- uses two plasma gases.
- Working time less
- higher arc travel speeds
- good weld quality

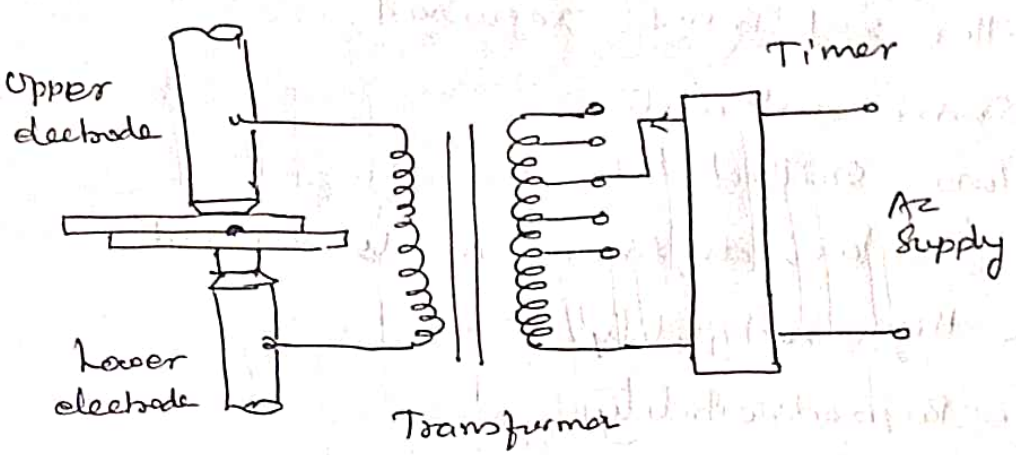
Disadvantages:

- Infrared, ultraviolet radiations required
- high noise, welders need ear plug
- More chances of electrical hazards
- gas consumption is high
- Equipments are more complicated.

Applications:

- used in tube weld applications
- Rocket motor cases
- Welding of carbon Steel, Stainless Steel, Ni, Cu, Al, Ti, brass etc
- Plasma torch can employed for spraying.

Resistance welding:



- heat obtained from resistance
- Amount of current passing through the w/p
- The pressure that electrode transfer to the work piece
- Time during which current flows
- Area of electrode
- current (3000, to 1,00,000 Amp)
- Volt 1 to 25 volt

$H \propto I^2Rt$

- Resistance welding - Two copper electrodes
- highest temperature at joint

Advantages:

- Rate of production is fast
- Filler rod is not required
- Semi automatic
- less skilled labourers
- similar, dissimilar metals welded
- High reliability
- Reproducibility

Dis advantages:

- Initial cost will be high
- Skilled persons required for maintenance
- Special surface preparation required
- thicker thickness can not be welded

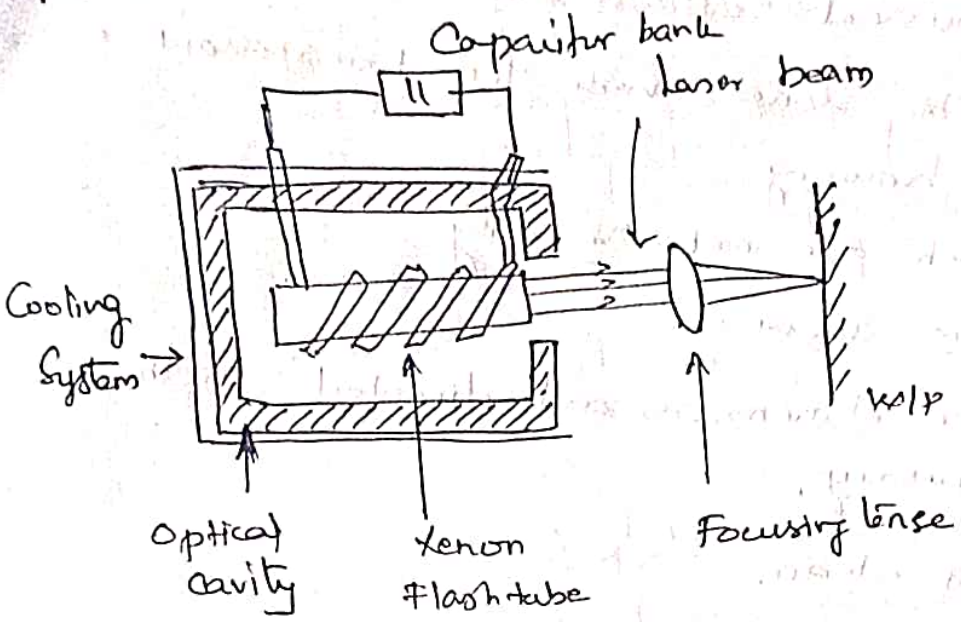
Applications:

- Joining of sheets, bars, rods and tubes
- Making of tubes and furniture
- Welding of aircraft and automobile parts
- Making of cutting tools, fuel tanks of cars, tractors etc.

Types of Resistance Welding:

- Spot welding
- Seam welding
- Projection Welding
- Percussion welding
- Flash butt welding
- Resistance butt welding
- High Frequency resistance welding.

Laser beam welding:



- heat obtained from laser beam
- waves identical and parallel
- Narrow light wave.
- Energy on small area for producing fusion welding pools
- using xenon flash lamp
- laser rod, laser tube consist of pair of mirrors
- Setup consist of flash tube/lamp, laser, power source, focusing source
- the light focuses the light beam
- beam melts the work mtl and due to this it vaporises.

- As electrode is no used, electrode contamination
  or high current effects are eliminated
- Welding can be done inside the transparent glass
  or plastic housing
- Areas which are not readily
- No vacuum required
- Microscopic dimensions and directed with
  high accuracy.
- Welding is clean.

Disadvantages:

- LBW is applicable only for thin sections
- control of hole size is difficult
- safety precautions and procedures are to
  be followed
- Durability and reliability of system is limited
- limited life flash lamp
- Initial cost of system is high
- low production rate
- highly skilled operator are required.

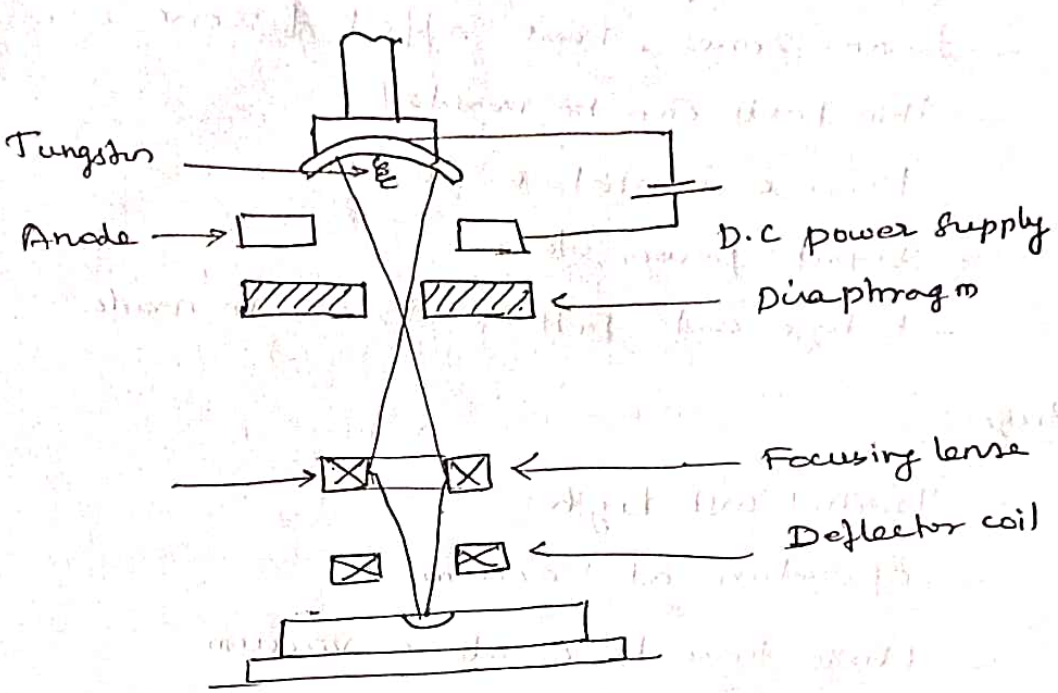
Applications:

- join hard high melting points
- both welding and cutting of metals
- Micro welding purpose
- laser can weld dissimilar metals also

Welding defects:

- Cracks
- Distortion
- Inclusions
- Porosity and blow holes
- Undercutting
- overlapping
- Spatter
- Poor fusion
- Poor weld bead appearance.
- Incomplete penetration.

Electron Beam Welding:



- EBW is a fusion welding process
- produced by the heat obtained from a concentrated beam
- high velocity electron produced
- Kinetic energy changes to thermal Energy
- Electron beam created by vacuum
- No need of electrode, gases, filler metals
- Focus - 0.25 to 1mm
- Energy density 0.5 to 10 KW/mm^2
- Temperature - 2500°c
- pressure of 10 mm of Hg
- Workpiece moved by Numerical control

Advantages:

- high quality welds produced
- fusion zone, heat affected zone are narrow
- thin parts can be welded
- Precise control is possible
- Input power less
- Edge and butt welds can be made

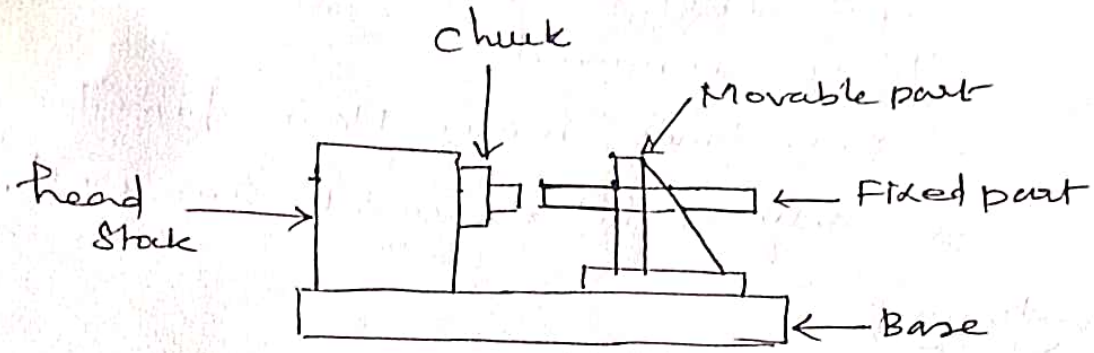
Disadvantages:

- Initial cost high
- operation at vacuum
- More time to create a vacuum
- To prevent damage from X-rays, precautions are needed
- Skilled operator required
- Work piece size limited.

Applications:

- For welding of automobiles, airplanes, farm and other type of equipments.
- Similar and dissimilar parts can be welded.

Friction Welding:



- produced by heat - obtained by mechanically induced sliding motion
- Work part under pressure
- Energy supplies conventional drive source.
- Welding component axially aligned
- one spindle rotates and the stationary
- Sufficient heat produced by friction.

Advantage:

- operating is simple
- Power required for the operation is low
- Welding time only few seconds
- lower cost
- No flux, No gas, No filler material
- No smoke, fumes.

Disadvantages:

- Only used for flat, angular butt welds
- If rubbing is welded, flash may have to be removed.
- Some times heavy Flash formed
- only similar metals can weld.

Applications:

- Joining Steels, Super alloys, non ferrous metals.
- production of Steering Shaft, worm gears, engine valves etc
- Production of drills, taps, reamers etc.
- Production of pump Shafts

Friction welding variables:

- Relative Speed
- Friction pressure
- Time for heating
- Forge pressure.

BULK DEFORMATION PROCESS:

Working of metal is a simply plastic-deformation performed to change the dimensions, properties and surface conditions with the help of mechanical pressures.

Recrystallisation:

The temperature is sufficiently high, the grain growth accelerated and continuous.

Recrystallisation temperature:

The process of formation of new grains at the temperature is the recrystallisation temperature of the metal.

Hot working:

Hot working accomplished at a temperature above the recrystalline temperature.

Hot working process:

- Hot rolling
- Hot extrusion
- Hot spining
- Roll piercing
- Hot drawing
- Hot forging.

