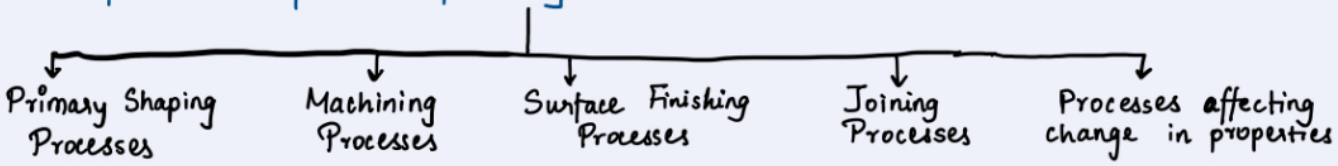
Manufacturing Processes

→ Process of converting raw materials into finished products

Classification of Manufacturing Processes



Metal Casting Process

→ Pouring molten metal into a refactory mould with a cavity of shape to be made & allowing it to solidify

→ After solidifying, desired casting removed by braking/taking apart the mould

→ Process is called founding

Casting Terms

Flask - The one that holds sand mould intact

Drag - Lower moulding flask

Cope - Upper moulding flask

Pattern - Replica of final object along w some modifications

Parting Line - Dividing line b/w 2 moulding flasks that makes up sand mould

Bottom board - Wood board on which replica is placed & mould making starts

Facing Sand - Small amount of carbonaceous material sprinkled on inner surface to give better finishing

Moulding Sand - Mixture of silica, clay & moisture used for making mould cavity

Backing Sand - Constitutes most of refractory material found in mould

Core - Used for making hollow cavities in casting

Pouring Basin - Small funnel shaped cavity into which molten metal is poured

Sprue - Passage thru which molten metal from pouring basin reaches mould cavity

Runner - Passageways thru which molten metal flow is regulated before reaching mould cavity

Gate - Entry point for molten metal to enter mould cavity

Riser - Reservoir of molten metal

Sand Moulding

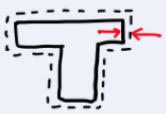
1) A bottom board is placed to make the surface even & drag moulding flask is kept upside down
2) Dry facing sand is sprinkled over board to provide non-sticky layer
3) Freshly prepared moulding sand of required quality is poured into drag upto thickness of 30-50 mm, rest of the drag is filled with backup sand & then rammed
4) Ramming is done uniformly, neither too compact nor too loose
5) Excess sand is completely scrapped using flat bar to level the edges of flask
6) A vent wire is used to create vent holes into the drag & pattern upto full depth to facilitate gas removal during casting solidification
7) A slick is used to repair edges of sand around pattern & cope half of pattern placed over drag pattern & aligning it with help of dowel pins
8) A cope flask is located aligning again with help of pins. Sprue pin is located at 50 mm from patter making a sprue passage & riser pin if necessary
9) Freshly prepared moulding sand is poured & backing sand is sprinkled, rammed thoroughly, excess sand is scraped & vent holes are made
10) Sprue & riser pins are removed carefully from flask & pouring basin is cut near top of sprue. Cope is seperated from drag & loose sand is blown off using bellows
11) Cope & Drag pattern halves withdrawn using draw & wrap the pattern to ensure mould walls aren't spoiled by withdrawing pattern. Runners & gates are cut in mould w/o spoiling mould
12) Cope is replaced on drag taking care of allignment of the 2 by means of pins. Suitable weight is kept on cope to take care of upward metallostatic force during pouring of molten metal. Now mould is ready for pouring

Pattern

→ A replica of the object to made by casting process along with modifications
→ Main modifications are :
  i) addition of pattern allowances
  ii) provision of core prints
  iii) elimination of fine details which can't be obtained by casting & hence obtained by further processing

Pattern Allowances

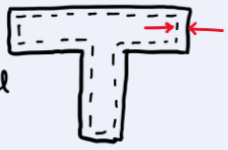
→ Dimensions of pattern are usually different from final dimensions of casting required.
→ Shrinkage Allowance
  → All metals shrink upon cooling because of inter-atomic vibrations which are amplified on increase of temperature
  → Liquid Shrinkage is reduction in volume when metal changes from liquid to solid state
  → Solid Shrinkage is reduction in volume when metal loses temperature in solid state
  → Pattern maker's experience & few trials are used to arrive at final shrinkages provided on pattern



→ **Finish / Machining Allowance**

→ Final finish after sand casting has poor accuracy & when casting requires an accurate finish, subsequent machining must be done

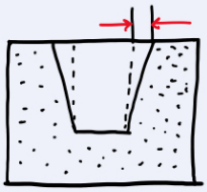
→ Ferrous materials have scales on skin to be removed by cleaning & extra material is provided so that it can be removed by machining / cleaning process



→ **Draft Allowance**

→ While removing pattern from sand mould, vertical faces of pattern are in continual contact with sand & damages mould cavity

→ To reduce the damages, vertical faces of pattern are tapered from parting line.



