# SREENIVASA INSTUTUTE OF TECHNOLOGY AND MANAGEMENT STUDIES

## CHITTOOR, ANDHRA PRADESH- 517127

**AN ISO 9001:2015 CERTIFIED INSTITUTION**

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## DEPARTMENT OF MECHANICAL ENGINEERING


NOTES FOR

# MANUFACTURING TECHNOLOGY

# UNIT-I

## METAL CASTING

# Unit - II METAL CASTING

## Fundamentals of casting:-

Manufacturing involves turning raw materials to finished products to be used for some purpose.

In fact, manufacturing involves a series of related activities and operations such as:
① Product design and development ② Material selection ③ Process planning ④ Inventory control ⑤ Quality Assurance ⑥ Marketing.

## classification of Manufacturing processes:-

① Casting:- ⓐ Sand casting ⓑ shell mould casting ⓒ Die casting ⓓ permanent mould casting ⓔ centrifugal casting.

② Metal forming processes:-
① Rolling ② Extrusion ③ Sheet metal operations ④ Wire Drawing ⑤ Press forging.

③ Fabrication:- ① welding:- Gas welding, Arc welding, Thermit welding, Brazing

④ Metal removing processes:-
① Machining:- ① Turning ② Drilling ③ Milling ④ shaping ⑤ Grinding & finishing.

## Casting:-

Casting means the pouring of molten metal into a mould, where solidification occurs. After the molten metal solidifies in the mould cavity the product is taken out to get the casting.

Casting is preferred because of the following reasons:-

① It is cheap and direct way of producing a shape with desired mechanical properties.

② Casting is best suited when different properties are required in different sections of product.

③ Cost associated in giving details by casting process is minimum when ... cost in mechanical working

4. It is possible to cast practically any material, be it ferrous or non-ferrous.

5. It is possible in the casting process to place the amount of material where it is exactly required. As a result, weight reduction in design can be achieved.

6. The dimensional accuracy and surface finish achieved by normal sand casting process would not be adequate for final application in many cases.

Casting Terms:-

7. Objects of large size can be produced easily.

8. The objects having complex and complicated shapes, which cannot be produced by an other method of production, can usually be cast.

Disadvantages:-

① The time required for the process of making casting is quite long.

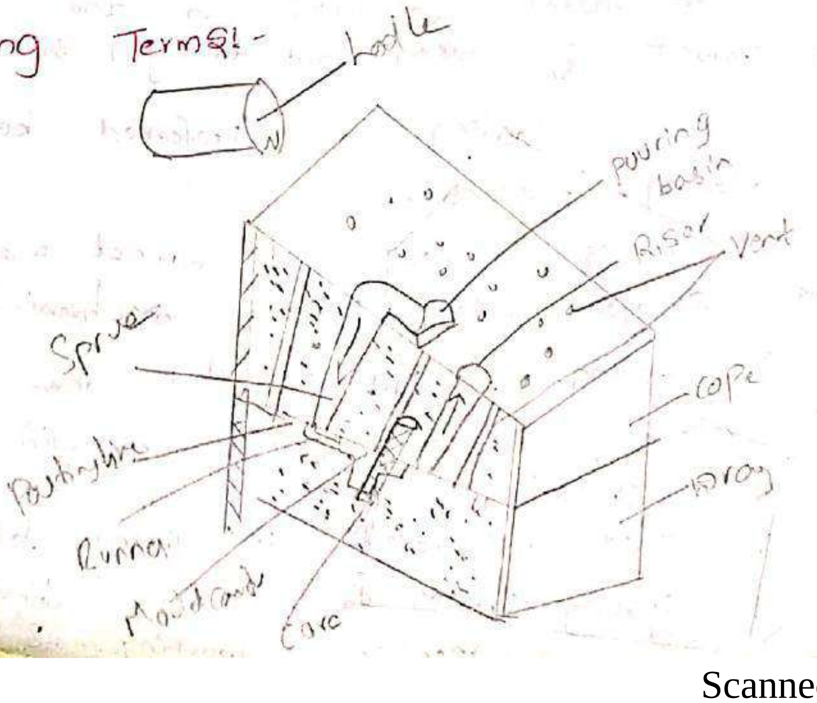
② Metal casting involves melting of metal which is a highly energy consuming process.

③ The working conditions in foundaries are quite bad due to heat, dust, fumes, slag etc. Compare to other process.

④ Metal casting is still highly labour-intensive Compared to other processes.

④ The productivity is less than other automatic processes:

Casting Terms:-



① flask:- A moulding flask is one which holds the sand mould intact. Depending upon the position of the flask in the mould structure, it is referred to various names such as drag, cope and cheek. It is made of wood for temporary applications or more generally of metal for long-term use.

② Drag:- Lower - moulding flask

③ cope:- upper - moulding flask

④ cheek:- Intermediate moulding flask used in 3 piece moulding.

⑤ pattern:- Pattern is a replica of an object to be made by casting

⑥ parting line:- This is the dividing line between the two moulding flasks that makes up the sand mould. In split pattern, it is also the dividing line b/n two halves of pattern.

⑦ Bottom Board:- This is a board normally made of wood, which is used at the start of the mould making. The pattern is first kept on the bottom board, sand is sprinkled on it, and then the ramming is done on the drag

⑧ Core:- It is used for making hollow cavities in castings.

⑨ Pouring Basin:- A small funnel-shaped cavity at the top of the mould into which the molten metal is poured.

⑩ Sprue:- The passage through which the molten metal from the pouring basin reaches the mould cavity. In many cases, it controls the flow of metal into the mould.

⑪ Runner:- The passage ways in the parting plane through which molten metal flow is regulated before they reach the mould cavity.

⑫ Gate:- The actual entry point through which molten metal enters the mould cavity.

⑬ chaplet:- chaplets are used to support cores inside the mould cavity to take care of its own weight.

⑭ chill:- chills are metallic objects, which are placed in the mould to increase the cooling rate of castings to provide uniform or desired cooling rate.

It is a reservoir of molten metal provided in the casting so that hot metal can flow back into the mould cavity, when there is a reduction in volume of metal due to solidification.

Steps involved in Casting process:-

1. Preparation of a Pattern
2. Preparation of Moulding Sand
3. Preparation of mould and core.
4. Melting the metal
5. pouring of metal into the mould.
6. Cooling and solidification
7. Removing the casting from the mould.
8. fettling. (i.e; cutting off the unwanted projection in the form of gates, risers, etc.,)
9. Heat Treatment
10. Testing and inspection.

foundry:- foundry is a plant where the castings are made.

All the foundries are basically two types.

1. Jobbing foundries:-

(1) These foundries are most independently owned.

(2) They produce castings on contract, with in their capacity.

2. Captive foundries:-

These foundries are usually a department of a big manufacturing company.

## Pattern:-

A Pattern is a replica of the Object to be made by casting process with some modifications. The main modifications are
(a) the addition of pattern allowances
(b) the Provision of core prints.

### Requirements of a good pattern:-

(1) Light in weight (2) convenient to handle
(3) Simple in design and ease of manufacture. (4) Smooth and wear resistant surface (5) Retain its dimension and rigidity during the definite service life.
(6) High strength and long life.
(7) Secure the desired shape and size of the casting
(8) cheap and readily repairable.

### Pattern Materials:-

(1) Wood (2) Metal (3) plastic (4) Quick setting Compounds.

(1) Wood:-
1. The wood used for pattern making should be properly dried and seasoned
2. It should be straight grained
3. It should be free from insects and excessive sap wood.

Adv:- (1) cheapness (2) Ease of availability (3) lightness.
(4) Ease of joining.

Limitations:-
(1) Easily affected by moisture, its shape changes by change in moisture content.
(2) It wears out quickly by sand abrasion.
(3) It cannot stand rough usage.

The following types of wood are:-

(1) White pine:-
(a) It is most widely used wood.
(b) It is soft and easy to work.

(2) Mahogany:- When straight grained, it be worked easily.
(2) It is harder and more d...

③ Mapple, Kirch and cherry:-

① These woods tend to warp in large sections, as such these should be used for small patterns only.

② They are heavier and harder than white pine.

② Metal:- Where durability and strength are required, patterns are made from metals.

② Metal pattern can be either cast from master wooden pattern or may be machined by the usual methods of machining.

Adv:-

① Resistant to wear, abrasion, corrosion.
② Posesses a smooth surface. ③ Do not undergo deformation in storage. ④ More durable and accurate in size than wooden patterns.

Limitations:

① Cannot be repaired easily. ② More Expensive than wooden patterns. ③ Heavier than wooden patterns.

The following metals are commonly used for pattern making:-

① Aluminium:- ⓐ It is light in weight
② It is corrosion resistant

② Brass:- ① It has a smooth, closed pore structure with fine grain

③ Cast iron:- ① Cast iron can be used as a pattern material.
② It is cheaper and more durable than other metals.

③ Plastic:-
① Highly resistant to corrosion
② Lighter and stronger than wood pattern.
③ The production process is facilitated
④ No moisture absorption.

④ Quick setting compounds:-

① Gypsum patterns are capable of producing castings with intricate details and to very close tolerances.

② Gypsum can be easily formed, has plasticity and can be easily repaired.

## Types of patterns:-

① Single - piece pattern:-

1. It is simplest of all the patterns and the cheapest.

2. As the name indicates, they are made of a single piece as shown in figure.

3. This type of pattern is used only in cases where the job is very simple and doesnot create any withdrawl problems.

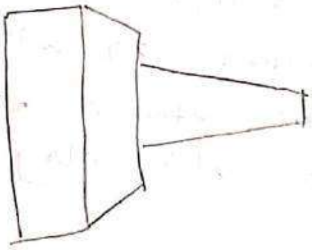
4. This pattern is expected to be entirely in the drag.

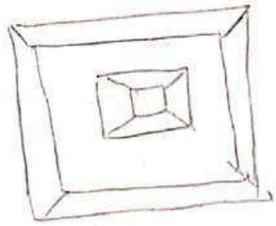
5. Its use can be made to a limited extent of production only since its moulding involves a large number of manual operations like gate cutting, providing runners and risers and the like.

**Application:-**

① stuffing box

② Gland of Steam Engines





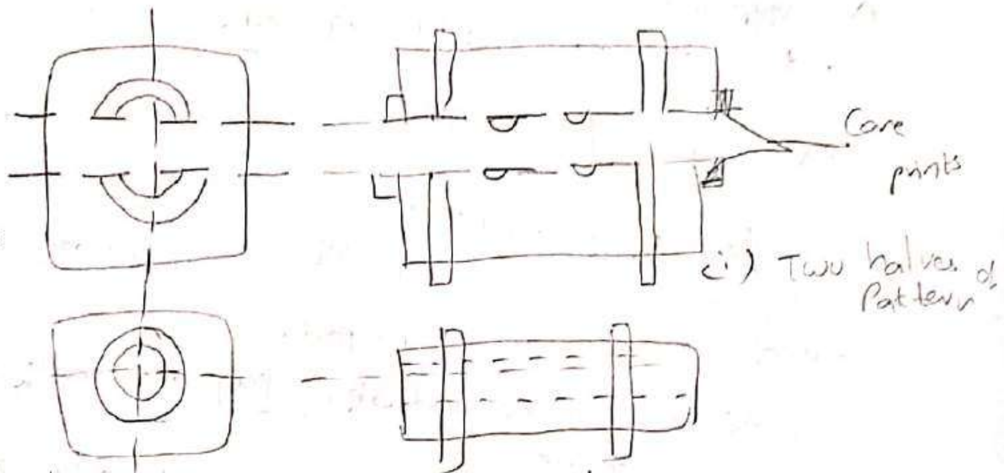
Solid Pattern

② split pattern (a)

Most of the patterns are not made in a single piece because of the difficulties encountered in moulding them. In order to eliminate this difficulty, some patterns are made in two (or) more pieces.