Cold working :

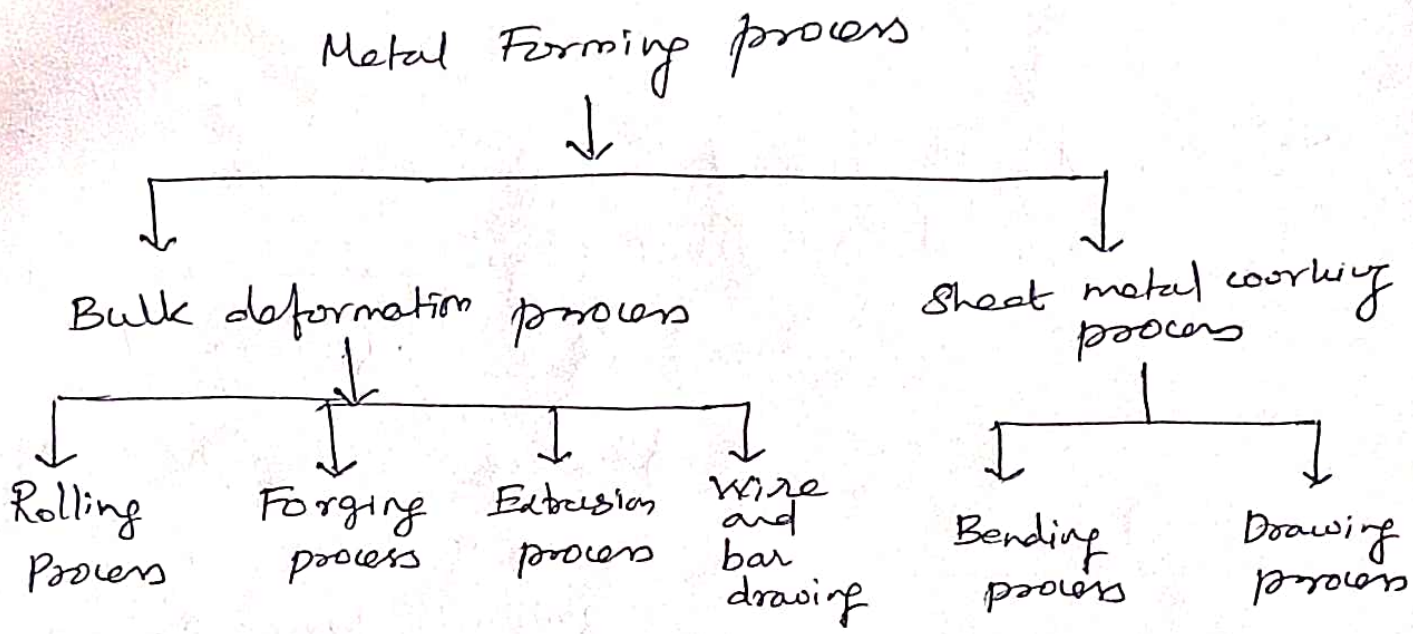
The working of metals at temperature belows their recrystallisation temp. is called cold working.

Methods of cold working

1. Cold rolling
2. Cold drawing
3. Cold Spining
4. Stretch forming
5. Cold forging
6. cold extrusion
7. coining
8. Embossing
9. cold bending
10. Roll forming
11. Shot peening
12. High Enery Rate Forming.

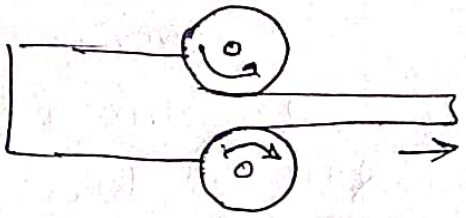
Warm working :

Refers to plastic deformation carried - out at intermediate temparature of hot and cold working.

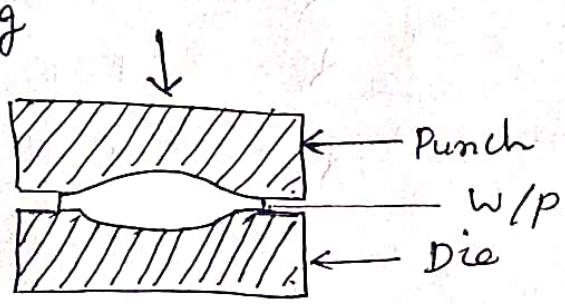


Bulk Deformation Process:

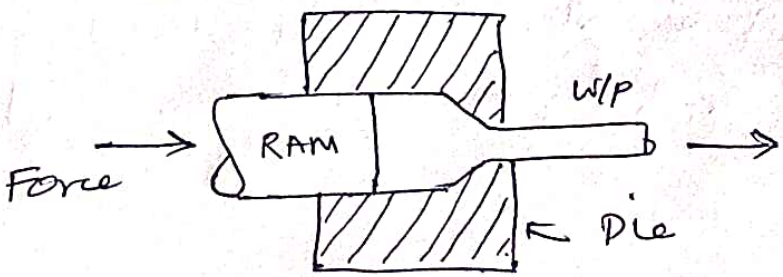
1. Rolling



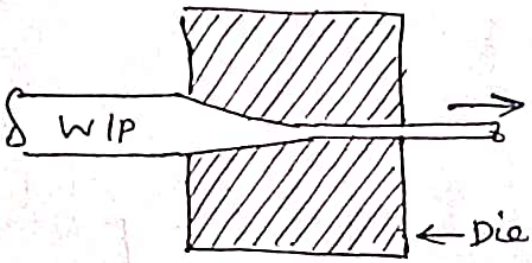
2. Forging



3. Extrusion:

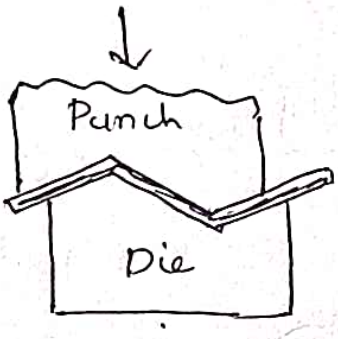


Drawing :

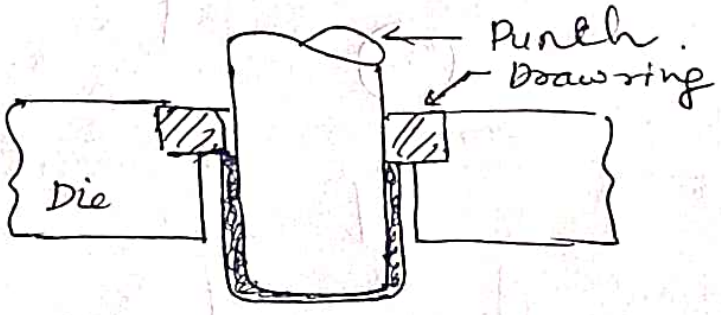


Sheet Metal Working process :

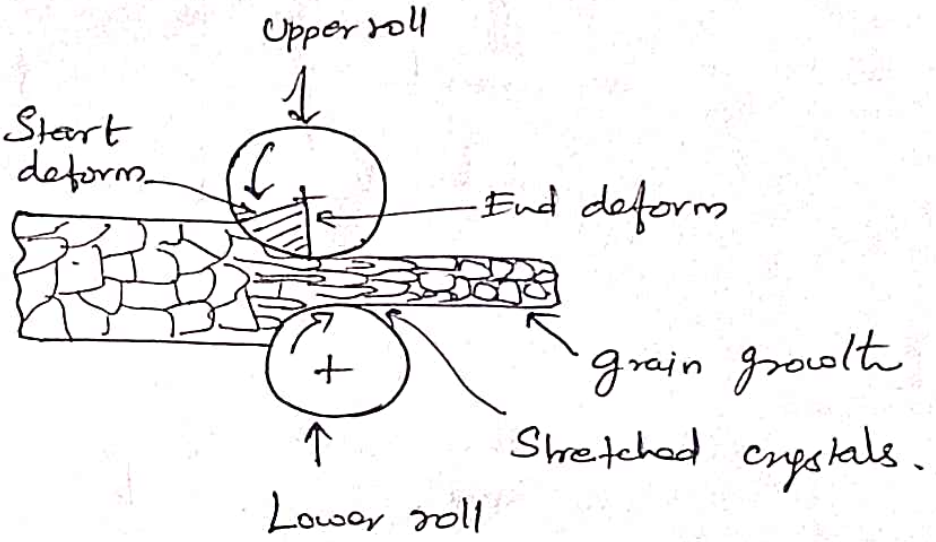
Bending :



Drawing :



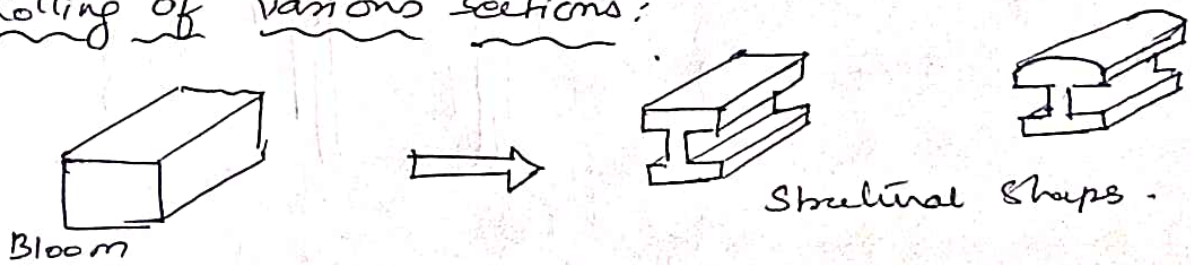
Hot Rolling Process:

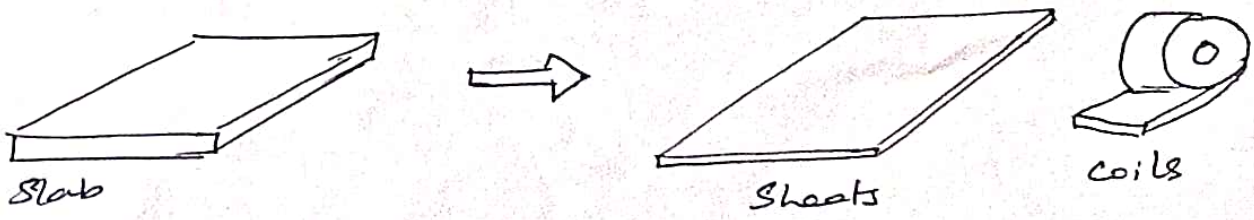


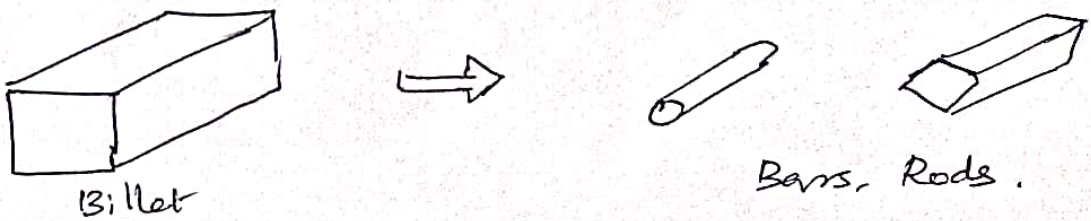
Basic processes:

1. Ingot
2. Bloom
3. Billets.
4. Slabs.

Rolling of various sections:

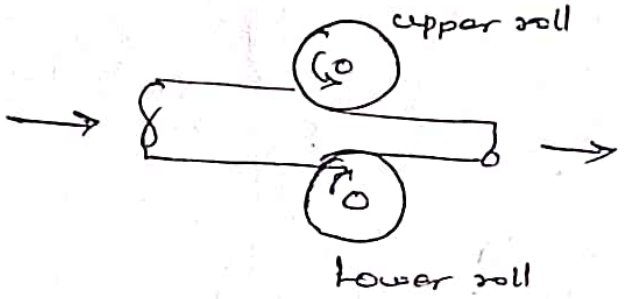




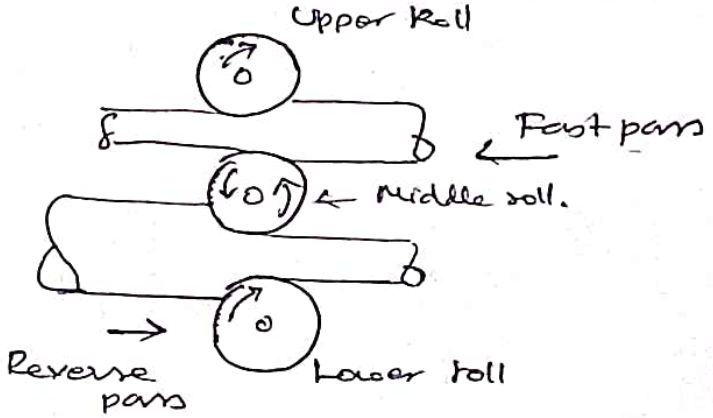


Types of Roll mill.