→ **Shake allowance**

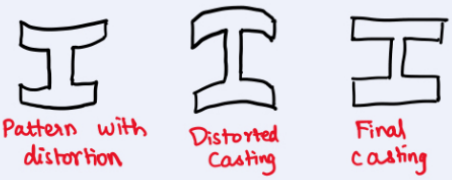
→ The pattern is wrapped all around the vertical faces before removing it from sand mould to enlarge mould cavity slightly & facilitate its removal

→ As the final casting enlarges, its desirable to reduce original pattern size to account for the increase & this can't be quantified as it depends on foundry personnel & practises involved

→ **Distortion Allowance**

→ A metal when solidified is generally very weak & is distorption especially in structures like V, U or any complicated casting which may have thin & long sections connected to thick sections

→ Usually the shape of distortion should be given equal distortion from opposite direction



Types of patterns

1) Solid / Single Piece pattern

→ Made of single piece

→ This is used when the job is very simple & has no withdrawl problems (or) very small scale production (or) prototype development

→ Pattern is expected entirely in drag

→ One of the surfaces is expected to be flat & used as parting plane

2) Split Pattern

→ The pattern is split into 2, so that one part is in drag & other in cope

→ Split surface of pattern is used as parting plane of mould.

→ 2 halves should be aligned properly using dowel pins which are fitted in cope half, & must match with precisely made holes in drag half of pattern & allign with 2 halves properly.

3) Cope & Drag Pattern

→ Similar to split pattern but also has gating & risering systems attached seperately to metal/wooden plates along with alignment pins.

→ Cope & Drag moulds may be produced maybe produced using these patterns seperately by 2 moulders but can be assembled to form complete mould.

→ Used for casting which are heavy & inconvinient for handling

4) Match Plate Pattern

→ Cope & Drag patterns along with gating & risering are mounted on a single matching metal/wooden plate on either side one side cope flask & drag flask on the other.

→ After moulding, match plate is removed & complete mould is obtained by joining cope & drag together

→ Used for small castings of high dimensional accuracy & large production

5) Loose Piece Pattern

→ Used when contour of the part is such that withdrawing the pattern from mould isn't possible, hence obstructing part of contour is held as loose piece by wire

→ After moulding, main pattern is removed & then loose pieces are recovered through gap generated by main pattern

6) Sweep Pattern

→ Used to complete casting by means of plane sweep.

→ Used for large shapes which are axi-symmetrical/prismatic in nature like bell/cylinder

→ Reduces cost of 3D patterns of large castings (Generally cast in pit moulds)

Properties of Moulding Materials

1) **Refractoriness** - Ability to withstand high temperatures & don't cause fusion

2) **Green Strength** - Moisture contained in moulding sand (green sand) has good enough strength so that constructed mould retains shape

3) **Dry Strength** - When molten metal is poured into a mould, moisture in sand evaporates & gets converted into dry sand due to heat & can retain mould cavity & withstand metallostatic forces

4) **Permeability** - Moulding sand should be sufficiently porous so gases can escape

5) **Cohesiveness** - Property of moulding sand which enables sand particles to stick together Shape & Size of grain, Bonding material & distribution, Moisture affect the cohesiveness of moulding sand

6) **Adhesiveness** - Enables sand particles to stick to other objects (like moulding box) It ensures sand mass is together in moulding box & not fall upside down

7) **Flowability** - Ensures moulding sand to flow all over the pattern when mould is rammed

8) **Collapsibility** - Permits easy break down of sand mass & subsequent use after casting has been taken out of mould

Melting & Pouring – Molten metal transfers from furnace to ladle & cleaned & held until it reaches certain temperature, which is poured into mould & allowed to solidify.