A pattern consisting of two pieces is called a two piece split pattern. one-half of the pattern rests in the lower part of the moulding box known as drag and the other half in the upper part of the moulding box known as cope. The line of separation of the parts is called parting line.

Applications
① Lap joint
② Dowel joint

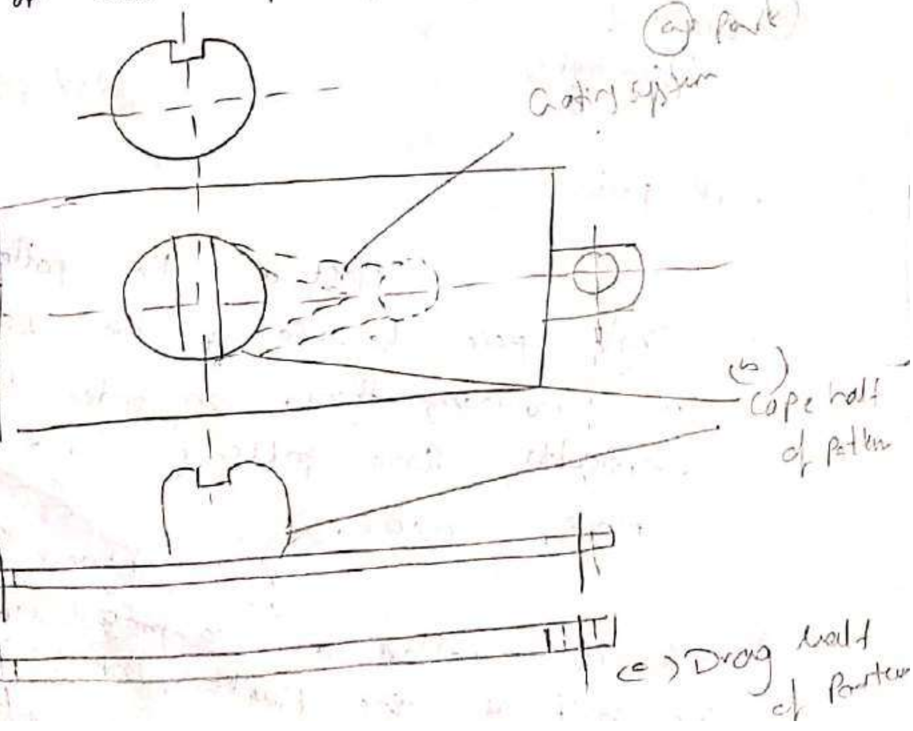



③ Cope and drag pattern:-

(ii) Prepared Casting

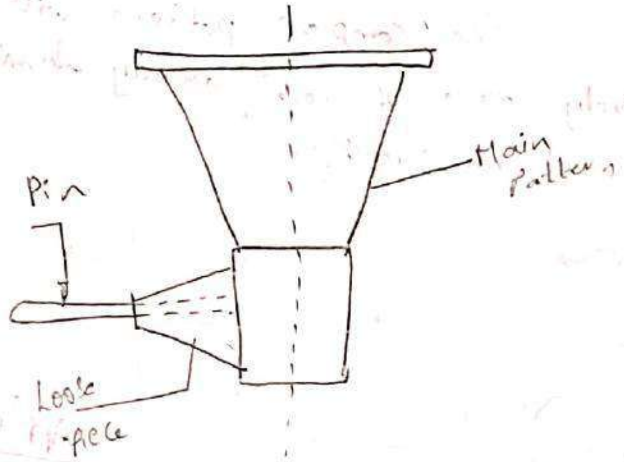
When very large castings are to be made, the complete pattern becomes too heavy to be handled by a single operator. Such a pattern is made in two parts which are separately moulded in different moulding boxes. After completion of the moulds, two boxes are assembled to form the complete cavity, of which one part is contained by the drag and the other in cope. Here the cope and drag halves of the pattern along with the gating and rising systems are attached separately to the metal or wooden plates along with the alignment pins.

App:-
① Flange pipe
② Water jacket of JCB [illegible]



(4) Loose piece pattern:-

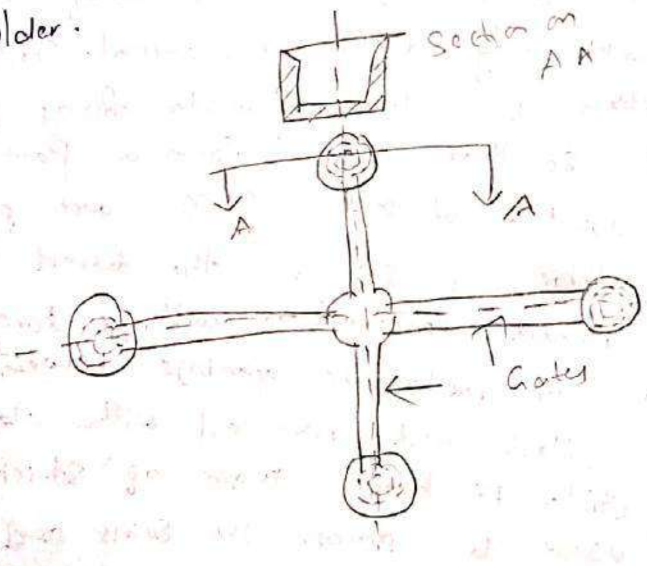
In some cases, a pattern has to be made with projections a over hanging parts. These projections make the removal of the pattern difficult. Therefore such projections are made in loose pieces and are fastened loosely to the main pattern by means of wooden or wire dowel pins. These pins are taken out during moulding operation. After moulding the main pattern is with drawn first and then the loose piece is removed by using a lifter.




Applica
(1) Rotor hub
(2) Axel pin

(5) Gated patterns:-

In production, where several small castings are required, gated patterns are used. This is an improvement over the simple pattern where the gating and runner system are integral with the pattern. This would eliminate hand cutting of the runners and gates and help in improving the productivity of a moulder.

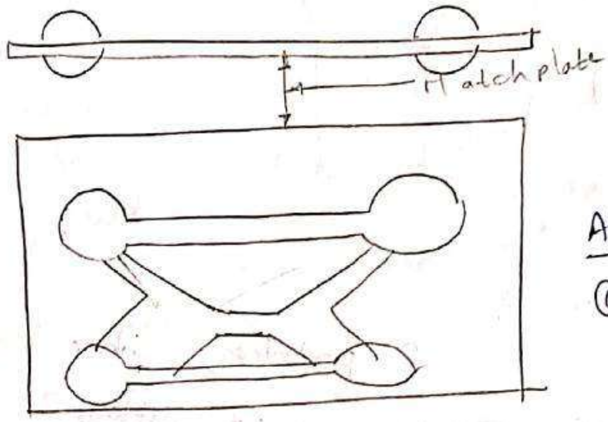



Appli:-
Corner bracket

⑥ Match plate patterns:-

Here, the cope and drag patterns along with the gating and the risering are mounted on a single matching metal or wooden plate on either side as shown in fig. on one side of the match plate, the cope flask is prepared and on the other, the drag flask. After moulding when the match plate is removed, a complete mould with gating is obtained by joining the cope and the drag together.

The complete pattern with match plate is entirely made of metal, usually aluminium, for its light weight and machinability.




Applⁿ :-
① piston rings of I.C Engine

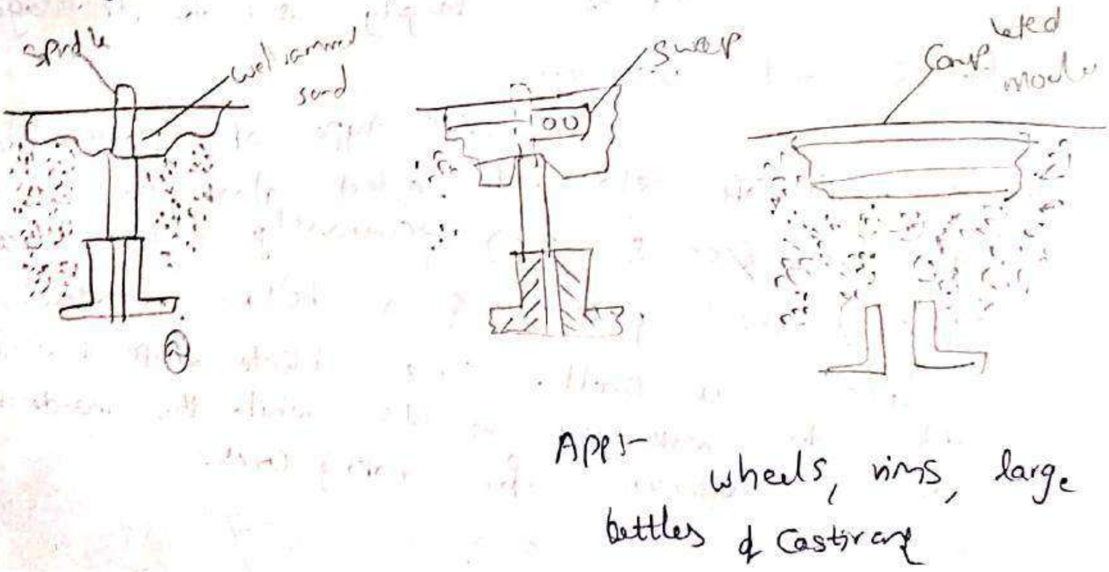
⑦ Skeleton pattern:- When a fewer large castings are required, it would require a tremendous amount of timber, which may not be economical. In such cases, the pattern is made of wooden frame and rib construction so that it will form a partially or interior outline of the casting and provide the general colour & size of the desired casting. The ribbed construction with a large number of square or rectangular openings between the ribs is filled and rammed with clay sand, A strike off board known as strickle board is used to scrape the excess sand out of the spaces between the ribs so as to make the exterior surface even with the outside of the skeleton.

Applications:- Turbine
Water pipes
L bends etc.

⑧ Sweep pattern:-

A sweep is a template of wood or other material which has contour corresponding to the shape and size of casting.

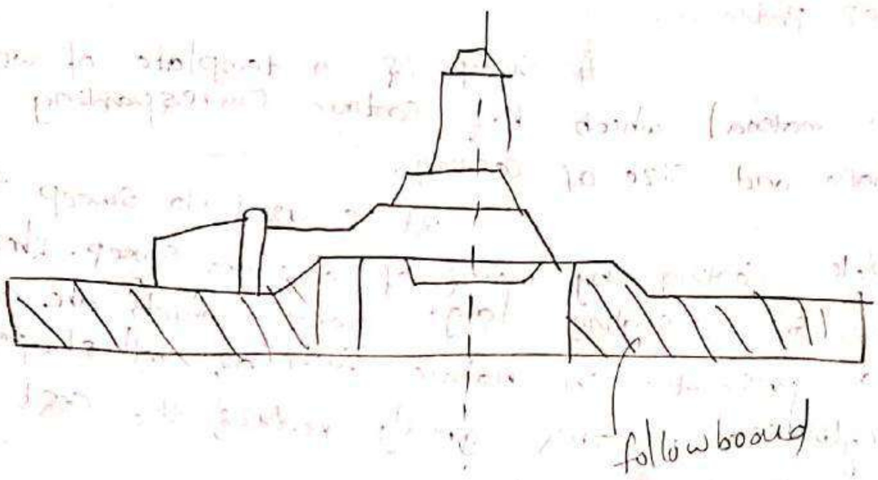
It is used to sweep the complete casting by means of a plane sweep. These are used for generating large shapes, which are axi-symmetrical or prismatic in nature such as bell shaped or cylindrical. This greatly reduces the cost of a 3-dimensional pattern.