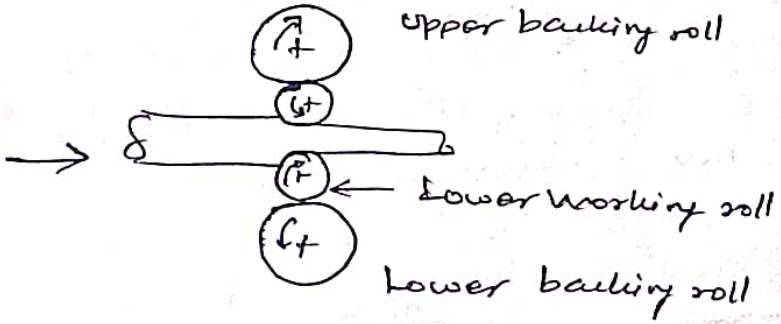
1. Two high rolling mill



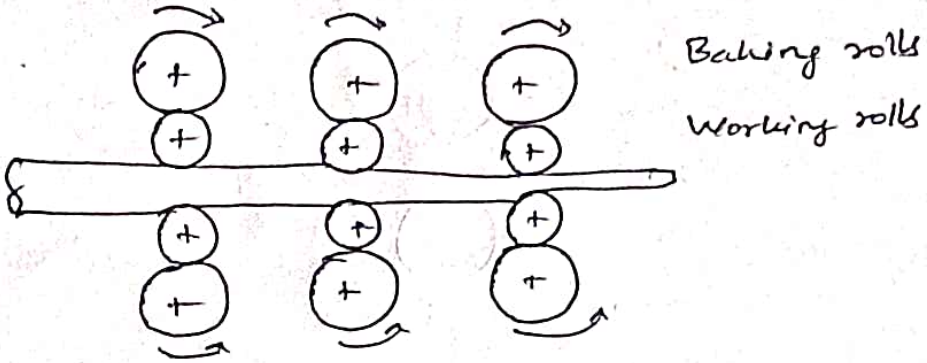
2. Three high rolling mill



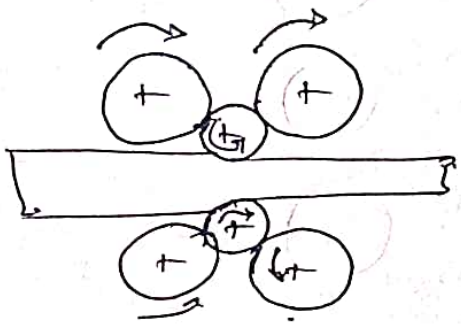
3. Four high rolling mill



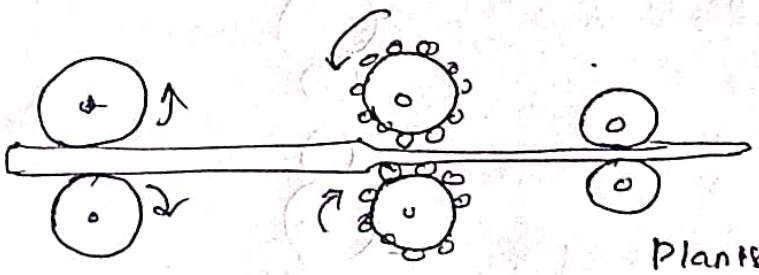
4. Tandem rolling mill



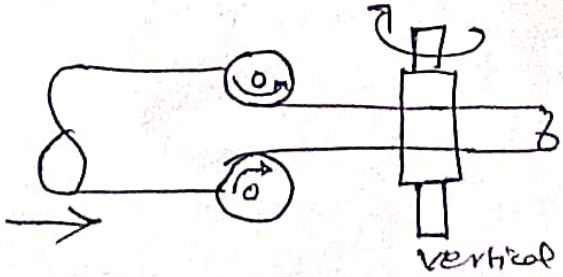
5. Cluster rolling mill



6. Planetary rolling mill



7. Universal roll mill



Forging :

It is the process of shaping heated metal by the applications of sudden blows or steady pressure and makes use of the characteristics of plasticity of the material.

According to the working temperature :

- hot forging
- cold forging

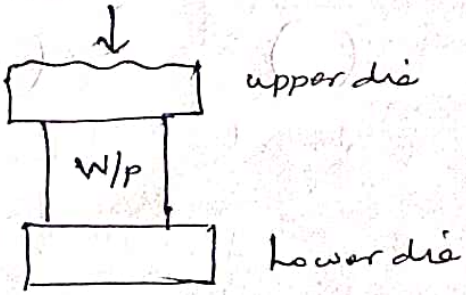
According to the method of applying force

- Impact forging
- Gradual pressure forgiy

According to the degree to which it flows of work piece

- open die forging
- closed - die or impression die

open die forging



- Fullering
- Eding
- Cogging

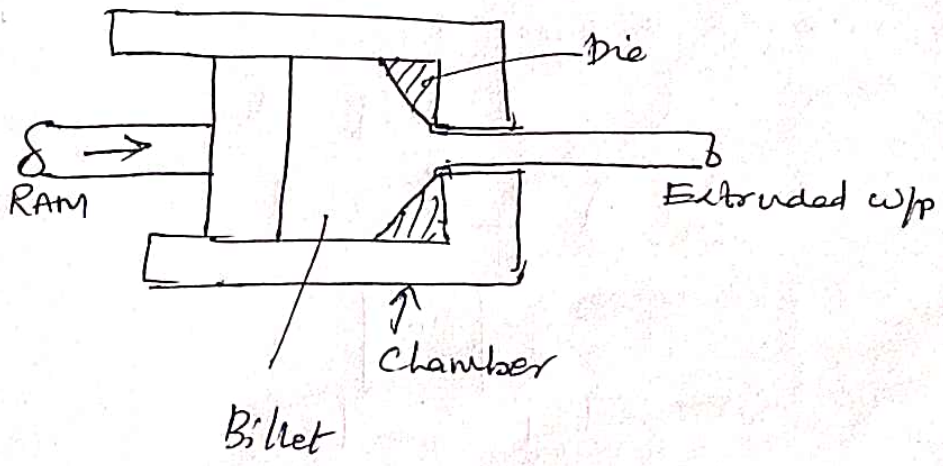
Extrusion:

Extruction is a compression process in which the coork metal is forced to flow through a small opening which is called as die to produce a required cross sectional shape.

classification;

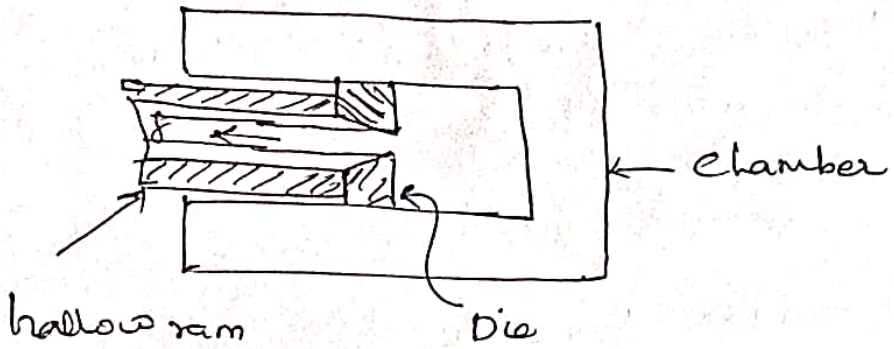
- According to physical configuration
  - Direct extruction
  - Indirect extrusion.
- According to working temparature
  - Hot extrusion
  - cold extrusion.

Direct Extrusion:



- extra portion butt

Indirect Extrusion:

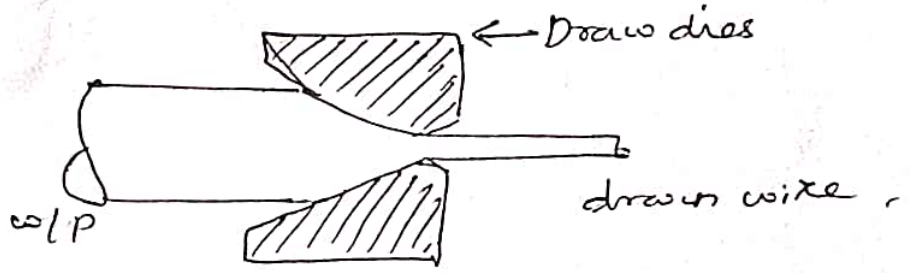


Defects in Rolled Parts:

- Surface defects
  - Scale, rust, cracks, scratches, gouges
- Internal structural defects
  - wavy edges, Zipper cracks, Edge cracks Alligatoring, Folds, Lamination.
- Defects due to homogeneous deformation
  - Cracks, Splitting of sheet
- Defects due to in homogeneous deformation
  - lateral deformation

Wire drawing :

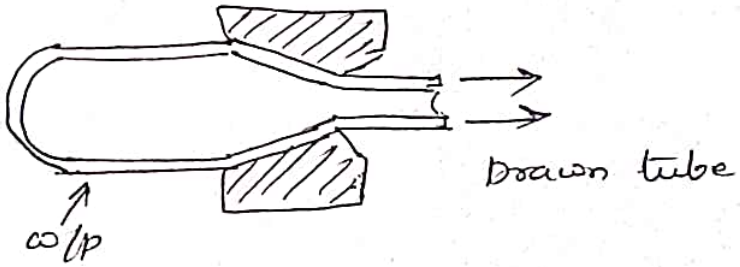
Drawing is an operation in which the cross section of a bar, rod or wire is reduced by pulling it through a die opening.



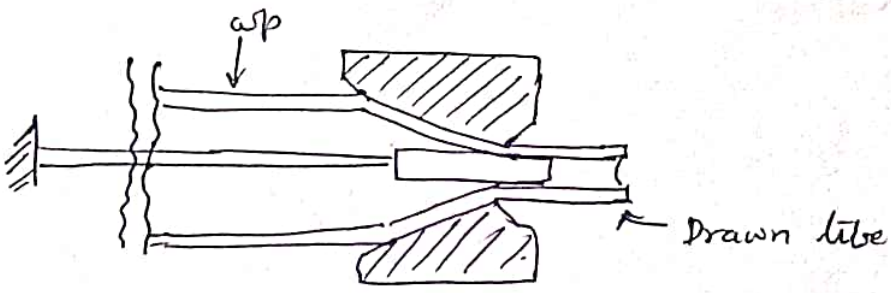
wire size - upto 0.03 mm

die material : Tungsten carbide.

Tube drawing :



(with out mandrel)



(with mandrel)

UNIT - IV SHEET METAL PROCESS

Micro Machining

Micro machining:

It is a basic technology for fabrication of micro components of size in the range of 1 to 500 microns.

Micro electronic Fabrication Process:

- Deposition of thin films
- Selective etching using masks
- Doping
- Photolithography
- oxidation
- Bonding
- Die bonding, wire bonding

Etching:

- Wet etching
- Isotropic etch } KOH, EDP, TMAH
- Anisotropic etch
- Electro chemical Etch (hydroxyl group)
- Lift-off patterning - Removal Technique.
- Dry Etch
- Plasma / Reactive Ion Etch (Radio frequency power)
- Deep Reactive Ion Etch (upto 1mm)
- Vapor phase dry Etch (XeF_2)

Thin Film Deposition:

- PVD - Physical vapor deposition
- Sputtering
- CVD - Chemical Vapor deposition
- LPCVD - low pressure CVD
- Epitaxy
- VPE (Vapor phase epitaxy)
- Electroplating
- Electroless plating
- Spin Casting

Bonding:

- Anodic bonding
- Silicon fusion bonding
- Adhesive bonding
- Eutectic bonding

Material removal methods:

- Real micro machining
- Micro EDM
- Abrasive cutting.
- laser machining
- FIB milling (Focused Ion Beam)

Local material additive process:

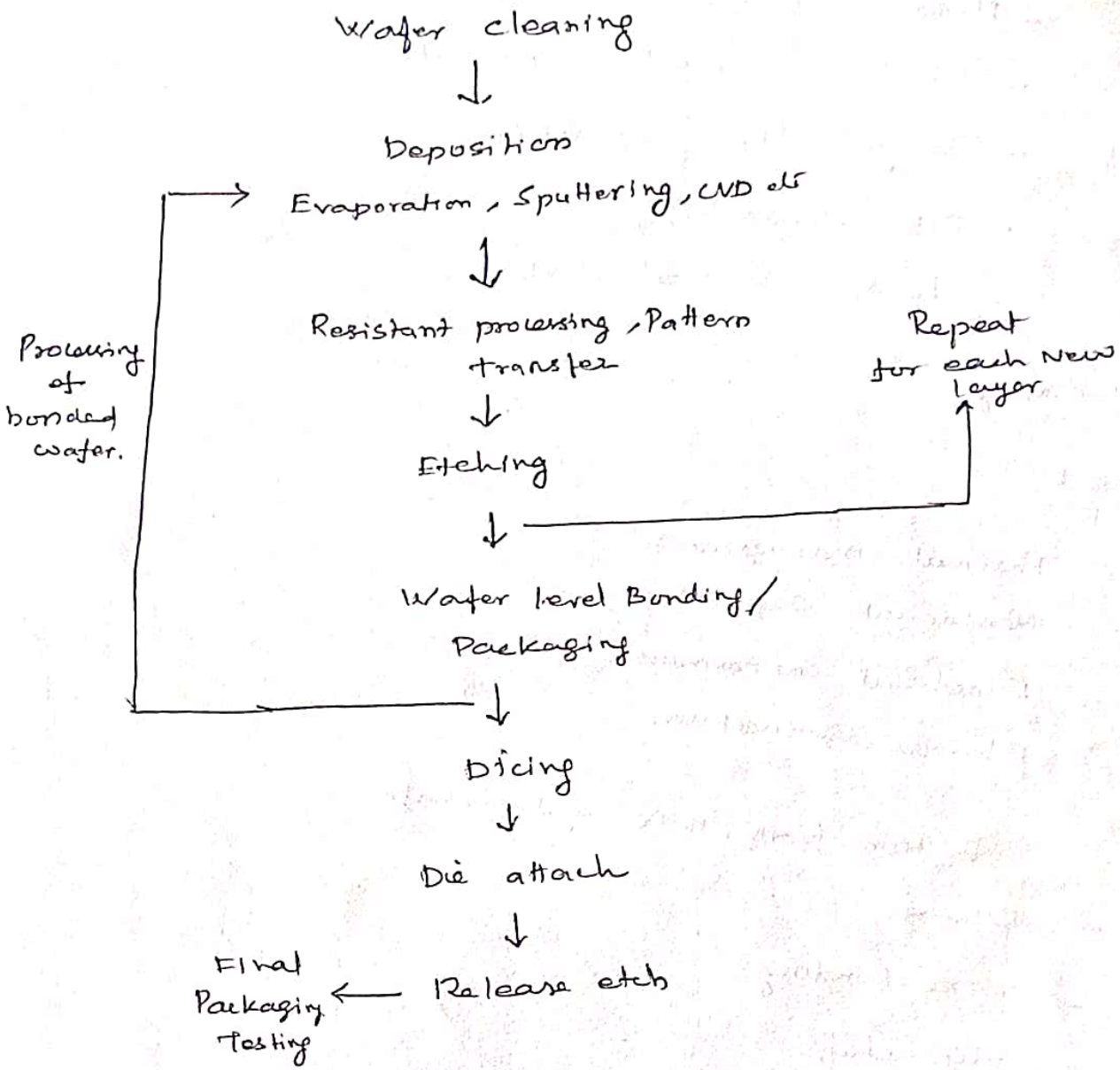
- Micro Stereo lithography
- Electro chemical deposition
- Inkjet type deposition
- FIB deposition
- Laser assisted CVD