Cooling & Shakeout – After pouring, mould is cooled. Castings are removed manually / vibratory tables

Fettling, Cleaning & Finishing – Gating system removed using band saws / abrasive cut-off wheels / electrical cut-off devices. A parting line flash is removed by grinding / chipping hammers

Casting Defects

→ Irregularities in moulding process

Gas Defects

→ Blow holes sink because of low permeability of mould

→ Pin holes porosity because of Hydrogen in molten metal

Shrinkage Defects

→ Caused by liquid shrinkage during solidification of casting.

Moulding material Defects

- Metal penetration – Molten metal enters b/w sand grains causing rough casting surface because of coarse sand (or) no mould wash applied to cavity
- Swell – Swell in dimensions of casting because of faulty mould making procedure.
- Drop – Dropping of lumps from cope to mould cavity because of improper ramming of cope.

Pouring Metal Defects

→ Misruns caused when metal is unable to fill mould cavity completely

→ Cold Shuts caused when 2 metals don't fuse properly causing a weak spot

→ Can be fixed by increasing fluidity of metal / raising pouring temperature

Metallurgical Defects

→ Hot tears caused due to low strength of metal at high temp & unwanted cooling, causing ruptures. This is because of poor casting design

Advantages of Sand Casting

→ Cast any material
→ Simple & inexpensive tools required
→ Weight reduction in design
→ No directional properties
→ Casting of any size/weight possible

Limitations of Sand Casting

→ Final dimensional accuracy & surface finish to be improved before application
→ Labour Intensive
→ Hard to fix sometimes

Applications

→ Cylinder Blocks, Wheels, Bells

Precision Investment Casting

→ Process where mould is prepared around an extendable pattern
→ To make the pattern,
  i) Molten wax (pattern material) is injected into metallic die under a pressure of 2.5 MPa
  ii) Wax upon solidification produces pattern
  iii) Cluster of wax patterns are attached to gating system by applying heat
  iv) Pattern is dipped into a slurry (made by suspending fine ceramic materials like ethyl silicate/sodium silicate) to make mould, excess is drained out
  v) Dry refractory grains (Fused silica/zircon) are 'stuccoed' on pattern forming a shell
  vi) When shell is 6–15 mm thick, the pattern is removed from mould by heating mould to melt the pattern & wax is drained
  vii) Molten metal is poured into mould under gravity & under slight pressure by evacuating mould first
  viii) Finally, molten metal is cooled & solidified, then moulds are subjected to shakeout using vibratory tables to remove the casting

Applications of Precision Investment Casting

→ Artefacts, jewellery, surgical instruments, blades of turbines, bolts

Centrifugal Casting

→ Process where mould is rotated rapidly about central axis as metal is poured into it & metal solidifies due to centrifugal force

→ Slag, oxides & other inclusions get segregated into center as they are lighter

→ 3 Types of Centrifugal Casting – True centrifugal casting, ✓
Semi centrifugal casting, X
centrifuging X

True centrifugal casting

→ Used for making hollow pipes, tubes, hollow bushes etc., which are axi-symmetric with concentric hole

→ Metal always pushed out, so no special core is required to make concentric hole

i) Moulding flask is rammed properly for outer contour of pipe

ii) Flask is dynamically balanced to reduce vibrations during casting & Finished flask is mounted b/w rollers & rotated slowly

iii) Molten metal is poured in requisite quantity through movable pouring basin & amount of metal poured determines thickness of pipe

iv) After pouring, it is rotated till it solidifies to form requisite tubing.

Forming

→ The process where metal maybe heated to a temperature below solidus temperature & large force is applied such that material flows & take desired shape

→ Generally, used for large-scale production

→ Forming includes rolling, forging, extrusion, wire drawing, sheet metal operations

Hot Working & Cold Working

→ Based on amount of heat applied before applying mechanical force, we have hot & cold working

→ If it works above recrystallisation temperature, its called hot working
If it works below recrystallisation temperature, its called cold working

→ Recrystallisation temperature generally varies b/w $\frac{1}{3}$ to $\frac{1}{2}$ of melting point
also higher the cold work, lower the Recrystallisation temperature

Adv of H.W:

→ No strain hardening

Lim of H.W:

→ Poor surface finish

→ Difficult to achieve dimensional accuracy

→ Handling hot materials is difficult

Adv of CW:

→ Increased strength & hardness

Lim of CW

→ Limited amount of deformation

Rolling

→ Process where metal is compressed b/w 2 rotating rolls for reducing cross-sectional area
→ Higher productivity & low cost
→ Many shapes like I, T, L are possible but not very complex shapes
→ Normally hot working process unless mentioned cold working.