Appl:- wheels, rims, large bottles & castings

9) follow-Board pattern:-

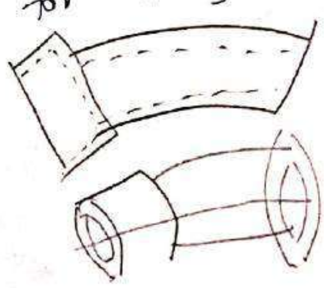
This type of pattern is adopted for those castings where there are some portions which are structurally weak and if not supported properly are likely to break under the force of ramming. Hence, the bottom board is modified as a follow board to closely fit the contour of the weak pattern and thus support it during the ramming of the drag. During the preparation of the cope, no follow board is necessary because the sand that is already compacted in the drag will support the fragile pattern.




10) Shell pattern:-

It is largely used for drainage fittings and pipe work.

This type of pattern is usually made of metal and parted along the centre line, the two sections being accurately dowelled together. The shell pattern is a hollow construction like a shell. The outside shape is used as a pattern to make the moulds, while the inside is used as a core box for making cores.



Moulding sand types:-

① According to their clay bonding material:

① Natural sand:- It contains sufficient amount of binding clay and therefore, no more binder is required to be added.

② Synthetic sand:- It is one which is artificially compounded by mixing sand and selected type of clay binders etc, These sands have the following advantages:-

① lower cost in large volume ② widespread availability.

② According to their use:-

① Green Sand:-

1. The sand in its natural or moist state is called green sand.

2. It is a mixture of silica sand with 20 to 30% clay, having total amount of water from 6 to 10%.

3. The green sand moulds are used for small size castings of ferrous & non ferrous metals.

② Dry sand:-

When the moisture from the green sand is evaporated by drying or baking after the mould is made is called dry sand mould.

The dry sand moulds have greater strength, rigidity and thermal stability. The dry sand moulds are used for large and heavy castings.

③ Loam sand:-

1. The loam sand consists of as high as 50% of clay contents.

2. It is used for loam moulding of large grey-iron castings.

4. facing Sand:-

This sand is used next to the pattern to obtain clearer and smoother casting surfaces. Generally sea coal (or) coal dust (finely divided bituminous coal of 2 to 8%) is mixed with the system sand to improve the mouldability and surface finish.

(5) parting Sand:-

Parting sand is purely clay-free silica sand which is sprinkled on the pattern and the parting surfaces of the mould so that the sand mass of cope and seperate with out clinging and do not stick to the pattern.

(6) Backing Sand (or) floor Sand:-

This is normally the reconditioned foundry sand and is used for ramming the bulk of the moulding flask.

The moulding flask is completely filled with backing sand after the pattern is covered with a thin layer of facing sand.

(7) Core Sand:-

A sand used for the preparation of the cores is called core sand.

Composition of green Sand:-

1. Silica - up to 75%
2. clay - 8-15%
3. Bentonite - 2-5%
4. Coal dust - 5-10%
5. Water - 7-8%

Properties of Moulding Sand:-

(A) Moulding sand properties:-

(1) Permeability:- It is the property to allow gases to escape easily from the mould.

Higher the silt content of sand, the lower is gas permeability. If the mould is rammed too hard, its Permeability will decrease and vice-versa.

It is measured in number such as 60, 80, 100, 120 etc.

(2) Strength (or) Cohesiveness:- It is defined as the property of holding together of sand grains.

A moulding sand should have ample strength so that mould does not collapse.

The strength of the moulding sand grows with density, clay content of the mix and decreased size of sand grains. Thus as the strength of the moulding sand increases, its porosity decreases.

(3) Refractoriness:- It is the ability of the moulding sand mixture to withstand the heat of melt without showing any sign of softening or fusion.

It increases with the grain size of sand and its content of and with the diminished amount of impurities.

(4) plasticity or flowability:- It should be of plastic nature so that it can easily take any desired shapes.

(5) Collapsibility:- This is the ability of the moulding sand mixture to decrease in volume to some extent under the compressive forces developed by the shrinkage of metal during freezing and subsequent cooling.

This property permits the moulding sand to collapse easily during shake out and permits the core to collapse easily during its knock out from the cooled casting.

Lack of collapsibility in the moulding sand and core may result in the formation of cracks in the casting.

(6) Adhesiveness:- This is the property of sand mixture to adhere to another body.

The moulding sand should cling to the sides of the moulding boxes so that it does not fall out when the flasks are lifted and turned over.

This property depends on the type and amount of binder used in sand mix.

(7) Coefficient of Expansion:- The sand should have low coeff of expansion.

(8) chemical resistivity:- The sand should not chemically react or combine with molten metal.

Sand Testing:-

In order to meet the required level of accuracy and surface finish of castings the mouldings should be of proper quality. proper quality of the moulding sand results in sound castings that will decrease the cost per unit and increase the production,

Periodic tests are necessary to determine the essential qualities of foundry sand. The properties of the moulding sand depend upon shape, size, composition and distribution of sand grain. These are standard tests to be used which are given in relevant Indian standards.

Scanned by CamScanner

Tests are conducted on a sample of standard sand. The moulding sand should be prepared exactly as is done in the shop on the standard equipment and then carefully enclosed in a closed container to safeguard its moisture content.

B.I.S has recommended the following tests.

1. Permeability test
2. Fineness test (or) Sand grain size test
3. Strength test
4. Moisture content test
5. clay content test
6. Mould hardness test

1. Permeability test: permeability is the measure of its ability to permit air to flow through it. It is measured in terms of "permeability number".

Procedure: To carry out this test, a test specimen of moulding sand (50.8 mm dia x 50.8 mm long) is placed in a specimen tube. Time taken for 2000 $cm^3$ of air at a pressure of 980 pa (10 g/$cm^2$) to pass through the specimen is noted. Then, the permeability number, P is given as:

$$P = \frac{V \times H}{P \times A \times t}$$

where V = volume of air = 2000 $cm^3$

H = Height of sand specimen = 50.8 mm = 5.08 cm

P = Air pressure = 10 g/$cm^2$

A = cross sectional area of sand specimen

$= \frac{\pi}{4} \times (5.08)^2 = 20.268 \, cm^2$.

t = Time in minutes for complete air to pass through.

Substitute the above value

$$P = \frac{2000 \times 5.08}{P \times 20.268 \times t} = \frac{501.28}{P \cdot t}$$

This permeability number is a relative number. It does not necessarily tell the permeability of a mould made with the same sand which depends on the compactness of the sand.

2. Strength Test:- The strength of the moulding sand can be carried out on the universal sand strength testing machine. The strength can be measured in compression, shear and tension. The sands that could be tested are green sand, dry sand or core sand.

(1) Green Compression strength:- It refers to the stress required to rupture the sand specimen under compressive loading. The sand specimen is taken out of the specimen tube and is immediately put on the strength testing machine and force required to cause the compressor failure is determined.

The green strength of sands is generally in the range of 30 to 160 kPa.

3. Moisture content test:- Moisture content may be determined by loss of weight after Evaporation.

procedure:-

To test the moisture of a moulding sand a carefully weighted test sample of 50g is dried at a temp of 105°c to 110°c for 2 hours by which time all the moisture in the sand would have been evaporated. The sample is then weighted. The weight difference in grams divided by the weight of sample (50g) and multiplied by 100 gives the percentage of moisture contained in the moulding sand.

4. Clay Content test:- The clay content of moulding sand is determined by dissolving or washing it off the sand.

Procedure:-

① A 50g sample of moulding sand is dried at 105 to 110°c. This dried sample is taken in a one litre glass flask and added with 475 ml of distilled water and 25 ml of a 1% NaOH solution (NaOH 25 g per litre). This sample is thoroughly stirred.

② After the stirring for a period of 5 minutes, the sample is diluted with fresh water up to a 150 mm graduation mark and sample is left undisturbed for 10 minutes to settle. The sand settles at the bottom and the clay particles washed from the sand would be floating in water.

⑤ Mould hardness test:- The mould hardness is measured by a method similar to the Brinell hardness test.

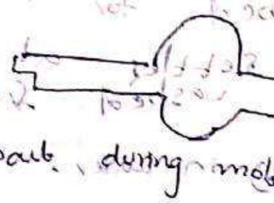
Procedure:- A spring loaded steel ball with a mass of 0.9 kg is indented into the standard sand specimen prepared. The depth of indentation can be directly measured on the scale which shows units 0 to 100. When no penetration occurs, then it is a mould hardness of 100 and when it sinks completely the reading is zero indicating a very soft mould.

# Defects in casting :-

(1) Blowholes (2) Mis run (3) cold shut
(4) MisMatch (5) Drop (6) fins (or) flashes
(7) fusion (8) Metal penetration (9) cut (or) Wash
(10) Scars and blisters (11) Hot tears (12) Swell
(13) Slag inclusion (14) Sponginess (15) Slag holes
(16) Buckle (17) Scab

(1) MisMatch :- The defect caused due to misalignment of upper and lower part of the casting and misplacement of the core at parting line

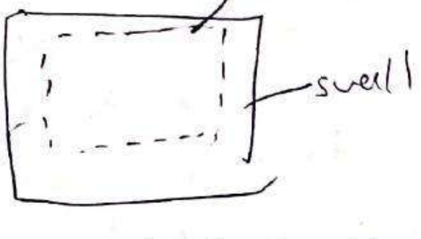
Cause :-



(1) Improper alignment of upper and lower part during mold preparation.
(2) Mis alignment of flask.

Remedies :-
(1) check the alignment of flask
(2) correct mountings of pattern
(3) Proper alignment of the pattern or die part.

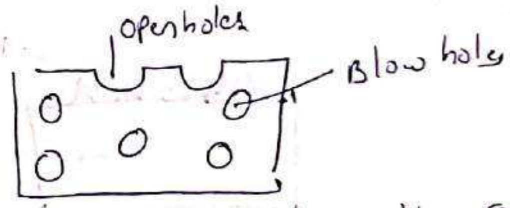
(2) Swell :- It is the enlargement of the mold cavity because of the molten metal pressure which results in overall enlargement of casting




Causes :-
(1) Improper ramming of the mold

Remedies :-
(1) The sand should be rammed properly evenly

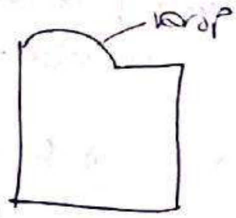
(3) Blow holes:- When gases entrapped on the surface of the casting due to solidifying metal, a rounded or oval cavity is formed called as blowholes. These defects are always present in the core part of the mould.




Causes:- (1) Excessive moisture in the sand
(2) Less permeability of the sand
(3) Sand grains are too fine
(4) Too hard rammed sand

Remedies:-
(1) The moisture content in the sand must be controlled and kept at desired level
(2) High permeability sand should be used
(3) Sand of appropriate grain size should be used.
(4) Sufficient ramming should be done

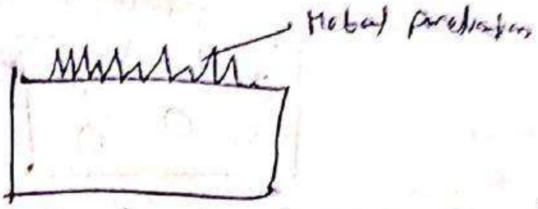
(4) Drop:- Drop defect occurs when there is cracking on the upper surface of sand and sand pieces fall into the molten metal.