Packaging:

Need:

- Thermal management
- Mechanical support
- Electrical connections
- Fluidic connections.
- Protection from noise and damage
- Dicing
- Wire bonding
- Flip chip
- Hybrid Integration.

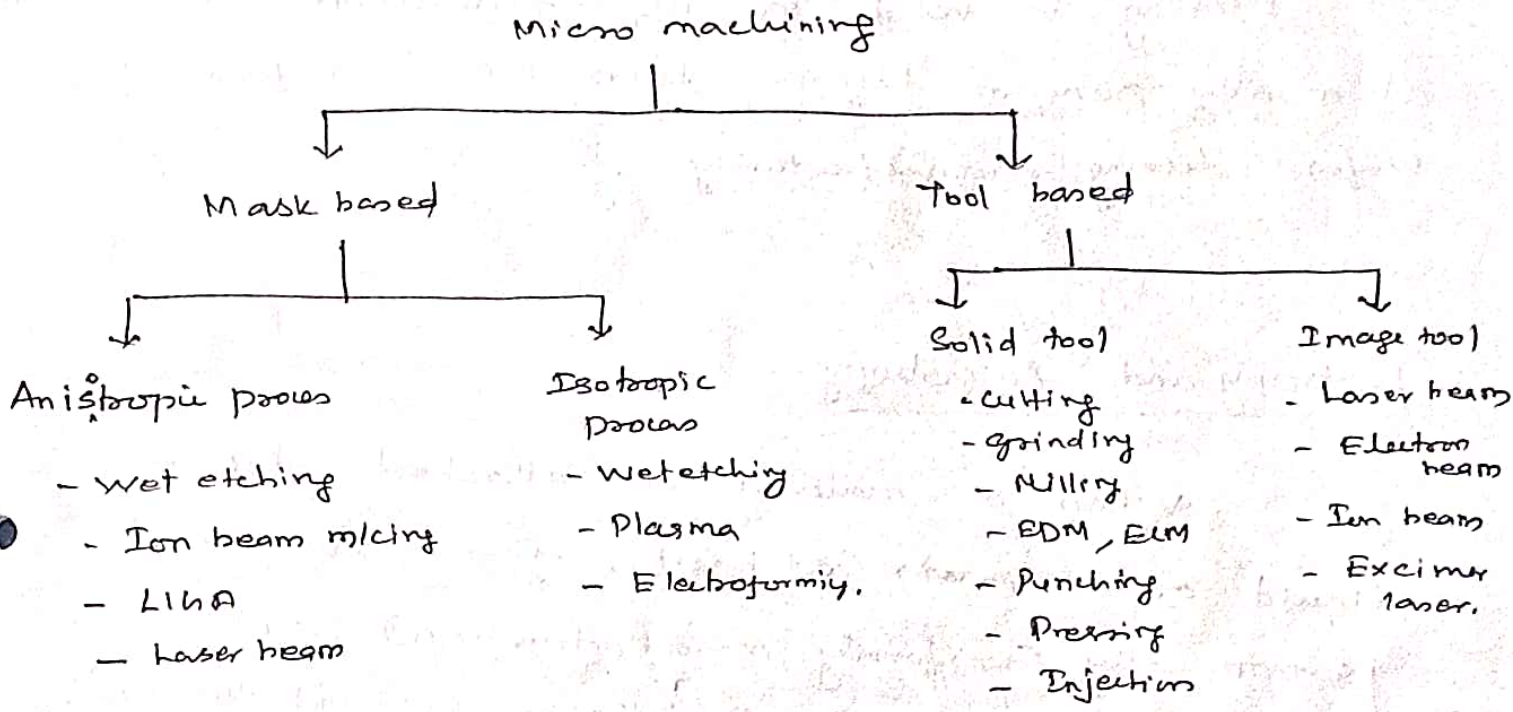
Fabrication of Micro systems:



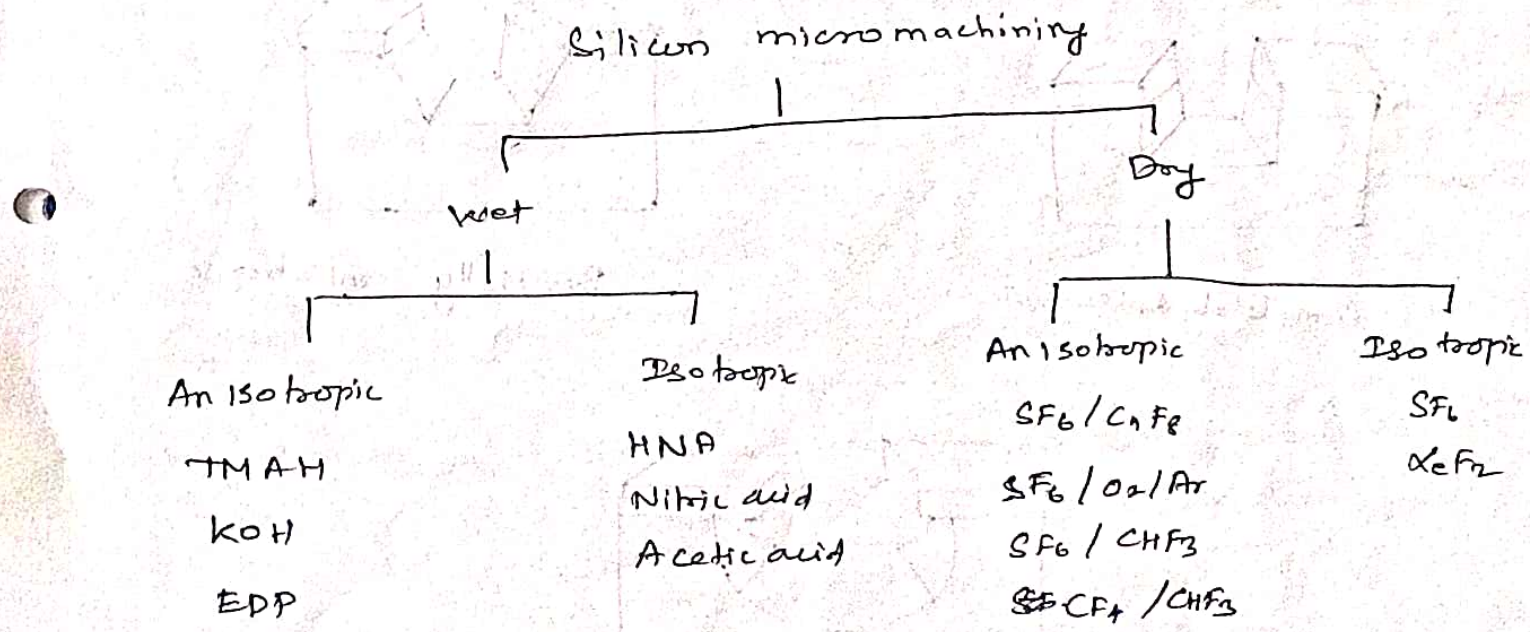
Categories of Micromachining Techniques.

1. Bulk micromachining
2. Surface micromachining
3. Micro-molding process
4. Non-lithography based localized micro machining.

Various Techniques of Micromachining proces



Classification of Silicon micromachining;

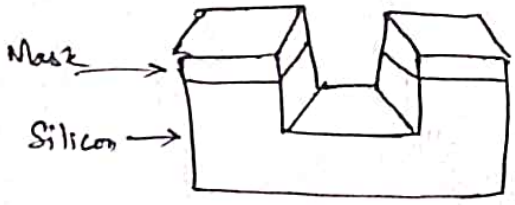


Etching :

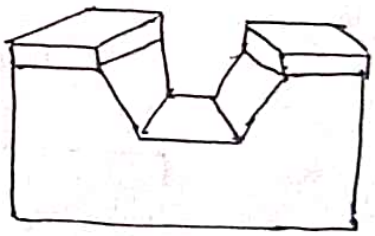
Etching is used in microfabrication to chemically remove layers from the surface of a wafer during manufacturing.

Isotropy and Anisotropy :

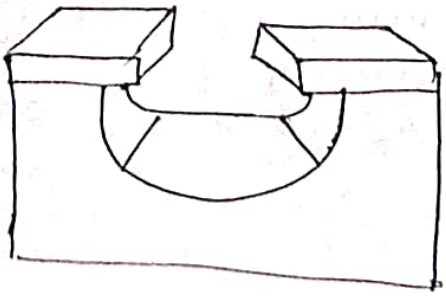
When a material is attacked by a liquid or vapour etchant, it is removed isotropically (uniformly in all direction) or anisotropic etching (uniformity in veritical direction)



Completely anisotropic.



Partially anisotropic



Isotropic etching Silicon.

Isotropic Etching : Etching rate is the same in both horizontal and vertical direction.

Anisotropic Etching : Etching rate is different in horizontal and vertical direction.

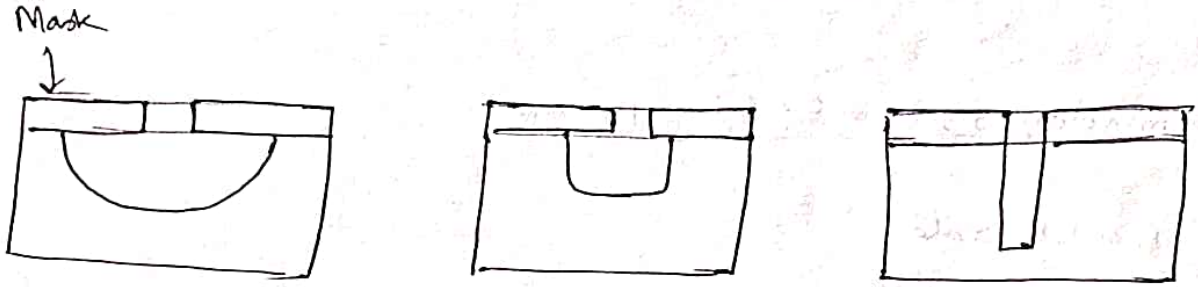
Lateral Etch Ratio

$$R_L = \frac{\text{Horizontal Etch Rate } (r_H)}{\text{Vertical Etch Rate } (r_V)}$$

Isotropic Etching $R_L = 1$

Anisotropic Etching $0 < R_L < 1$

Directional Etching $R_L = 0$



$R_L = 1$ $\quad 0 < R_L < 1$ $\quad R_L = 0$

Classes of Etching :

Wet etching : where the material is dissolved when immersed in a chemical solution.

Dry etching : where the material is sputtered or disolved using reactive ions or a vapor phase etchant.

Etching Techniques:

chemical etching in liquid - wet etching, or in gaseous from (dry etching) is used to remove any barrier materials protected by hardened PR (or Mask)

Wet etching
- Immersion
- Spray

Dry etching
- Plasma Etch — 13.56 MHz
  — 2.54 MHz
- RIE (reactive ion etch)
- Sputter etch.

Terminologies in Etching process:

1. Etch rate
2. Selectivity
3. Anisotropy
4. Uniformity
5. Undercut
6. Etching
7. Mask layer.

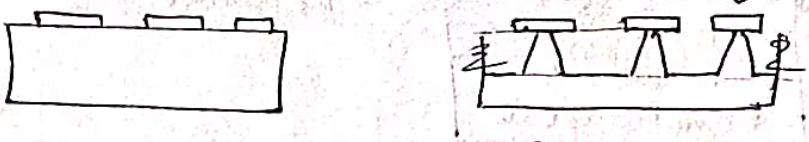
Wet Etching:

- chemical etching, liquid etching

Wet etching is a material removal process that uses liquid chemicals or etchants to remove material from wafer.