Forging

→ Operation where metal is heated & force is applied to manipulate metal in a way to obtain required final shape
→ Generally hot working
→ There are 2 types of operations

Drawing Out – Operation where metal gets elongated with reduction in cross-sectional area, so force is applied perpendicular to length axis

Upsetting – Operation where metal increases cross-sectional area with reduction in length, so force is applied parallel to length axis

→ There are 4 types of forging

Smith Forging – Traditional forging done openly / open dies by village blacksmiths by manual hammering / power hammers

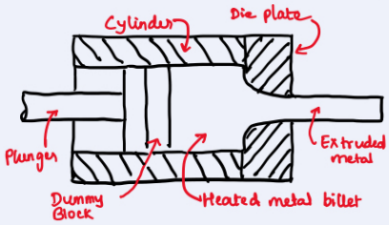
Drop Forging – Operation done in closed impression dies by drop hammers. Here force for shaping is applied in series of blows

Press Forging – Similar to drop forging, done in closed impression dies with exception that force is continuous squeezing by hydraulic press

Machine Forging – The material is only upset to get desired shape unlike drop/press forging

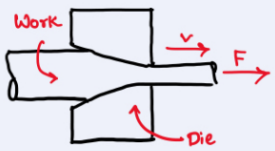
Extrusion

→ Process of confining metal in a closed cavity & allowing it flow from one opening so metal takes shape of opening
→ Equipment consists of cylinder / container into which heated metal billet is loaded
→ One end, die plate with necessary opening is fixed & other end plunger / ram compresses metal billet against container walls & die plate forcing it to acquire shape of opening



Wire Drawing

→ Process of wire drawing is to obtain wires from rods of bigger diameter through a die
→ Wire drawing die is conical in shape
→ End of wire is further reduced to point shape & inserted through die opening
→ This end is gripped on other side with gripper which would pull the wire through the die & then coiled round a power reel
→ Cold working process



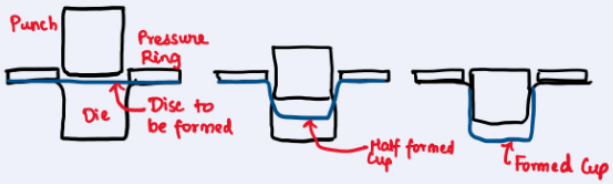
Sheet Metal Forming

→ Sheet metal is a plate with thickness less than 5mm

→ Operations are mostly cold working

→ Blank is first kept on die plate. The punch slowly descends on blank & forces to take cup shape formed by end of the punch, by the time it reaches bottom of die

→ Shallow drawing is defined as where cup height is less than half the diameter (Deep drawing)



Joining

→ Joining 2 or more parts to make a single part

→ Various joining processes are :

1) Mechanical Joining
2) Adhesive Bonding
3) Welding, Brazing, Soldering

General Considerations

1) Type of Joints

→ Butt 

→ Lap 

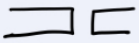
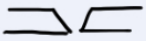
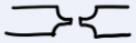
→ Corner 

→ Tee 

→ Edge 

2) Edge Preparation

→ When thickness ↑, edge prepared so heat can penetrate entire depth

1)  Straight
2)  Single V
3)  Single U
4)  Double V
5)  Double U

3) Cleaning

→ Remove oily substances (Organic solvents like acetone & CCl_4)

→ Heavier oxide films removed by acid pickling, wire brushing or emery

Welding

→ A localised coalescence of metals obtained by heating to a suitable temperature with/without application of & with/without use of filler material

→ Fusion welding (Non-pressure, with additional filler metal & heat) are 3 types

Electric Arc

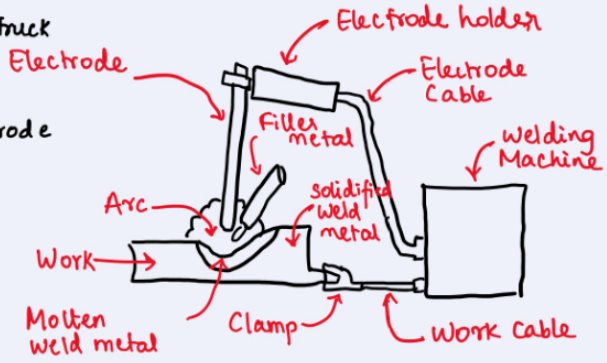
→ Welding process which makes use of heat produced by electric arc to fuse metallic pieces

Principle of Arc :

→ Arc is generated b/w 2 conductors of electricity, cathode & anode.
e^- are liberated from cathode & move towards anode.
When they strike the anode at high velocity, heat of 6000°C is generated

Procedure :

→ Tip of electrode touches workpiece, arc struck
→ Electrodes move 2-4 mm
→ High heat melts workpiece & tip of electrode
→ Molten metal transfered as globules
→ Deposited metal fills joint & bonds to form single piece of metal
→ Electrode moved along surface to weld completely.