Causes:-
(1) Insufficient fluxing
(2) Low strength of sand

Remedies:-
(1) High strength sand should be used.
(2) There should be proper fluxing of molten metal.

(5) Metal penetration:-
These casting defects appear as an uneven and rough surface of the casting. When the size of sand grains is larger, the molten fuses into the sand and solidifies giving up metal penetration defect

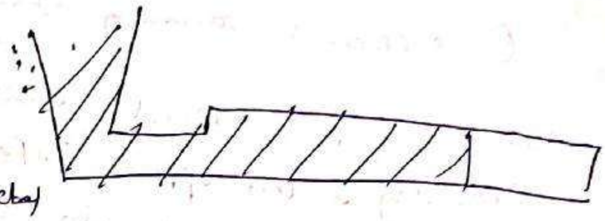



Causes:-
It is caused due to low strength, large permeability & soft ramming of sand

Remedies:-
It can be eliminated by using high strength, low permeability

(6) Misrun:- When the molten metal solidifies before completely filling the mold cavity and leaves a space in the mold called as misrun

Causes:-



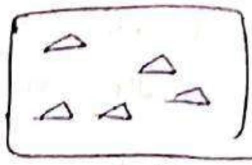
(1) Low fluidity of the molten metal
(2) low temp of molten metal
(3) Too thin section

Remedies:- (1) Increasing the pouring temp of molten metal
(2) Too thin section is avoided

(7) Slag Inclusion:- This defect is caused when the molten metal containing slag particles is poured in the mold cavity and it gets solidifies.

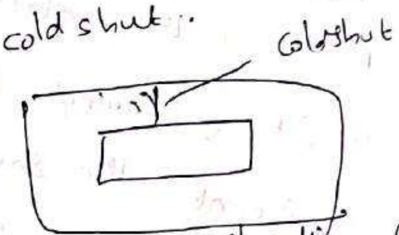
Causes:-

① The presence of slag in the molten metal



Remedies:- Remove slag particles from the molten metal before pouring into mold cavity

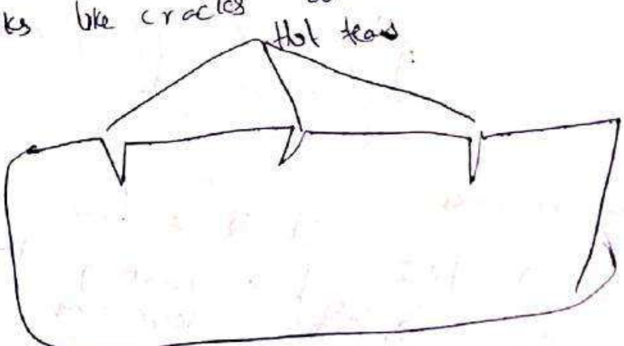
⑧ cold shut:- It is a type of surface defects and a line on the surface can be seen. When the molten metal enters into the mold from two gates and when these two streams of molten metal meet at a junction with low temp than each other & solidifies they do not fuse with create a cold shut.




Causes:- ① Lack of fluidity ② poor gating system

Remedies:- ① Improved gating systems
② proper pouring temp

⑨ Hot cracks:- When the metal is hot it is weak and the residual stress in the material cause the casting fails as the molten metal cools down. The failure of casting in this case is looks like cracks and called as hot cracks




Causes:- ① Improper mold design

Remedies:- ① proper mold design
② elimination of residual stress

(10) Fins:- A thin projection of metal, not considered as a part of casting it called as fins. It is usually occurs at the parting of the mold or core section.

Causes:-
① Incorrect assembling of mold and cores
② Improper clamping of flask may produce fins

Remedies:-
① Correct assembly of mold and cores

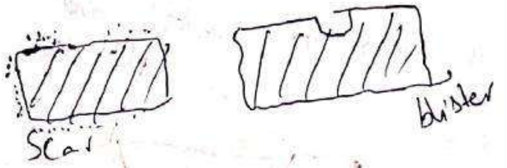
(11) Sponginess:- It is an internal defect in which there is a number of small cavities in close proximity present in the metal casting.

Causes:- ① It is caused due to dirt

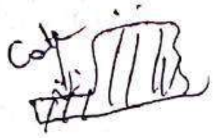
Remedies:- ① Prevent the entry of dirt
② prevent sand wash

(12) Scars and blisters:- A scar is a shallow blow. It generally occurs on a flat surface, where as a blow occurs on a convex casting surface.

A blister is a shallow blow like a scar with a thin layer of metal covering it.



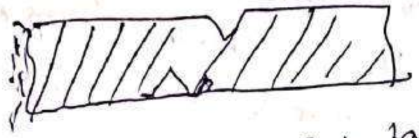

(13) Cut or wash:- It is a low projection on the drag face of a casting that extends along the surface, decreasing in height as it extends from one side of the casting to the other end.




It usually occurs in bottom gating castings in which the moulding sand has insufficient strength.

(14) Buckles:- A buckle is a long, fairly shallow, broad, Vee depression that occurs in the surface of flat casting.

It occurs due to sand expansion caused by the heat of metal, when the sand has insufficient hot deformation. It is also caused due to poor casting design.



(15) Rat tail:- A Rat tail is a shallow, angular depression in the surface of a flat casting and resembles a buckle except that it is not shaped like broad vee.

(16) pour short:- It occurs when the mould cavity is incompletely filled because of insufficient metal.

This defect occurs due to interruptions during pouring operation, and insufficient metal in the ladles being used to pour the molds.

## Pattern Allowances:-

While making patterns, certain dimensional allowances must be given in the pattern so that the casting obtained is of the required specifications.

1. Shrinkage allowance
2. Draft (or) taper Allowance.
3. Machining Allowance
4. Rapping (or) Shaking allowance
5. Distortion allowance.

(1) Shrinkage Allowance:-

(1) All metals shrink when cooling except Bismuth. This is because of the inter-atomic vibrations which are amplified by an increase in temperature.

Liquid shrinkage refers to the reduction in volume when the metal changes from liquid to solid state at the solidus temperature. To account for this risers are provided in the moulds.

Solid shrinkage is the reduction in volume caused when metal loses temp in solid stage.

The actual value of shrinkage depends on various factors specific to a particular casting namely the actual composition of the alloy cast, mould materials used, mould design, complexity of the pattern & component size.

(1) for example steel contracts to a higher degree compared to alluminium. The shrinkage also depends upon the metallurgical transformation taking place during the solidification.

(2) for Example White cast iron shrinks by about 21.0 mm/m during casting. However when annealed it grows by about 10.5 mm/m, resulting in a net shrinkage of 10.5 mm/m.

(2) Draft (or) Taper Allowance:-

It is given to all surfaces perpendicular to parting line.

Draft Allowance is given so that the pattern can be easily removed from the moulding material tightly packed around it without damaging the mould cavity.

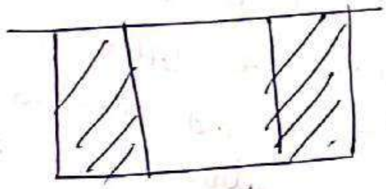
To reduce the changes of this happening, the vertical faces of the pattern are always tapered from the parting line. This provision is called draft allowance.

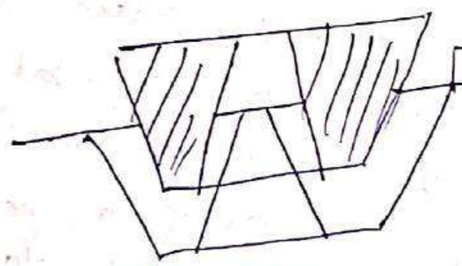
The amount of taper depends upon:-

(1) shape and size of pattern in the depth direction in contact with the mould cavity.

(2) Moulding methods (3) Mould Cavity (3) Mould materials.

Draft allowance varies with the complexity of the job. But in general, inner details of the pattern require higher draft than outer surfaces. The draft allowance given varies for hand moulding and machine moulding. More draft needed to be provided for hand moulding compared to machine moulding




(3) Machining Allowance:- The finish and accuracy achieved in sandcasting are generally poor and therefore, when the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining. Also ferrous materials would have scales on the skin, which are to be removed by cleaning. Hence, extra material is to be provided which is to be subsequently removed by machining or cleaning process. This depends on

dimensions, the type of casting material and the finish required. This may range from 2 to 20 mm. The machining allowance provided would ultimately have to be removed by machining. Hence cost of providing additional machining allowance should be carefully examined.

The type of machining allowance depends on metal cast, type of mold used the class of accuracy required on the surface and complexity of surface details.

(4) Shaking Allowance:- Before withdrawl from the sand mould, the pattern is rapped (all around the vertical faces to enlarge the mould cavity slightly, with a wooden piece from side to side. This is done so that the pattern a little is loosened in the mold cavity and can be easily removed. Hence a allowance is provided on the pattern i.e; the pattern dimensions are kept small in order to compensate the enlargement of mould cavity due to rapping.

It is a negative allowance and is to be applied only to those dimensions which are parallel to the parting line. One way of reducing this allowance is to increase the draft, which can be removed during the subsequent machining.

(5) Distortion Allowance:-

A metal when it has just solidified is very weak and therefore is likely to be distortion prone. This is particularly so for weak sections such as long flat portions, V, U section or in a complicated casting. The foundry practice should be to make extra material provision for reducing the distortion.

A casting will distort or wrap if

① It is of irregular shape

② All it parts do not shrink uniformly i.e; some parts shrinks while others are restricted from during so, it is U or V-shape.

When large number of castings is to be produced, hand moulding consumes more time, labour and also accuracy and uniformly in moulding varies, based on the methods of ramming moulding machines are classified as follows.

① Jolt machine

② Squeeze machine.

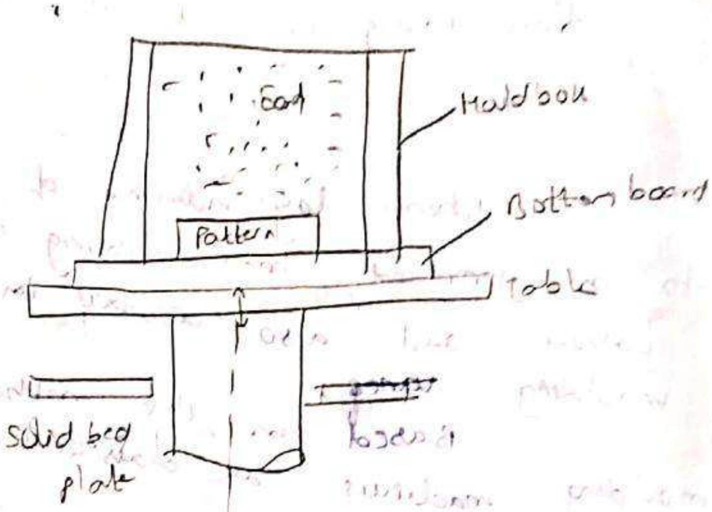
③ Sand slinger

① Jolt machine:- It consists of a flat table mounted on a piston-cylinder arrangement and can be raised or lowered by means of compressed air. In operation, the mould box with the pattern and sand is placed on the table. The table is raised to a short distance and then dropped down under the

influence of gravity against a solid bed plate.
The action of raising and lowering is called Jolting.

Jolting causes the sand particles to get packed tightly above and around the pattern. The number of "jolts" may vary depending on the size and hardness of the mould required. Usually <20 jolts are sufficient for a good moulding.

The disadvantage of this type is that, the density and hardness of the rammed sand at the top of the mould box is less when compared to its bottom portions.