Etching agents: (Anisotropic)

- KOH - potassium hydroxide
- EDP - Ethylene diamine procatechol
- TMAH - tetra methyl ammonium hydroxide.



Etching agents (Isotropic)

- hydrofluoric acid
- Nitric acid
- Acetic acid (HNA)

Etch Stop Techniques:

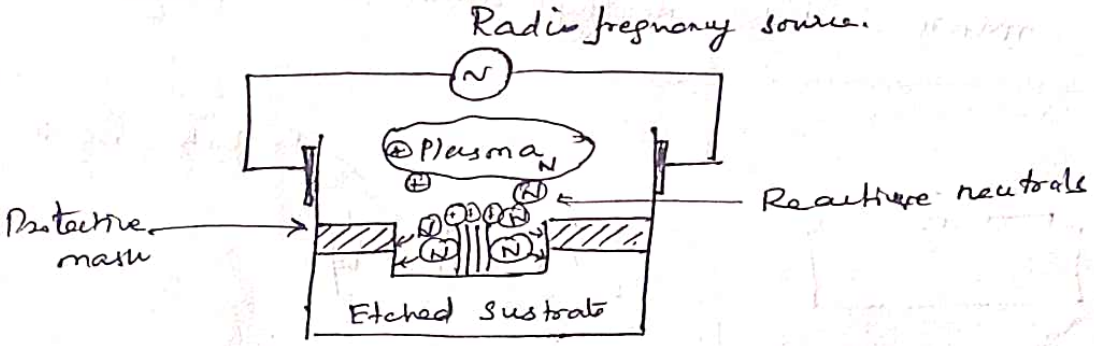
1. Dopant Controlled etch Stops.
2. Electrochemical Etch Stop.

Dry Etching:

- Plasma Etching, gas etching, physical dry etching, chemical dry etching, physical chemical etching.

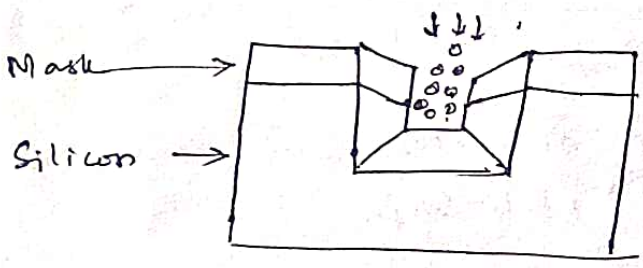
In dry etching plasmas or etchant gasses remove the substrate material the reaction that take place can be done utilizing high kinetic energy of particle beams, chemical reaction or a combination of both.

Plasma etching:



Physical dry Etching:

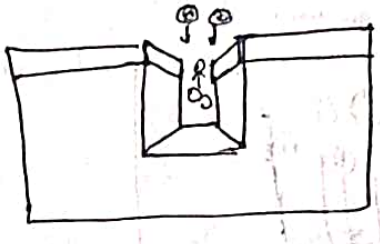
In physical dry etching the surface to be etched bombared with ions, electrons or photons.



- Plasma
- Silicon atom

The silicon atoms being evaporated off from the surface.

Chemical dry etching :

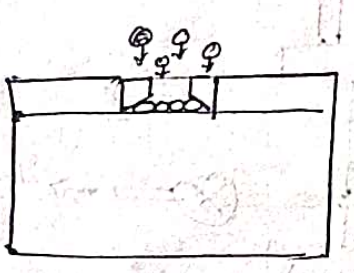


● Reactive Ion
○ Silicon atom.

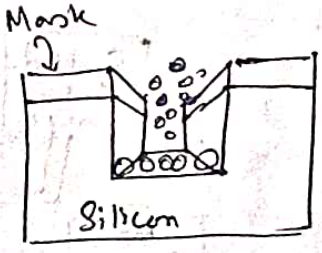
Chemical dry etching (Vapor phase etching) does not use liquid chemical or etchants. This process involves a chemical reaction between etchant gases attack the Silicon surface.

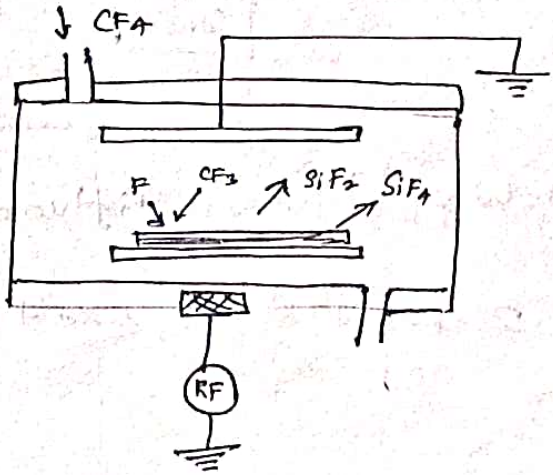
Reactive Ion Etching (RIE)

RIE uses both physical and chemical mechanisms to achieve high levels of resolution.

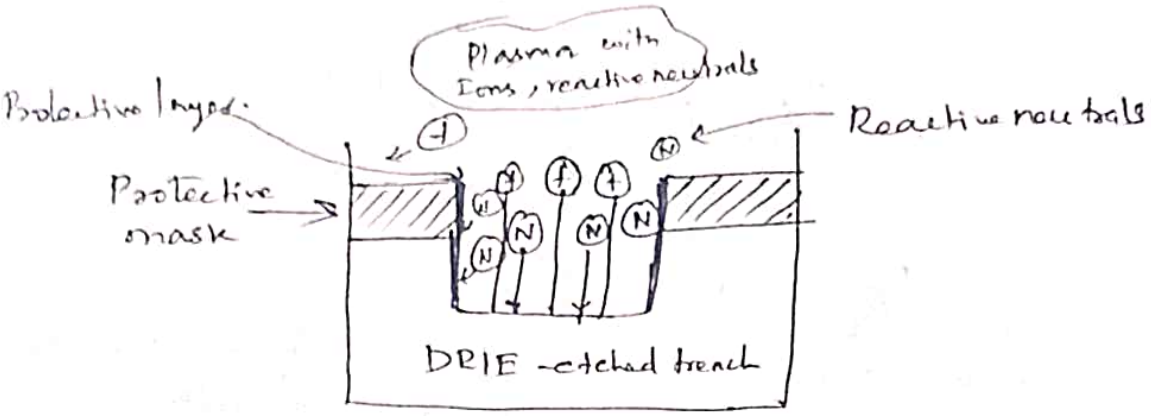


● Plasma
○ Silicon atom
○ reactive Ion.

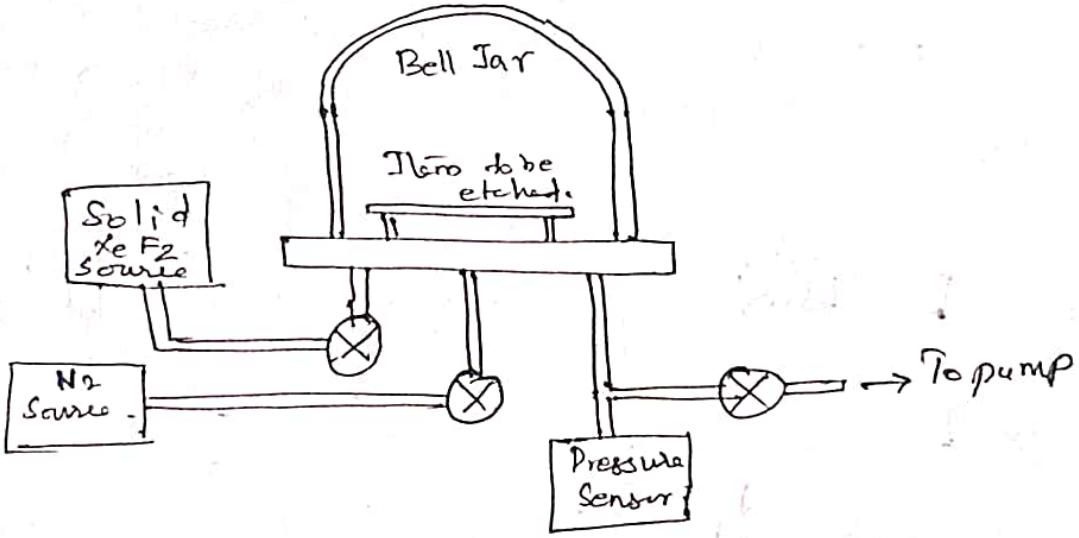




Deep Reactive Ion Etching:



Gas phase Etching:



I. XeF_2 Etching (Xenon difluoride)

$$2XeF_2 + Si \rightarrow 2Xe + SiF_4$$

1. Crystal Sublimate into gas which etches Silicon surface
2. Isotropic etching, controlled by temp and Pressure
3. High Etching rate 3-10 μm/min
4. High Selectivity to SiO_2, Si_3N_4, Al
5. Very sensitivity to moisture, forming HF which attack many materials
6. Good for post CMOS process
7. produce a rough surface -

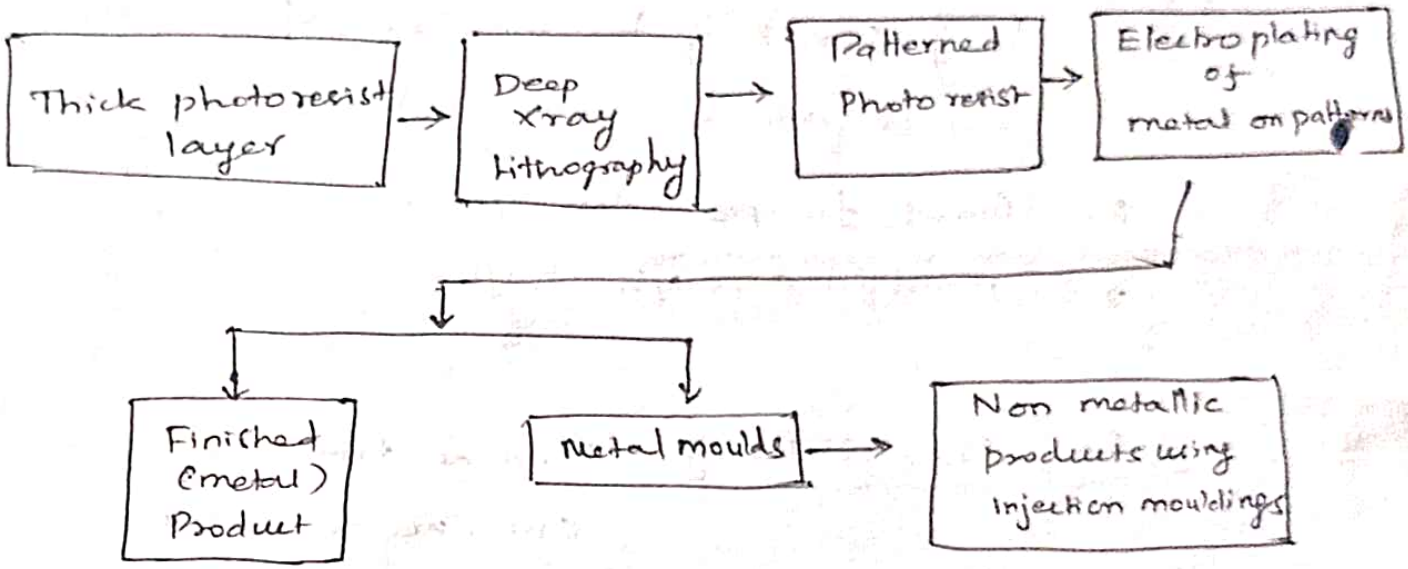
II. BrF_3, ClF_3 Etching (Bromine trifluoride, Chlorine trifluoride)

- Isotropic etching
- High etching rate for Silicon
- High Selectivity to SiO_2, Si_3N_4, Al
- Smooth surface
- Corrosive gas

LIGA Process

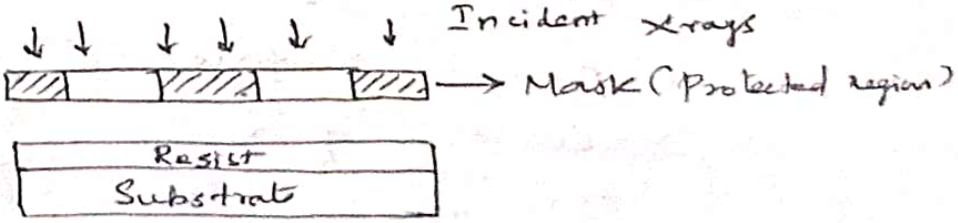
LIGA - LIthographic, electroforming, Galvanoforming, and molding Abforming

Steps for LIGA Process:

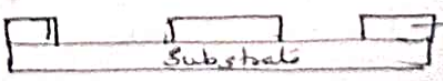


Process Steps in LIGA technology:

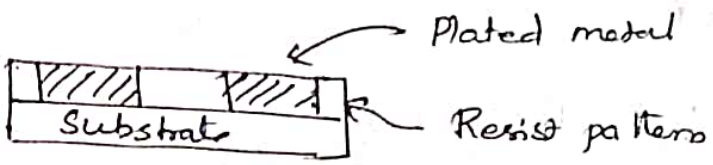
(a)



(b)

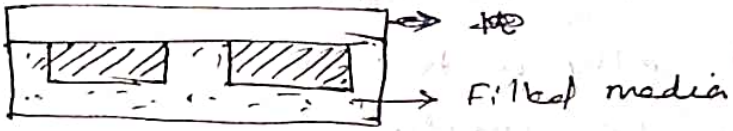


(c)

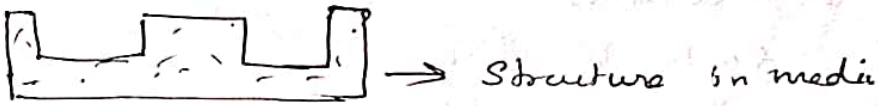


(d)

(e)



f



(a) Substrate is coated with thick photoresist. The photoresist is exposed x-rays

(b) Photo resist is developed to obtain patterned sample

(c) Suitable metal is electroplated

(d) Removal of photo resist material

(e) mold is filled with polymer, alloy, or metal.