Electrodes

Consumable

→ Weld metal under arc & tip of electrode melt & mix together
→ Made of materials like steel, copper, brass, bronze, Al, cast iron etc.,
→ Can be bare or coated

Non-Consumable

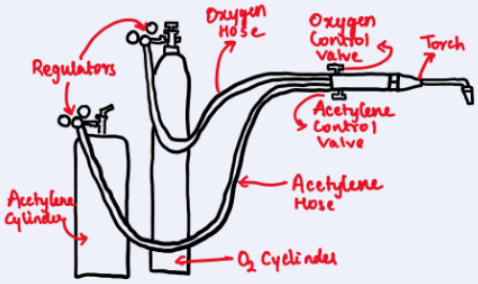
→ Made of Carbon, Graphite (DC welding) or Tungsten (Ac & DC welding)
→ Filler metal deposited through seperate filler rod

Coating

→ Gives off inert gas under heat, shields molten pool from atmospheric O_2, H_2, N_2 & reduces contamination of weld metal
→ Coating provide flux, which mixed with oxides & other impurities present in puddle forms slag
→ Slag floats on top & protects from air & helps to cool
→ Arc is stabilised using required elements
→ Physical properties & strength also improved by special alloying elements

Gas Welding

→ Oxy-acetylene gas is used as fuel to derive heat by combustion
→ The joint is completely melten to obtain fusion by using sufficient heat



→ Heat from combustion of fuel gas
→ Joint completely melted for fusion
→ Free Acetylene → Highly explosive, stored in strong cylinder, filled with 80% porous material, rest with acetone
→ Acetylene & O_2 brough to torch, mixed & flowed out through nozzle
→ Acetylene valve slightly opened, friction spark lighter used
→ Adjustment of flame depends on type of material to be joined
→ Combustion in 2 stages :

$C_2H_2 + O_2 \rightarrow 2CO + H_2 + 448\ KJ/mol$ (18.76 MJ/m^3 of acetlyne)

$4CO + 2H_2 + 3O_2 \rightarrow 4CO_2 + 2H_2O + 812\ KJ/mol$ (35.77 MJ/m^3)

Flames

Neutral

→ Acetylene fully burned, all heat released
→ Most desirable flame

Reducing

→ Less O_2
→ Carburising
→ Third phase b/w blue flame & white cone
→ Reddish & longer flame
→ Not for general use, Only for high C steels, Cast irons etc.,

Oxidising

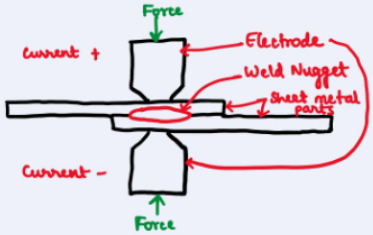
→ More O_2
→ Inner white cone is small
→ Tip temperature is high
→ Used for non-ferrous alloys

Resistance Welding

→ Both heat & pressure applied, but no filler metal / flux is added
→ Heat is obtained by heating effect of electrical resistance
→ A low voltage & high current is passed through joint for a short time causing joint to get heated up & metal fuses together under this pressure.

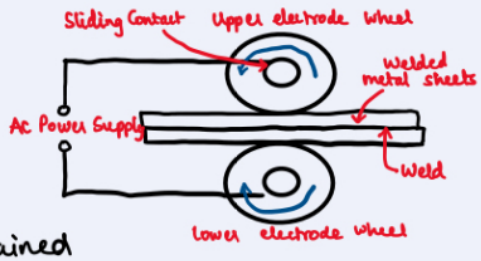
$H = KI^2RT$

- H: Heat (J)
- K: Heat loss constant
- I: Current (A)
- R: Resistance (Ω)
- T: Time (s)