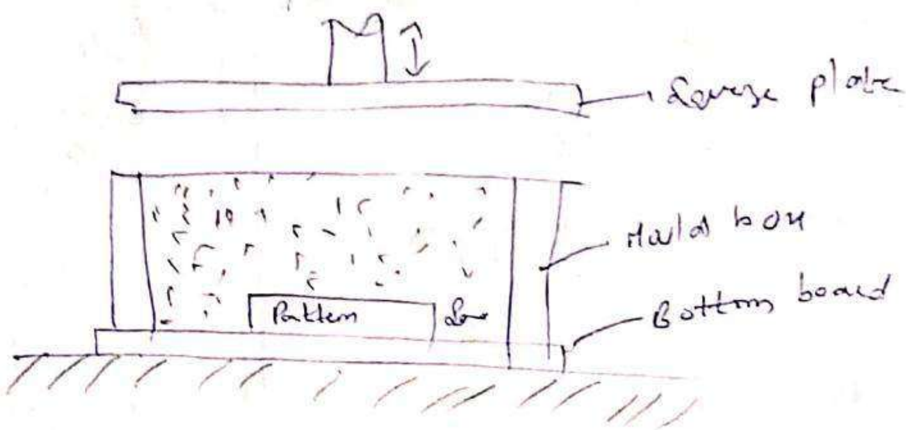

(2)

In squeeze machine, the mould box with pattern and sand in it is placed on a fixed table as shown in figure. A flat plate is brought in contact with the upper surface of the loose sand and pressure is applied by a pneumatically operated piston.

The squeezing action of the plate causes the sand particles to get packed tightly above and around the pattern.

Squeezing is continued until the mould attains the desired density.

The disadvantage of squeeze machine is that, the density and hardness of the rammed sand at the bottom of the mould box is less when compared to its top portions




Sand slinger :-

A sand slinger is an automatic machine equipped with a unit that throws sand rapidly and with great force into the mould box. It consists of a rigid base, sand bin bucket elevator, belt conveyor, ramming head and a swinging arm.

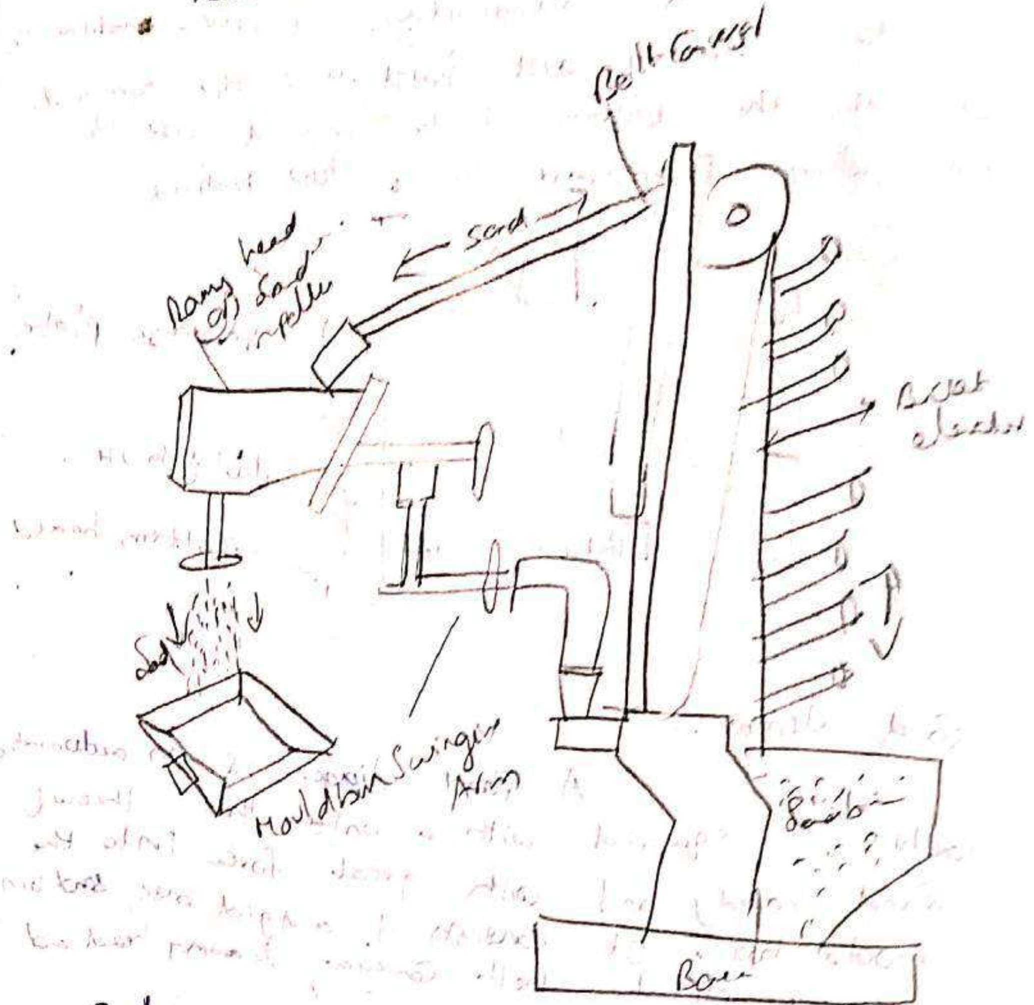
In operation the pre-mixed sand mixture from the sand bin is picked by the bucket elevator and is dropped on the to the belt conveyor.

The conveyor carries the sand to the ramming head inside which there is a rotating impeller having cup shaped blades rotating at high speeds

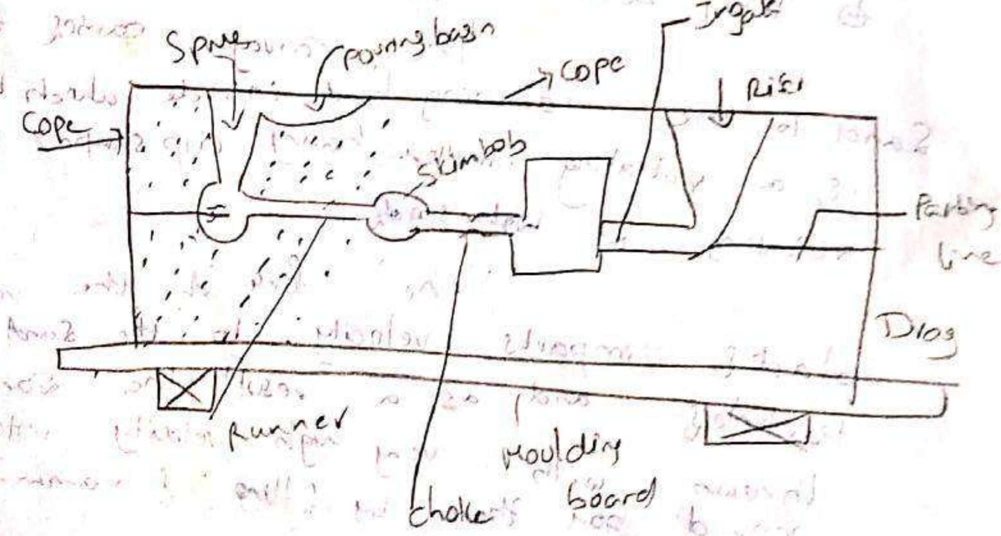
The force of the rotor blades imparts velocity to the sand particles and as a result the sand is thrown with very high velocity into the mould box there by filling & ramming the sand at the same time.

The density of the ramming sand can be controlled by varying th

Speed of the impeller, Rest of the operations, removal of pattern, gate etc, are done manually




Grating System:- The passage way in the mould meant for carrying molten metal to the mould cavity is known as gating system.



① Pouring basin:- The molten metal from the ladle is Poured into the pouring basin from where it moves into the sprue and through the runner to other areas.

② Sprue:- The vertical passage way through which the molten metal flows down from a parting plane is called sprue.

It is connected to the moulding Cavity by a gate or series of gates.

The function of the sprue is to provide an entrance to mould Cavity for the molten metal.

③ Sprue base or well:- At the bottom of the sprue is a reservoir for molten metal called sprue well. It serves to dissipate the kinetic energy of the falling stream of molten metal. The molten metal then changes direction and flows into the runner.

④ Runner:- It is generally located in the horizontal plane which connects the sprue to its ingates, thus letting the metal enter the mould cavity. The runners are normally made trapezoidal in cross section.

⑤ Skim bob:- It is an enlargement along the runner whose function is to trap heavier and lighter impurities such as dross or eroded sand. It thus prevents these impurities from going into mould cavity.

Gates:- These are also called the ingates, are the openings through which the molten metal enters the mould Cavity.

Gates depending on their position may be top, parting, bottom type and step gate.

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M.

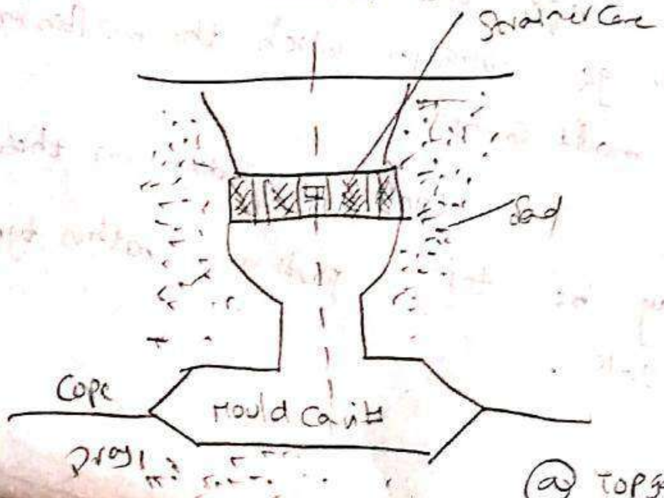
(1) Top gate :- Top gates are usually limited to Small and simple mould or large castings made in moulds of erosion resistant material. It is not advisable for light and oxidisable metals like aluminium & magnesium because of fear of entrapment due to turbulent pouring.

(2) parting gate :- As the name implies the metal enters the mold at the parting plane when part of the casting is in the cope and part in the drag, for the mould cavity in the drag it is a top gate and for the cavity in the cope it is a bottom gate. This is widely used.

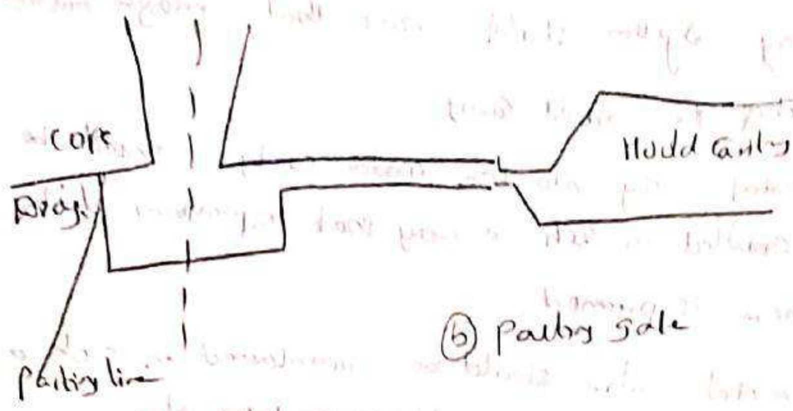
(3) Bottom gates :- The molten metal flows down the bottom of the mold cavity in the drag and enters at the bottom of the casting and rises in the mould & around the cores.

En bottom gating directional solidification is difficult to achieve because the metal continue to lose its heat into the mould cavity and when it reaches the riser, metal becomes much cooler.