Materials for LIGA

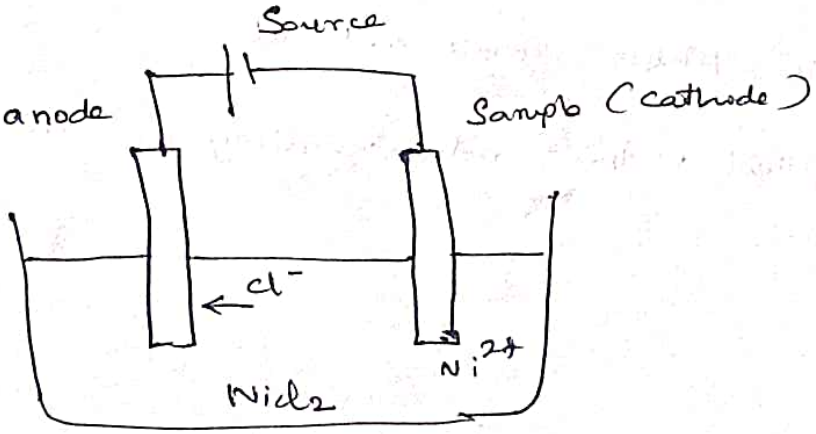
LIGA materials characteristics:

- Sensitivity to x-ray radiation
- High resolution
- Resistant to dry and wet etching
- Thermal Stability up to around 140°c
- Good line width control
- Good adhesion to substrate during pattern plating experiments.

Substrates materials

- Austenite Steel
- Silicon coaters
- titanium or Agler
- Copper plated with gold
- Nickel
- glass plate with metal layer.

LIGA Electro plating process:



Common refilling trenches
- Nickel
- Cu
- Au
- Ni Fe
- Ni W

$$Ni^{2+} + 2\bar{e} \rightarrow Ni$$

$$2H^{+} + 2\bar{e} \rightarrow H_2$$

Features of LIGA process

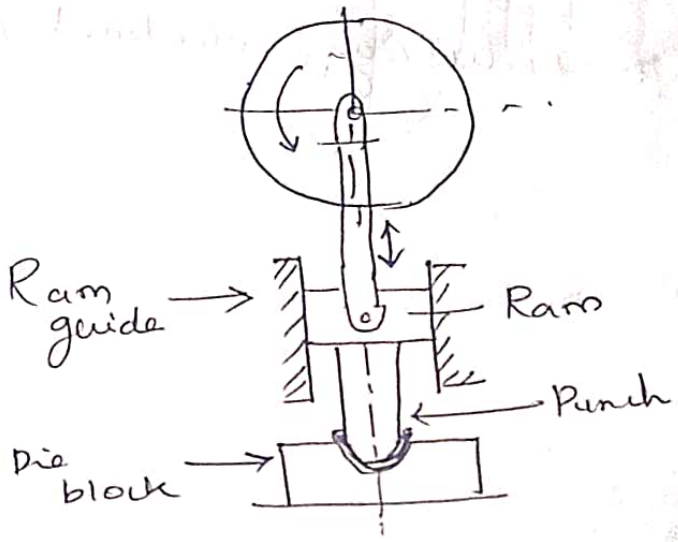
- Most expensive
- deep X-ray lithography
- Micro injection moulding
- No restriction on aspect ratio
- has capability to produce metallic microstructures.

S LIGA - (Scarifial LIGA)

- Modified LIGA process
- Scarifial layer introduced in between PMMA photo resist
- layer removed, metal mold without the attached substrate is obtained
- Polyimide is suitable layer.

UNIT-IV

Sheet metal Process:



- Punch and die block assembly is called die set
- Thickness of metal varies from 0.1 to 10mm

Advantages:

- No of operations can be formed
- various shapes can be formed
- low cost
- high production rate
- Does not require skilled labour

Disadvantages:

- only used mass production
- cost of die is very high
- Initial cost too high
- Metal thickness > 10mm difficult
- More noise and vibration.

Applications:

- Press parts are widely used in automobile (bikes, cars, trucks, buses etc)
- Industry Vehicle parts doors, roofs, fuel tanks, guards etc
- Air craft Industry, electrical parts etc.

Metals used in Sheet metal works:

1. Black Iron
2. Galvanised Iron
3. Aluminium Sheets
4. Copper Sheets
5. Stainless Steel
6. Tin Plates

Types of Sheet metal working:

1. Metal cutting operations
   - Blanking
   - Punching
   - Notching
   - Perforating
   - Slitting
   - Lancing
   - Shaving
   - Shearing
   - Nibbling.
2. Metal forming process:
   - Bending
   - Drawing
   - Embossing
   - Forming
   - coining.

Press Machine :

- Press working is also called as "cold Stamping"

Types of Press :

1. According to the Power Source
   - Manually operated
     - hand press or Fly press
   - Power press
     - Hydraulic, Mechanical Press
2. According to the type and design of the frame
   - Inclinable frame
   - Gsoup frame
   - Straight side frame
   - Horning press
   - Adjustable bed type press
3. According to the actions
   - Single action
   - Double action
   - Tripple action
4. According to the ram driving mechanism
   - Crank press
   - Eccentric press
   - Toggle press
   - Knuckle press
   - Rack and pinion press
   - Hydraulic press

Parts

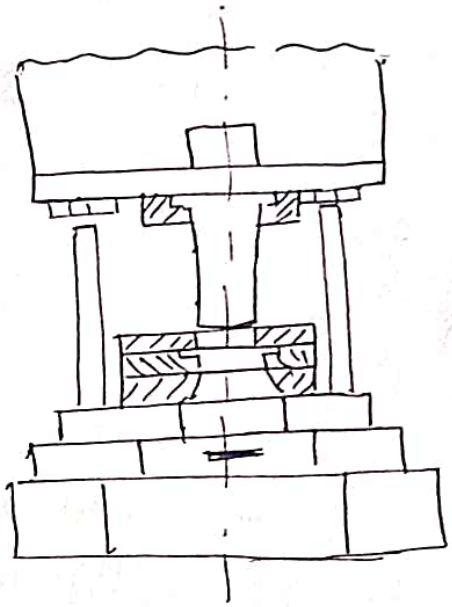
5. According to the number of drive gears
   - Single drive presses
   - Twin drive presses
   - Quadruple presses
6. According to the no of Crank Shafts.
   - Single crank
   - double crank
7. According to the power transmission method
   - Direct drive press
   - Non geared or fly wheel driven press
   - Sigle drive gear press
   - Double geared drive press.

Parts of press:

- Base
- Frame
- Ram
- Pitman
- cluth
- Bolster plate

Die details:

- Die set
- Die
- Die block
- Punch
- Lower shoe
- Upper shoe
- Punch plate
- Back up plate
- Stripper plate
- Knock out



Selection of Press:

- Size of the work piece
- Material of the work piece
- Speed of the operation
- production rate
- Power required for the operation
- Dimensional tolarance
- Quantity of production
- Types of dies required.

Cutting force:

The distance which the punch enters into the stock to cause rupture is called as penetration.

Maximam force required to cut

F_{max} = Sheared area x Shearing Strength

$= A \times \tau_s$, N

If circular blank

$F_{max} = A \times \tau_s$

$= \pi D t \times \tau_s$

D is blank diameter, mm

t - Stock thickness, mm

τ_s - Shearing Strength, mm

For Reactangular block

$F_{max} = 2(L+b)t \times \tau_s$

Energy in press work, (work done)

$E = F_{max} \times$ Punch travel

$= F_{max} \times k \times t$

Actual cutting force

$$F = \frac{F_{max} \times k \times t}{k \times t + I}$$

Formability Tests:

1. Test for bulk deformation
   - Stress - strain characteristics
   - Process - economic analysis
   - Scale experiments.
2. Test for Elastic deformation
   - Tensile test
   - Stretch forming test

$$\sigma = B \epsilon^n$$

   - Drawing test

$$r_m = \frac{1}{4} \sqrt{r_0 + 2r_{45} + r_{90}}$$

r_{45}, r_{90} - metal flow rate at 45°, 90°c

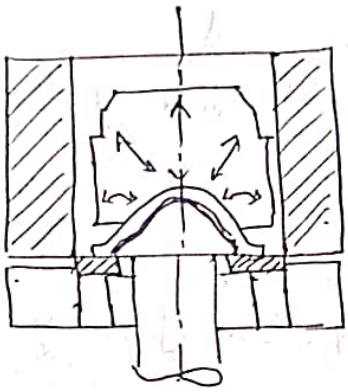
3. Test for forming operation
   - Erichsen cupping test

Special Forming Process:

- Hydro forming
- Rubber pad forming
- Pean forming
- High velocity rate forming
- Roll forming
- Explosive forming
- Magnetic pulse forming
- Super plastic forming
- Metal spining
- Press brake forming

Hydro forming:

1) hydro mechanical forming.

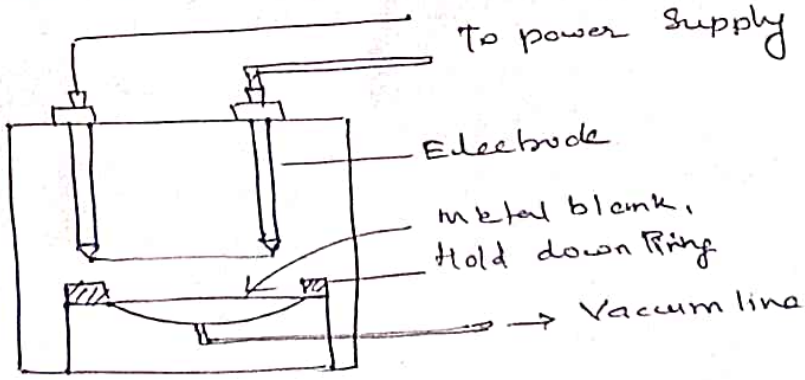


- Flexible die consists rubber diaphragm
- Punch used to perform to shape
- pressure chamber continues to increase

Advantages:

- Tooling can be changed
- Irregular contours are easily formed
- Sharp corners possible
- Tooling cost low
- Tolerance ± 0.005 mm/mm possible.

ii) Electro hydraulic forming:



Advantages:

- Tooling cost low
- Complicated shapes easily produced
- high reproducibility

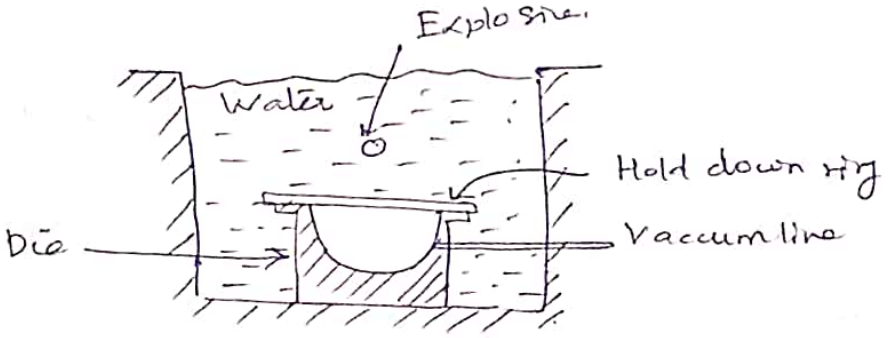
Disadvantages:

- Energy produced for forming is less
- Not suitable for low ductility metals.

Applications:

- Small qty production
- Engine cradles
- Aluminium bicycle frame
- suspension, Radiator Support

Explosive forming:



- Stand off operator
- contact operation.