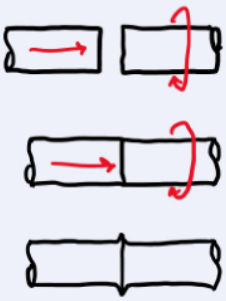
→ 2 electrodes, 1 fixed & other fixed to a rocker arm for transmitting mechanical force from a pneumatic cylinder

Resistance Seam Welding



→ Specialised process of spot welding
→ Disc electrodes are continuously rotated so work pieces get advanced underneath them while at same time pressure on joint is maintained
→ Electrodes are never seperated

Friction Welding



→ Heat Obtained caused by friction b|w 2 parts
→ One part rotated at high speed & other axially axially alligned & pressed
→ Friction raises temperature
→ Rotation stopped abruptly, pressure increased, metals join

Brazing

→ The coalescence of joint using filler metal whose melting point above 450°c & below melting point of base metal
→ Uses capillary action
→ Widely used because of many advantages
→ Disimilar metals can be joined (Except Al & Mg)
→ Brazed joints are resonably strong but not useful for high temperature services

→ Joint should be extremely clean, otherwise filler metal won't flow
→ Fluxes (Mix of borax, boric acid, chlorides etc.,) are added to remove oxides

→ Copper based materials are used for brazing ferrous materials
→ Silver brazing uses silver brazed filler metal & gives high strength joints
→ Heat sources are used for brazing like oxy-acetylene torch, induction heating etc.,

Soldering

→ Joining metals using filler metal & capillary action

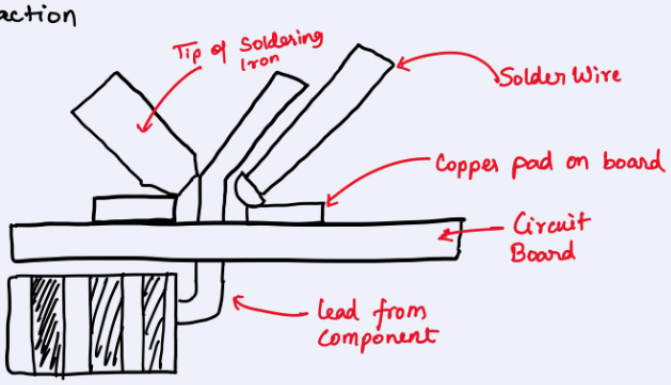
→ Strength of joint limited by strength of filler metal

→ Usually heat leak proof & low electrical resistance joints are used

→ Not suitable for high temperature services

→ Cleaning is done to give chemically clean surfaces using solvents, acid pickling etc.,

→ Flux is used to remove oxides & prevent oxidisation of filler metal
(rosin & rosin+alc, $ZnCl_2$, NH_4Cl)



→ Types of Soldering

Soft Soldering

→ Alloys of Sn, Pb have low MP

→ Used where no heavy load & high temp on joints

Hard Soldering

→ Alloys of Ag, Pb, Cu, Zn

→ MP b/w 300 – 600°C

→ Strong joints resist high temp

Fasteners

→ Small to large pieces of hardware to join objects together

Threaded Fastener

→ Bolts

→ Studs

→ Screws

Non-Threaded Fastener

→ Keys

→ Pins

→ Thread Application : hold parts together
move parts relative to others

Threads

External (Male)
→ Thread outside cylindrical body

Internal (Female)
→ Thread inside cylindrical body

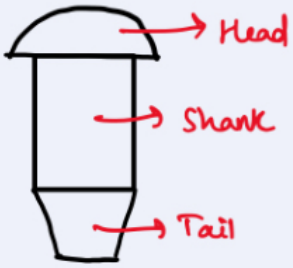
Right-Hand
→ Thread that will assemble when turned clockwise

Left-Hand
→ Thread that will assemble when turned anti clockwise

Thread terminologies

→ Crest - peak edge
→ Root - bottom
→ Thread angle - angle b/w thread faces
→ Major diameter - Largest diameter on internal / external cylinder
→ Minor diameter - Smallest diameter on internal / external cylinder
→ Pitch - Distance b/w crests
→ Lead - Distance screw advances when turned 360°

Rivets



→ Semi-permanent joints
→ Used in ship building, bridges, tanks etc.,
→ Two metal sheets are held together & holes are drilled through them
→ Hole diameter is kept slightly more than shank & rivet is passed through such that head rests against an anvil
→ Tail is forged to form another head by exerting pressure on die bar

Rivets

Lap Joint

→ Plates overlap
→ All rivets pass through plates

Butt Joint

→ Plates lay in same plane