(4) step gate :- The metal enters mould cavity through a no. of ingates which are arranged in vertical step




(a) Top gate




(b) Parting gate

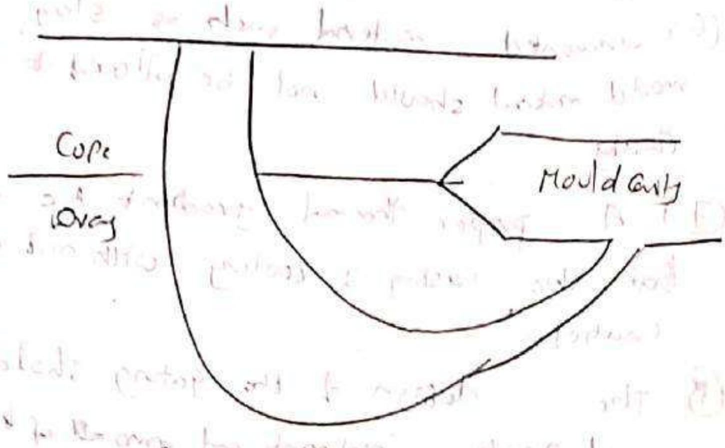



fig: Bottom gate

Gate ratio:- It is defined as the ratio of sprue area to total runner area to total gate area

Sprue area : Runner area : Gate area.

Riser:- Risers are reservoirs designed and located to feed molten metal to the solidifying casting to compensate for solidification shrinkage. Riser is a hole cut or moulded in the cope to permit the molten metal to rise above the highest point in the casting. It provides a visual check to ensure filling up of mould cavity.

Design requirements of the gating system:- Any gating system should aim at providing a defect free casting.

(1) The metal should flow smoothly into the mould with out any turbulence.

(2) The mould should be completely filled in the smallest time possible with out having to raise metal temperatures nor use higher metal head.

(3) The gating system should ensure that enough molten metal reaches the mould cavity.

(4) The metal entry into the mould cavity should be properly controlled in such a way that aspiration of the atmospheric air is prevented.

(5) The metal flow should be maintained in such a way that no gating or mould erosion takes place.

(6) Unwanted material such as slag, dross and other mould material should not be allowed to enter the mould cavity.

(7) A proper thermal gradient be maintained so that the casting is cooling with out any shrinkage of cavities.

(8) The design of the gating should be economical and easy to implement and removal after casting solidification.

## Riser Design:-

If during casting no riser is provided, the solidification will start from walls and liquid metal in the centre will be surrounded by a solidified shell and the contracting liquid will produce voids towards the centre of the casting. further cooling of the solid in centre sets up undesirable stresses in the casting.

The above problems are overcome by the provision of risers as these supply molten metal for a solidifying casting. To accomplish this, the risers must be large enough to remain liquid after the casting has solidified and must contain sufficient metal to provide for the contraction losses. Further, these should be so positioned that they continue to supply metal throughout the solidification period.

The risers should loose heat at a slower rate, since they are designed to solidify last so as to feed enough metal to heavy sections of the casting to make up for

Shrinkage before and during Solidification.

The riser size for a given casting can be obtained from the following relations:

① chvorinov's rule: - chvorinov's rule for metal casting states that total freezing (solidification) time for a casting is a function of the ratio of volume to surface area.

Solidification time, $t = C\left[\frac{\text{Volume}(V)}{\text{Surface area}(A)}\right]^2$ i.e,

$$t = C\left(\frac{V}{A}\right)^2$$

where C = A constant that reflects mould material, metal properties like latent heat & temperature.

Best riser is one whose $\left(\frac{V}{A}\right)^2$ is 10 to 15% larger than that of the casting.

Since V and A for the casting are known, $\left(\frac{V}{A}\right)_{riser}$ can be determined.

This rule helps in determining the solidification time of casting.

Limitations: Chvorinov's rule is not very accurate, since it does not take into account the solidification contract or shrinkage. This method is valid for calculating proper riser size for short freezing range alloys such as steel and pure metals.

② Caine's Method: - This method of determining riser size is based on experimentally determined hyperbolic relationship b/n relative freezing times and volumes of casting and the riser.

According to Caine, If the casting solidifies infinitely rapidly, the feeder (riser) volume should be equal to the solidification shrinkage of the casting and if the feeder and casting solidify at the same rate, the feeder should be infinitely large.

Relative freezing time or freezing ratio ($R_F$) is defined as:

$$R_F = \frac{(A/V)_{casting}}{(A/V)_{riser}}$$

volume ratio ($R_V$) is given as:

$$R_V = \frac{V_{riser}}{V_{casting}}$$

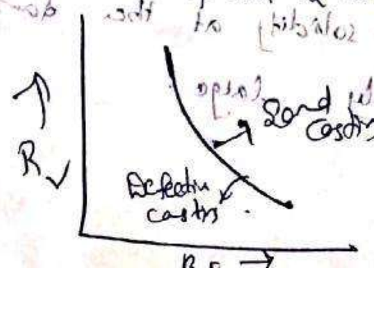
Then, Caines formula is given as $R_f = \frac{a}{R_V - b} + c$

where a = freezing characteristic constant for the metal
b = Contraction ratio from liquid to solid
c = Relative freezing rate of riser and casting.

Typical values of a, b, c for commonly used metals are given below:

| S.No | Cast-metals | a | b | c |
|---|---|---|---|---|
| 1. | Grey Cast iron | 0.33 | 0.03 | 1.00 |
| 2. | Cast-Iron, brass | 0.04 | 0.017 | 1.00 |
| 3. | Steel | 0.12 | 0.05 | 1.00 |
| 4. | Aluminium | 0.10 | 0.06 | 0.8 |
| 5. | Aluminium bronze | 0.24 | 0.17 | 1.00 |
| 6. | Silicon bronze | 0.24 | 0.17 | 1.00 |

For determining the riser size for a given casting the diameter and height of the riser are assumed. Then knowing the values of a, b & c, the values of $R_f$ and $R_V$ are calculated and plotted on hyperbolic curve figure. In case the values of $R_f$ and $R_V$ meet the above curve, then assumed riser size is satisfactory, otherwise a new assumption is made.



What will be the solidification time for a 1100 mm diameter and 33 mm thick casting of aluminium if the mould constant is 2.2 sec/mm² ?

Sol:- Diameter of Casting, $d = 1100$ mm

Height / thickness of casting $h = 33$ mm

Mould Constant, $C = 2.2$ Sec/mm²

Solidification time $t$:

volume of the Casting, $V = \frac{\pi}{4} d^2 \times h$

$= \frac{\pi}{4} \times (1100)^2 \times 33$

$= 31,360,948$ mm³

Surface area of the casting $A = 2 \times \frac{\pi}{4} d^2$

$= 2 \times \frac{\pi}{4} (1100)^2$

$= 1,900,663$ mm².

$t = C\left(\frac{V}{A}\right)^2$

$= 2.2 \times \left(\frac{31,360948}{1,900,663}\right)^2$

$= 598.95$ sec (or) 9.98 min

(2) Two castings of the same metal have the same surface area. One casting is in the form of sphere and other is a cube. What is the ratio of solidification time for sphere to that of a cube.

Let $V$ = volume of casting, $A$ = surface area of casting

$A_{sphere} = A_{cube}$

According to chvorinov's rule solidification time, $t \propto \left(\frac{V}{A}\right)^2$

∴ Ratio of solidification time for the sphere to that of cube

$$\frac{t_{sphere}}{t_{cube}} = \left(\frac{V_{sphere}}{A_{cube}}\right)^2$$

$$= \left[\frac{\frac{4}{3} \times \pi R^3}{a^3}\right] = \frac{16\pi^2 R^6}{9a^6}.$$

Gating System Design

The liquid metal that runs through the various channels in the mould obeys Bernoulli's theorem which states that the total energy head remains constant at any section. The same stated in the equation form ignoring frictional losses is

$h + \frac{P}{W} + \frac{V^2}{2g} =$ Constant, where h = potential head, m

P = pressure, Pa, V = liquid velocity, m/s. W = specific weight of liquid, N/m³, g = gravitational constant.

Though quantitatively Bernoulli's theorem may not be applied, it helps to understand the metal flow in the sand mould qualitatively.

As the metal enters the pouring basin, it has the highest potential energy with no kinetic or pressure energies. But as the metal moves through the gating system, a loss of energy occurs because of the friction between the molten metal and the mould walls. Also, heat is continuously lost through the mould material though it is not represented in the Bernoulli's equation. This lets the casting solidify.

Another law of fluid mechanics which is useful in understanding the gating system behaviour is the law of continuity, which says that the volume of metal flowing at any section in the mould is constant.

$Q = A_1 V_1 = A_2 V_2$ where Q = rate of flow, $m^3/s$.

A = area of cross section $m^2$.

V = velocity of metal flow, m/s.

Sprues are tapered to reduce the aspiration of air due to the increased velocity as the metal flows down the sprue.

Pouring Time:- The gating system design is to fill the mould in the smallest time. The time for complete filling of a mould termed pouring time, is a very important criterion for design. Too long a pouring time requires a higher pouring temp and too less a pouring time means turbulent flow in the mould which makes the casting defect-prone.

-0.124 wl²)

The pouring time depends on the casting materials, complexity of the casting, section thickness and casting size. The general considerations for choosing pouring time for grey cast iron may not be much relevant for steels since they lose heat very fast and therefore, the pouring time should be very less. For non-ferrous materials, a longer pouring time would be beneficial since they lose heat slowly.

Since the thickness of casting is effected to a great extent by the ratio of surface area to volume of the casting it is an important variable in calculating the optimum pouring time in addition to the mass of the casting itself. Normally while considering the mass of the casting it may not be necessary to consider the mass of the gating system because the gating system is completely filled before metal starts entering the mould cavity. The following are some standard

① Grey Cast Iron, Mass less than 450kg.

Pouring time, $t = K\left(1.41 + \frac{T}{14.59}\right)\sqrt{W}$ s

$K$ = fluidity of iron in inches / 40

$T$ = average section thickness, mm. $W$ = mass of the casting, kg.

② Grey Cast Iron, Mass greater than 450kg

Pouring time, $t = K\left(1.236 + \frac{T}{16.65}\right)\sqrt[3]{W}$ s

Typical pouring times for cast iron are

| Casting mass | |
|---|---|
| 20 | 6 to 10 |
| 100 kg | 15 to 30 |

③ Steel castings

Pouring time, $t = (2.4335 - 0.3953 \log W)\sqrt{W}$ s

④ Shell-moulded Ductile Iron

Pouring time $t = K_1\sqrt{W}$ s

where $K_1$ = 2.080 for thinner sections
= 2.670 for sections 10 to 25 mm thick
= 2.970 for heavier sections

(5) Copper Alloy Castings

Pouring time, $t = K_2 \sqrt[3]{W}$ s

$K_2$ is a constant given by

| | |
|---|---|
| Top gating | 1.30 |
| Bottom gating | 1.80 |
| Brass | 1.90 |
| Tin bronze | 2.80 |

(6) Intricately shaped thin-walled castings of mass up to 450 kg

Pouring time, $t = K_3 \sqrt[3]{W'}$ s

where $W'$ = mass of the casting with gates and risers, kg, and $K_3$ = a constant as given below

| T (mm) | $K_3$ |
|---|---|
| 1.5 to 2.5 | 1.62 |
| 2.5 to 3.5 | 1.68 |
| 3.5 to 8.0 | 1.85 |
| 8.0 to 15.0 | 2.20 |

(7) for castings above 450 kg and up to 1000 kg.