Advantages:

- large and expensive presses not required
- Component formed one cycle.
- only one die is required
- large size components made easily
- low capital investment

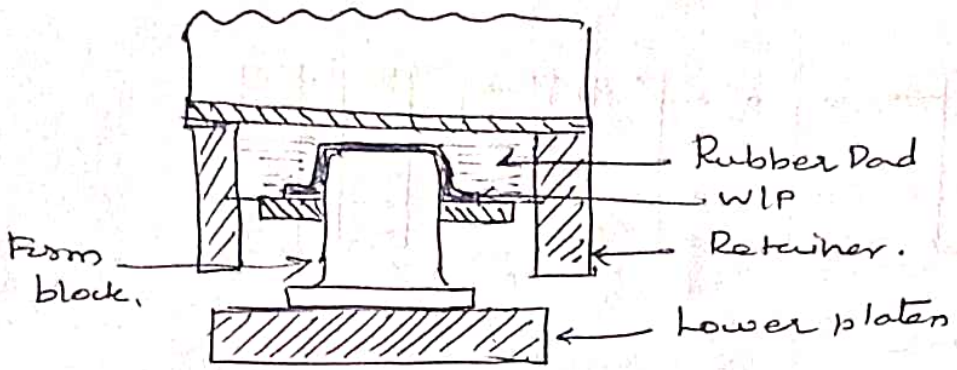
Disadvantages:

- high skilled operators
- Complex components cannot be made in one cycle
- Suitable only low Qty

Applications:

- Mainly used aero space industries.

Rubber Pad forming:



- Also known as marform process
- Punches, Rubber pads
- Rubber - Polyurethane

Advantages:

- Cost of tooling is less
- Process more flexible
- Tool setting time less
- Lubricants not required
- Deep shells can be produced
- Process more economical

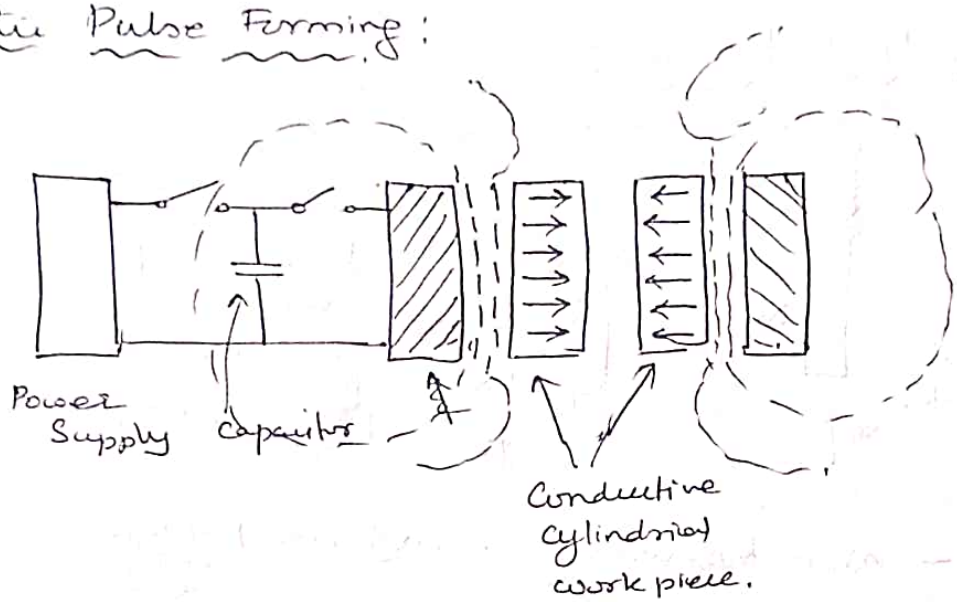
Disadvantages:

- Difficulty in the forming of sharp corners
- Rubber pad will wear out faster also

Applications:

- Producing cylindrical, Rectangular cups, spherical domes, shells
- Also used for producing variety of unsymmetrical shapes.

Magnetic Pulse Forming:



- Insulated induction is wrapped
- Capacitor charged 3 to 6 sec
- Rapidly discharge 15 to 20 μs
- Magnetic field is developed -
  - work piece collapse
  - Compress
  - Shrink or expand

Advantages:

- high conductive metals can be formed
- There is no friction lubricants not required
- No tool marks
- Designed for repetition rates

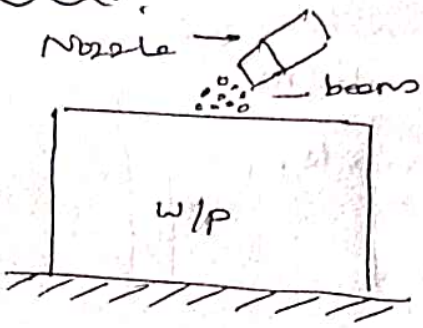
Disadvantages:

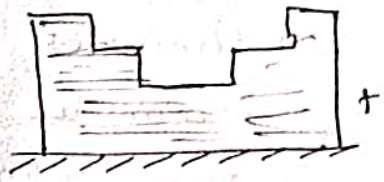
- Short duration of pr pulse
- deep drawing not possible

Applications:

- Attachment of rubber boots
- used to expand, compress or to form tubular shapes.
- Piercing, Shearing, & cupping, Sizing etc.

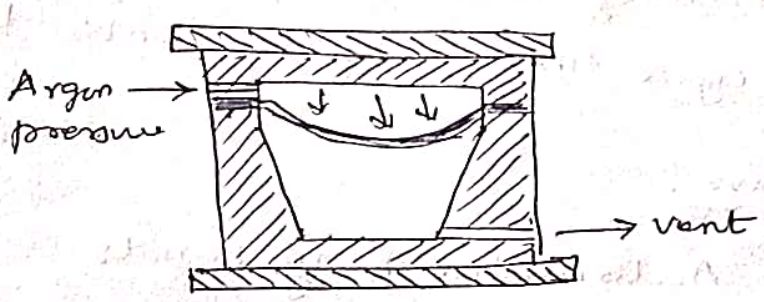
Peen Forming:





Fivdl component.

Super plastic Forming: (SPF)



- During this process metal is heated
  titanium - 900°c
  aluminium - 450°c
- Argon gas applied for expansion.
- Sheets elongate 10-30%.
- low Strain order of 10^{-3} to 10^{-4} S^{-1}

Some metals used for SPF

- tin (200% Elongation)
- Zinc aluminium
- Titanium
- Aluminium
- Al li alloys.

Advantages:

- large, complex operations
- Eliminates joints, rivets.
- Minimizes scraps
- less tooling cost
- does not suffer spring back

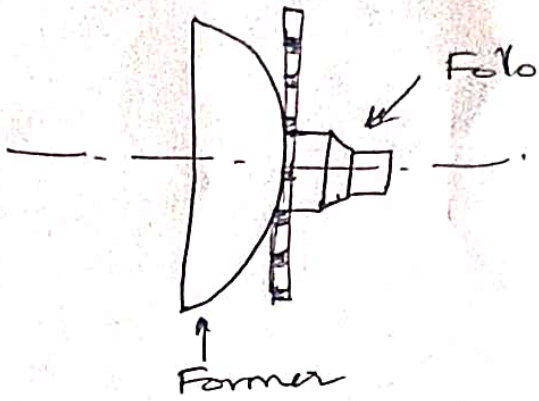
Dis advantages:

- Forming rate is slow
- cycle time vary two minutes to two hrs

Applications:

- Automotive body panels
- Aircraft frames
- Diaphragm forming of plastics
- complex shape parts.

Metal Spining:



- Spining is the pressure forming of metal on a rotating chuck, former or die
- deformation of metals during spining is combination of bending and stretching.
- generally applied to thin materials

Advantages:

- low equipment cost
- low tooling cost
- Complex parts can be easily and economically produced.

Limitations:

- Depends on skilled operator
- Finished parts not always uniform
- closer tolerance cannot be obtained
- thining of the metal takes place.

UNIT - V

Manufacturing of Plastic Components.

Characteristics of Plastics:

- Light wt
- High corrosion resistance
- low density
- low thermal and electrical Properties.
- low Mechanical properties.
- low co-efficient of friction
- Low tensile Strength
- Easy to fabricate
- Low wst

Types of Plastics:

1. Thermoplastics
   Soften when heated and harden when cooled
2. Thermo set plastics.
   become soft during first heating and become permanently hard when cooled.

Comparison between thermoplastic and thermosetting Plastic

	Thermo Plastic	Thermo setting Plastic.
1.	Formed addition Polymerisation.	Condensation Polymerisation
2.	linear polymers	cross linked polymers.
3.	Soft, week, less brittle	hard, strong, more brittle.
4.	Recyclable	not recycled.
5.	Soluble in organic solvents	insoluble.

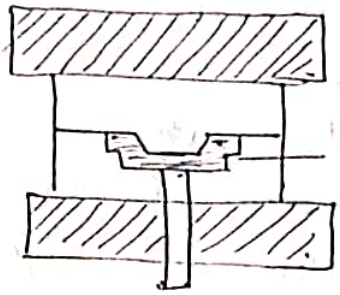
Structured of Polymers:

- Linear Polymer
- Branched Polymer
- Cross linked polymer
- Network Polymer

Processing of Plastics:

1. Processing of thermo setting Plastics
   - Compression moulding
   - Transfer moulding.
2. Processing of thermo plastics.
   - Injection moulding
   - Blow moulding
   - Thermo forming
   - Extrusion.

Compression moulding :



1.- Mostly used thermosetting Plastics

- Pressure varies from 0.5 mpa to 50 MPa
- Processing temparature 125°- 250°C
- Curing time depends on thickness of the material
- 0.5 minutes to 5 minutes
  - Quantity of materials
  - Heating time and technique
  - Force applied to the mould
  - Cooling time and technique

Common materials

- Phenolics, melamine, urea-formaldehyde epoxies, urethanes, elastomers

Types of compression moulding

- Positive type
- Semi positive type
- Flas type

Advantages of Compression moulding

- Simple and less cost
- low maintenance
- low residual Stresses
- Initial Setup cost is low
- process capable of large size parts
- Good Surface finish
- high thermal Stability

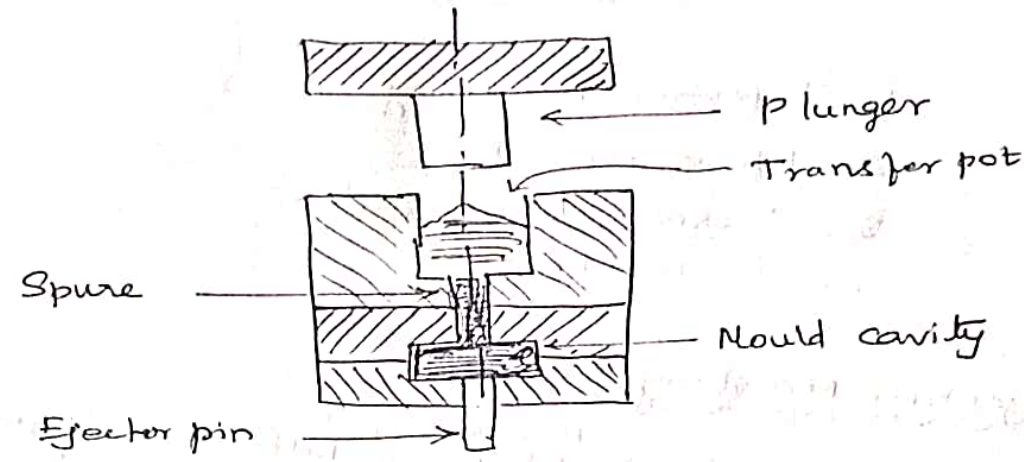
Disadvantages

- cycle time of the process is long
- low production rate

Applications :

- Making flatwares, gears, buttons, buckles, knobs, handles, dishes, container taps and fittings
- Electrical and Electronic Components.

Transfer Moulding :



- Commonly used thermosetting plastic
- Gate moulding
- Advanced method of Compression moulding.
- Preheated form to transfer port
- Pressure range 20 MPa – 100 MPa

Advantages :

- Moulding of different inserts, metal prongs, semi conductor chips
- high accuracy
- higher production rate comparatively compression moulding
- lower maintenance cost

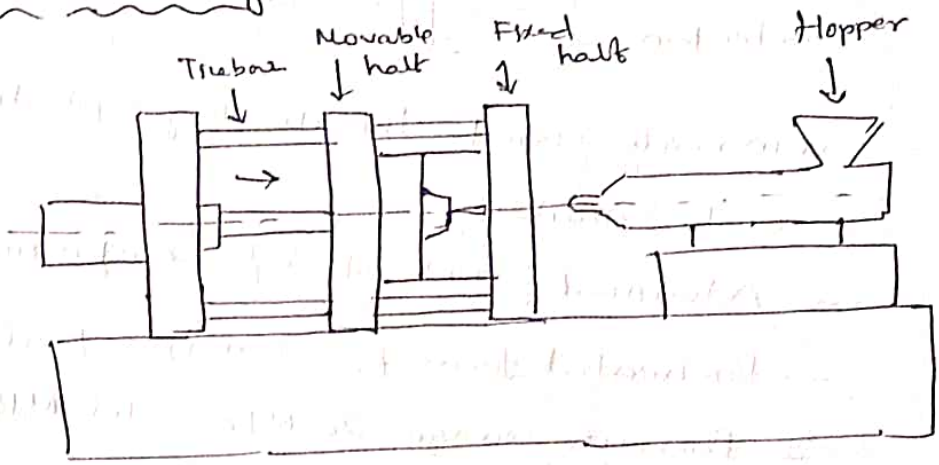
Limitations :

- Initial cost of the mould is high
- process wastage is high.