Pouring time, $t = K_4 \sqrt[3]{W'T}$ s

where $K_4$ is a constant given by

| T (mm) | $K_4$ |
|---|---|
| up to 10 | 1.00 |
| 10 to 20 | 1.35 |
| 20-40 | 1.50 |
| above 40 | 1.70 |

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① Calculate the optimum pouring time for a casting whose mass is 20 kg and having an average section thickness of 15 mm. The materials of the casting are grey cast iron and steel. Take the fluidity of iron as 28 inches.

Grey Cast Iron

Pouring time, $t = K\left(1.41 + \frac{T}{14.59}\right)\sqrt{W}$ s

where $K$ = fluidity of iron in inches / 40 $= \frac{28}{40}\left(1.41 + \frac{15}{14.59}\right)\sqrt{20}$

$= 7.632$ s

Steel:

Pouring time $t = (2.4335 - 0.3953 \log W)\sqrt{W}$ s

$= (2.4335 - 0.3953 \log 20)\sqrt{20}$

$= 8.5825$ s

Methods of Melting:-

Melting Equipment:- The main types of furnaces used in foundries for melting various varities of ferrous and non-ferrous metals and alloys are

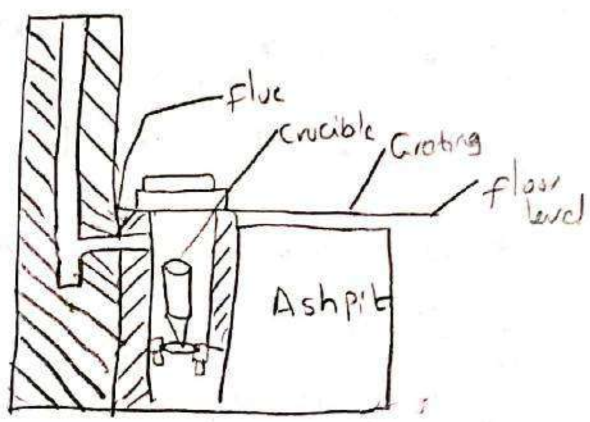
① Crucible furnace ② Air furnace ③ Cupola furnace ④ Blast furnace ⑤ open hearth furnace ⑥ Electric furnace

① Crucible furnace:-

A crucible furnace is most suited for small foundries and can be designed for melting any of the metals. It consists of the following two main types:

① Pit type furnace ② Tilting type furnace.

① pit type crucible furnace:-

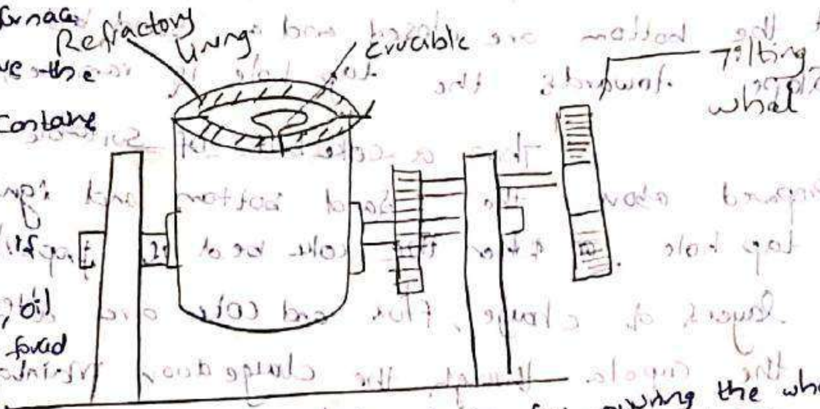


(1) It is built to suit the type of metal to be melted.
(2) These are fixed wholly or partly in the ground from which the crucible must be lifted when the metal is ready.

→ Here a crucible (a heat resisting pot for metal melting and made of fire clay mixed with coke dust or graphite) is placed in a pit in the floor. The furnace is usually fired with sufficient coke being packed around and above the crucible pots to melt and superheat the charge without re-coking. The natural draught provided by tall chimney is controlled by means of loose brick or damper at the foot of the stack.

② Tilting type crucible furnace:-

1. This type of furnace is built above the ground level and contains a firmly fixed crucible.




2. The furnace is fired with coke, oil or gas and the forced draught is used.

3. When the metal charge is ready for pouring the whole furnace is tilted and the crucible emptied by operating a geared trunnion.

4. For the metals of high melting points clay crucibles are used; for the low melting point metals such as zinc-base or aluminium cast iron or steel crucibles are suitable.

③ Cupola furnace:- A cupola consists of a cylindrical shell with its interior lined with heat-resistant firebricks. It consists of drop doors at the bottom, after closing which a proper sand bed could be prepared. This sand bed provides the necessary refractory bottom for the molten metal and the coke. Immediately above the sand bed is the metal tapping hole which is initially closed with clay called 'bot' till the molten metal is ready for tapping.

Above the metal tap hole, normally in a position opposite to it is the slag hole, through which the slag generated during the melting process is tapped.

Above the slaghole is the wind box which is Connected to the air blowers supplying the requisite air at a given pressure. The air enters the cupola through the tuyeres. A little above the charge platform is the charging hole in the shell, from where the charge consisting of a combination of pig iron, scrap iron, coke and fluxes is put into the cupola. The refractory lining above the charge door need not necessarily be as thick as that below, since it is not exposed to much heat.

Working. → To operate the cupola, first, the drop doors at the bottom are closed and a sand bed with a gentle slope towards the tap hole is rammed.

Then a coke bed of suitable height is prepared above the sand bottom and ignited through the tap hole. When the coke bed is properly ignited, alternate layers of charge, flux and coke are alternately fed into the cupola through the charge door maintaining the necessary proportions and rate of charging.

The charge is then allowed to soak in the heat for a while, and then the air blast is turned on. Within 5 to 10 min, the molten metal is collected near the tap hole. When enough molten metal is collected in the well of the cupola, the slag is drained off through the slag hole before opening the tap hole. The molten metal is collected in the ladles and then transported to the moulds into which it is poured with a minimum time loss.

The charge needed to produce cast iron essentially consists of pig iron, cast iron scrap and steel scrap. The proportions of these depends on their chemical composition and on the final chemical composition of cast iron desired.

The fluxes are added in the charge to remove oxides and other impurities present in the metal. The flux most commonly used is $CaCO_3$ in a proportion of about 2 to 4%. Other fluxes used are dolomite, sodium carbonate and calcium carbide.

## Special Casting processes

① Shell Moulding:- It is a process in which the sand mixed with a thermosetting resin is allowed to come into contact with a heated metallic pattern plate, so that a thin & strong shell of mould is formed around the pattern.

Generally dry and fine sand that is completely free of clay is used for preparing the shell-moulding sand. The grain size to be chosen depends on the surface finish desired on the casting.

The synthetic resins used in this are thermosetting resins which get hardened irreversibly by heat. The resins most widely used are the phenol formaldehyde resins, the phenolic resins used in shell mouldings usually are of 2-stage type, that is the resin has excess phenol & acts as like a thermoplastic material. During coating with the sand, the resin is combined with a catalyst such as hexamethylene-tetramine in a proportion of 14-16% to develop thermosetting characteristics.

Additives may be added into the sand mixture to improve surface finish and avoid thermal cracking during pouring. Some are manganese dioxide, coal dust etc.

Steps:- ① The first step in preparing the shell mould is the preparation of the sand mixture in such a way that each of the sand grains is thoroughly coated with resin. To achieve this first the sand, hexa and additives which are all dry are mixed inside a muller for a period of 1 min.

② Then the liquid resin is added and mixing is continued for another 3 min. To this warm air is introduced into the muller and mixing is continued till all the liquid is removed from the mixture.

Since sand-resin mixture is to be cured at about 150°c temp, the metallic pattern plate is heated to a temp of 200-350°c depending on the type of pattern. It is very essential that the pattern plate is uniformed heated. The heated pattern is securely fixed to a dump box as shown in fig (a)

Where in the coated sand in an amount larger than required to form the shell of necessary thickness.

Then the dump box is rotated as shown in fig (b) so that the coated sand falls on the heated pattern. The heat from the pattern melts the resin adjacent to it.

When the desired thickness of shell is achieved, the dump box is rotated backwards by 180° so that excess sand falls back into the box, leaving the formed shell intact with the pattern. The avg shell thickness depends on the temp of pattern, and the time the coated sand remains in contact with the heated pattern.

The shell along with the pattern plate is kept in an electric for curing the shell.

Adv:-

① Shell-mold castings are generally dimensionally more accurate than sand castings.

② A smoother surface can be obtained in shell castings.

③ Draft angles which are lower than the sand castings are required in shell molds. The reduction in draft angles may be from 50 to 75% which saves the material costs.

④ Also very thin sections up to 0.25mm of type of air-cooled cylinder heads can be readily made by the shell molding because of higher strength.

⑤ Very small amount of sand needs to be used.

Limitations

① The patterns are very expensive and therefore are economical only if used in large-scale production.

② The size of the casting obtained by shell moulding is limited.

③ Highly complicated shapes cannot be obtained

Applications:-

(4) cylinder and cylinder heads for air-cooled I.C. engines, automobile transmission parts, brake beam, steel eyes, gear blanks, small crank shafts, radone hubs etc,

② Continuous casting:-

Continuous casting, also refered to as strand casting, is a process used in manufacturing industry to cast a continuous length of metal (or) produces higher quality steels for less cost.

It involves the following steps.

① The molten metal in the ladle is cleaned and equalised temperature by blowing nitrogen gas through it for 5 to 10 minutes.

② The metal is then poured into a refractory-lined intermediate pouring vessel called tundish (it holds the liquid metal for casting). The tundish holds as 3 tonnes of metal. This is placed about 80-90 feet above the ground level.

③ The molten metal travels through water-cooled copper moulds and begins to solidify as it travels downward along a path supported by rollers (pinch rolls).

④ Before the casting process is started a solid starter or dummy bar is inserted into the bottom of the mould. The molten metal is then poured and solidifies on the starter bar. The bar is withdrawn at the same rate the metal is poured. The cooling rate is such that the metal develops a solidified shell to support itself during its travel downwards at a typically of 25 mm/s. The shell thickness is about 12 to 18 mm. The moulds are generally coated with graphite to reduce friction.

⑤ The continuously cast metal may be cut into desired lengths by torch cutting or shearing, or it may be fed directly into a rolling mill for further reductions in thickness and for shape rolling of products such as channels and I-beams.

⑥ The metal casting moves outside the mould with the help of different sets of rollers.

⑦ while one set of rollers bend the metal cast, another set will straighten it.

⑧ This helps to change the direction of flow of the steel slab from vertical to horizontal.

Adv:-

① The process is cheaper than rooling.

② Labour cost is less.

③ Costing surface

④ Grain size and structure of the casting can be easily controlled.