Processing of Thermoplastics:

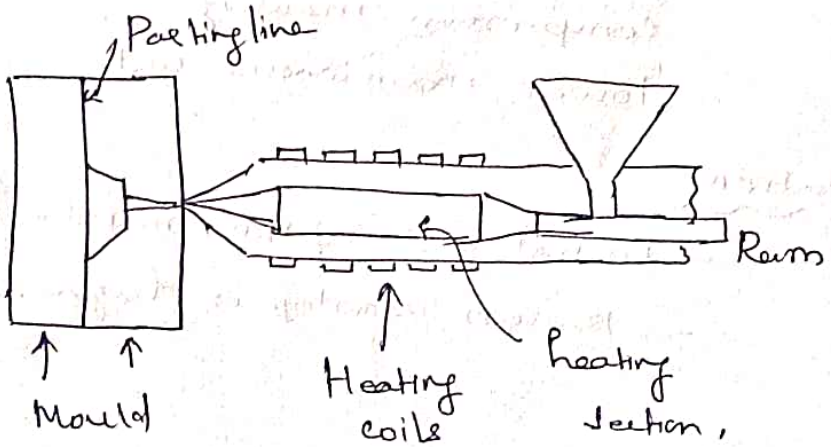
1. Injection moulding
2. Blow moulding
3. Thermo forming
4. Extraction.

Injection Moulding:

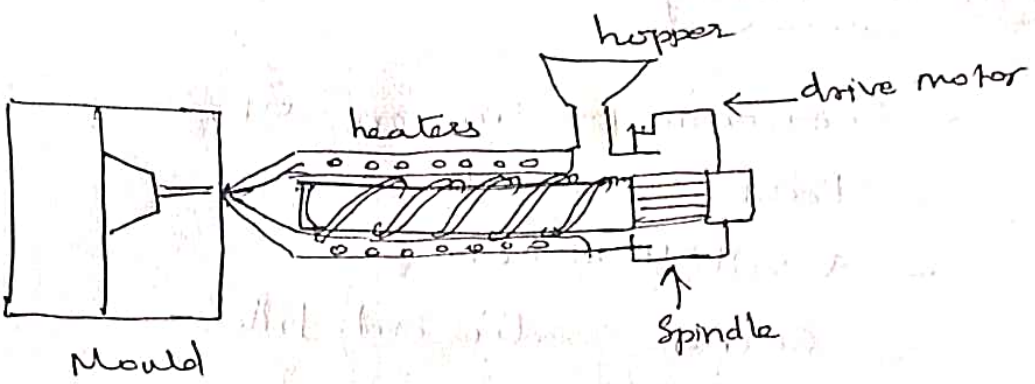


1. Injection unit
2. clamping unit
3. control unit

Ram or Plunger type Injection moulding:



Screw type Injection moulding:



Advantages

- Faster process
- Mass production
- high accuracy
- low material wastage.

Limitations:

- Initial cost is high
- Reliable temperature and Pressure controls are required
- Forming of Thermoplastic materials only

Applications of IM:

- process of cups, chairs
- toys, containers, knobs,
- Automobile parts
- Air conditioner parts
- Pumpings
- Electrical items
- Electronic items.

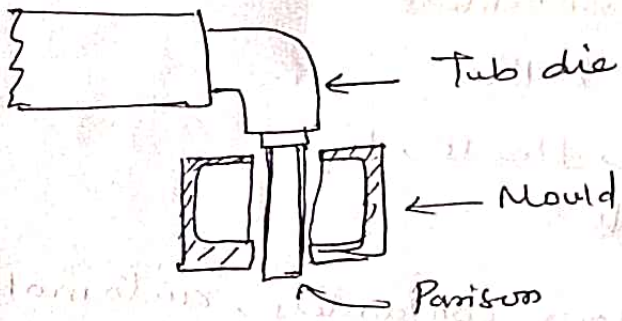
Blow

Design parameters for Injection, Compression, Transfer Moulding

- Economic production qty
- Part Complexity
- Wall thickness
- Corner radii and fillets
- Holes
- Draft
- Tolerances

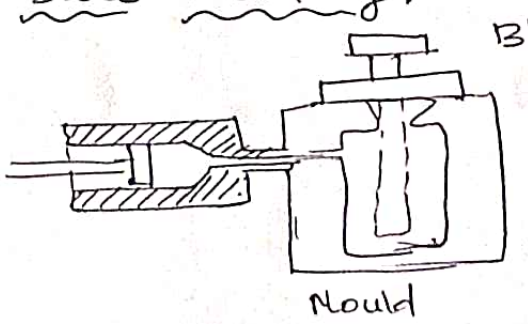
Blow Moulding :

Extrusion blow moulding :



- Blow moulding consists of extrusion of the heated tubular plastic piece is called as parison.
- Air pressure about 400 - 800 kPa
- bottles

Injection blow moulding :



Advantages :

- low mould cost
- Tool flexibility
- Production flexibility
- No restriction of container shape

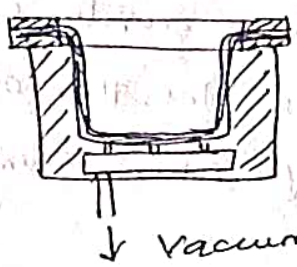
Applications:

- Mainly used for making cosmetic packing
- Food containers
- Water bottles
- Pipes, floats, toys
- dolls
- hollow containers, automobile fuel tanks
- boat fenders
- heat ducts.

Thermoforming :

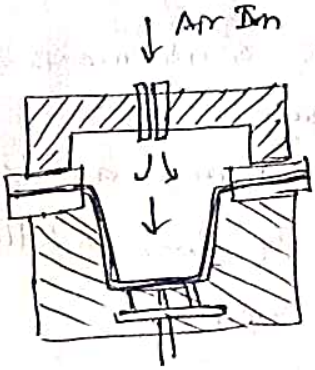
- Vacuum forming
- Pressure forming.

Vacuum forming :



- Plastic Sheet thickness about 0.125 – 3.2 mm
- Consists of two steps -
  - heating
  - forming
- Temparature - 55°C to 90°C

Pressure forming :



- blow forming
- higher pressure to be applied
- Air exist to the bottom area

Advantages :

- Initial setup cost is low
- Time required for setup is low
- Production cost is low
- less thermal stresses
- Intricate shapes are easily formed
- holes in the moulds - less than 0.5mm
- Moulds made up of Aluminium.

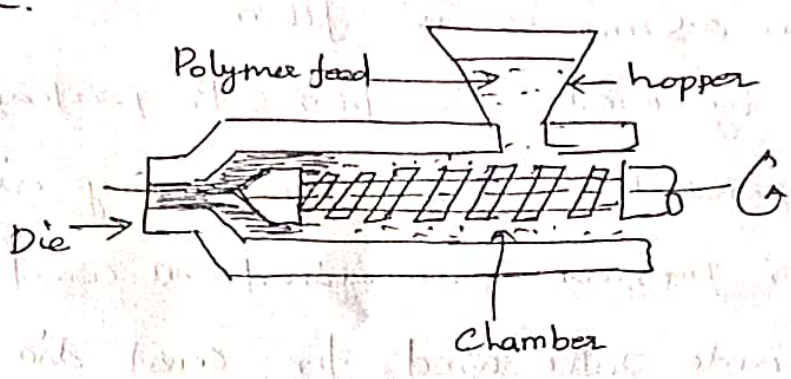
Limitations :

- Components with openings or holes cannot be produced
- drawing and stretching -
- Low uniform elongation.

Applications :

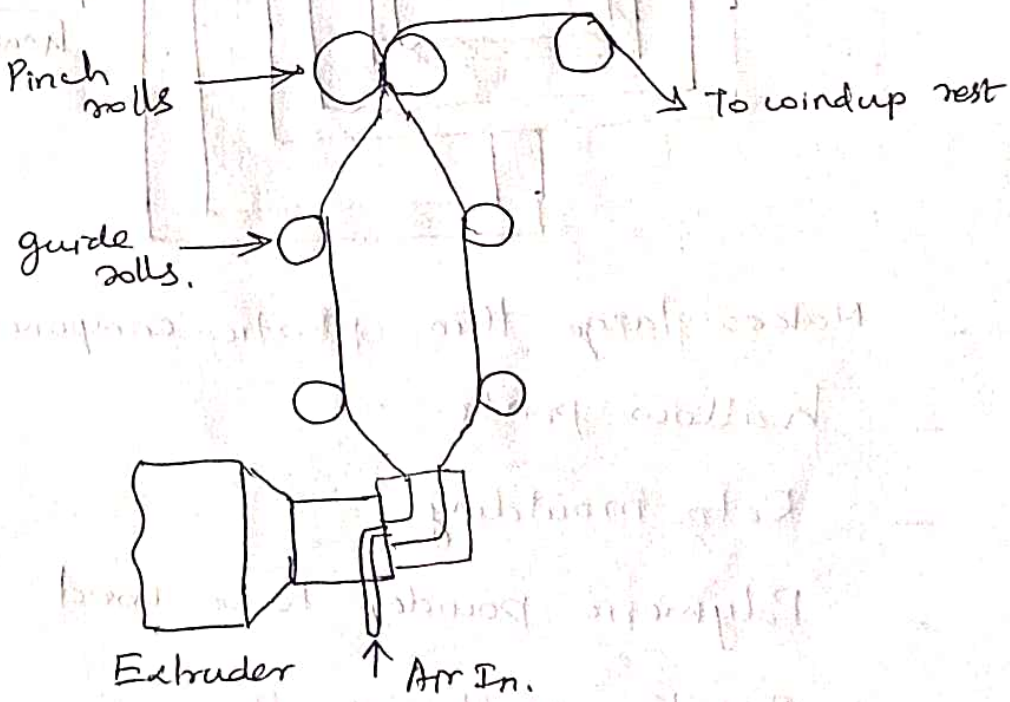
- Making small containers
- luggage bags
- Refrigerator Inner pannels
- Forming of shower stalls and advertising signs.

Extrusion :



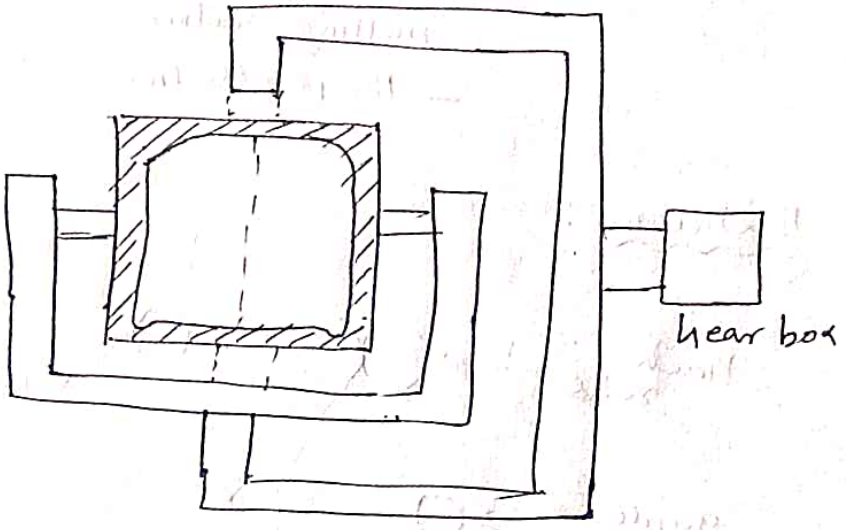
- Continuous process
- Form of thermoplastic pallets, granules, powder.
- heaters around the extruder
- Three sections
  - Feed section
  - melting section
  - Pumping section.

Film Extrusion :



- Below 0.5mm is is film
- Widely used PE film, for packaging
- Expanded in size by blowing air
- Air pressure maintained at const dia.
- guide rolls used for const dia

Rotational Moulding:



- Makes large thin plastic components
- hallow parts
- Roto moulding
- Polymeric powder to be used
- Rotates multi axially
- temparature 260 to 300 °C

- heated through heaters.
- cooled at Air cooling

Advantages :

- Simple process, No pressure applied
- low mould cost
- Excellent surface finish
- low production cost
- different shapes to be mould.

Applications :

- Boat manufacturing.
- large containers, coolie tanks
- Particians.

Bonding of Plastics:

- Mechanical fastening
- Solvent bonding
- Ultrasonic welding
- Induction welding
- Vibration welding
- Hot platen welding
- Hot gas welding
- Spin welding

duff moulding:

Another form of compression moulding.

Placing measured amount of DMC into a heated mould, then forcing it into the mould cavities using a heating plug.

- Initial development
- duff get warmer
- Smoother and drier.