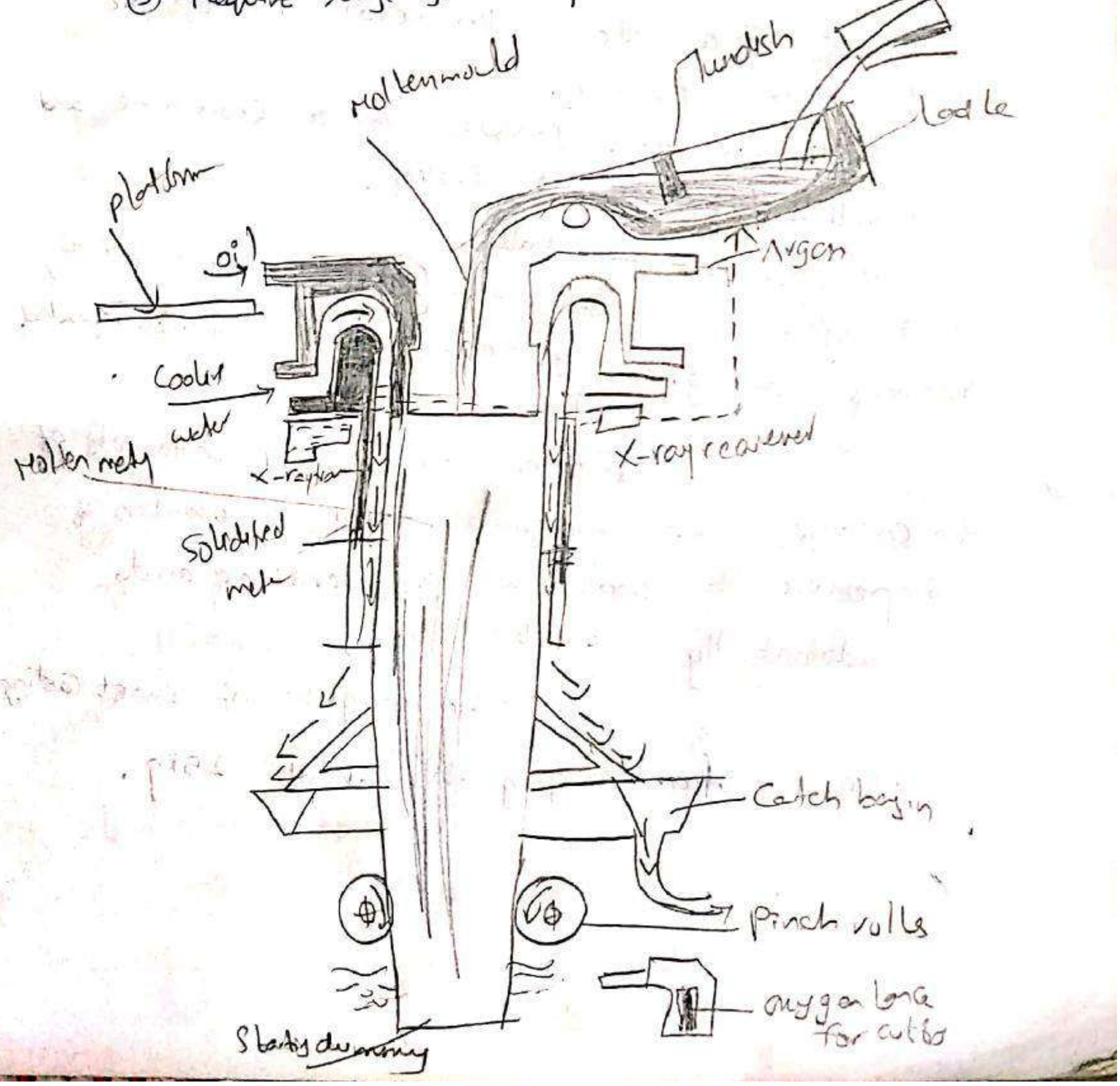
Dis:- ① continuous and capable cooling of mould is required

② Just simple shapes can be cast.

③ capital investment is necessary to set up process.

④ Not proper for small scale production.

⑤ Require large ground space.



② Die-casting:-

Die-casting or Pressure Die Casting is essentially Permanent mould casting in which pressure forces the molten metal into the mould cavity. However, the mould used is much more expensive (called die) and a complex machine is employed, to produce casting at a very high rate.

If the molten metal is forced into a metallic die under a gravity head the process is known as "Gravity die casting" (or) "permanent mould casting".

The mould is normally called a metallic die with two halves. one half is fixed and the other is movable.

Die materials like medium Carbon, low alloys, hot steels are used.

In die casting the following steps are involved:-

① close and lock the two halves of the die.

② force the molten metal into the die cavity under pressure.

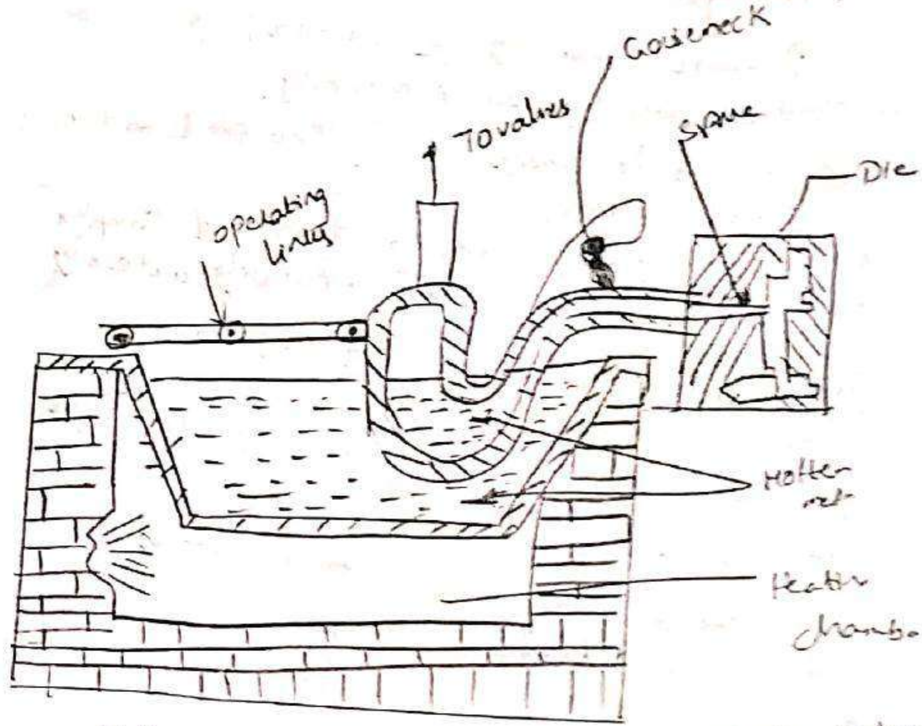
③ Maintain the pressure for a short time and permitting the metal to solidify.

④ open the die halves.

⑤ Eject the casting with its assembly of sprue, runners and gates by pins. The above cycle is repeated

In order to obtain uniformity of die castings and maximum speed of operation is imperative to employ a predetermined and automatically controlled cycle.

The weight of most castings range from 90 g to about 25 kg.




following are the 2 types of die-casting processes:-
① Hot-chamber process ② cold-chamber process.

① Hot-chamber process:- This process involves the use of piston, which traps a certain volume of molten metal and forces it into the die cavity through a gooseneck and nozzle. The pressure ranges up to 35 MPa, with an average of about 15 MPa. The metal is held under pressure until it solidifies in the die.

Low melting point alloys such as zinc, tin & lead are commonly used.

② cold-chamber process:- In this process, molten metal is introduced into the injection cylinder (shot chamber). The shot chamber is not heated, hence the term cold chamber. The metal is forced into the die cavity at pressures usually ranging from 20 to 70 MPa, although it may be high as 150 MPa. The machinery may be horizontal or vertical.

High-melting point alloys of aluminium, magnesium & copper are normally cast by this method.

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Advantages:-

① Large quantities of identical parts can be produced rapidly and economically.

② very little machining is required on the parts produced.

③ The parts having thin and complex shapes can be casted accurately and easily.

④ The castings produced by this are less defective.

⑤ The rapid cooling rate produces high strength and quality in many alloys.

⑥ Cored holes down to 0.75 mm dia at accurate locations are possible.

⑦ The sprue, runners and gates can be remelted resulting in low scrap loss.

⑧ The die casting requires less floor area than other casting process.

Disadvantages:-

① The cost of equipment & dies high.

② There is a limited range of non-ferrous alloys which can be used for die casting.

③ The die castings are limited in size.

④ It requires special skill in maintenance

⑤ It contains some porosity due to entrapping of air.

Applications:-

① Transmission housings

② valve bodies. ③ Carburettors, ④ Hand tools

⑤ Toys ⑥ Motors etc.

Centrifugal Casting:-

This is a process where the [mould] is rotated rapidly about its central axis as the metal is poured into it. Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies. The slag, oxides and other inclusions being lighter, get seperated from the metal and segregates toward the centre.

There are 3 types of Centrifugal casting. They are

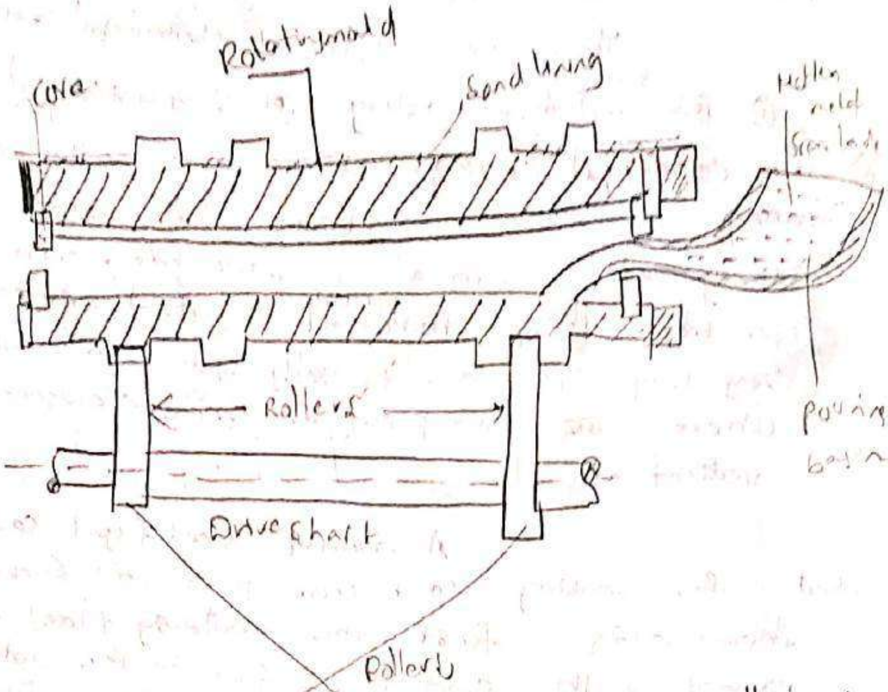
① True centrifugal casting ② Semicentrifugal casting ③ Centrifuging

① True centrifugal casting:- This is normally used for the making of hollow pipes, tubes, hollow bushes etc, which are axi-symmetric with a concentric hole. The axis of rotation can be either horizontal or vertical or any angle in betwee[n]. Very long pipes are normally cast with horizontal axis, where as short pieces are more conveniently cast with a vertical axis.

A normal centrifugal casting machine used for making cast-iron pipes in sand moulds is shown in fig. First, the moulding flask is properly rammed with sand to confirm to the outer contour of the pipe to be made. Any end details such as spigot ends, or flanged ends are obtained with the help of dry sand cores located in the ends. Then the flask is dynamically balanced so as to reduce the occurence of undesirable vibrations during the casting process. The finished flask is mounted in between the rollers and the mould is rotated slowly. Now the molten metal in requisite quantity is poured into the mould through the movable pouring basin. The amount of metal poured determines the thickness of the pipe to be cast. After the pouring is complete, the mould is rotated at its operational speed till it solidifies, to form requisite tubing.

Metal moulds can also be used in this process for large quantity production. A water jacket is provided around the mould for cooling it.

The casting machine is mounted on wheels, with the pouring ladle which has a long spout extending till the other end of the pipe is made. To start the mould is rotated with the metal being delivered at the extreme end of the pipe.




Advantages:

⇒ The mechanical properties of centrifugally cast jobs are better compared to other process because the inclusions such as slag and oxides get segregated towards the centre and can be easily removed by machining.

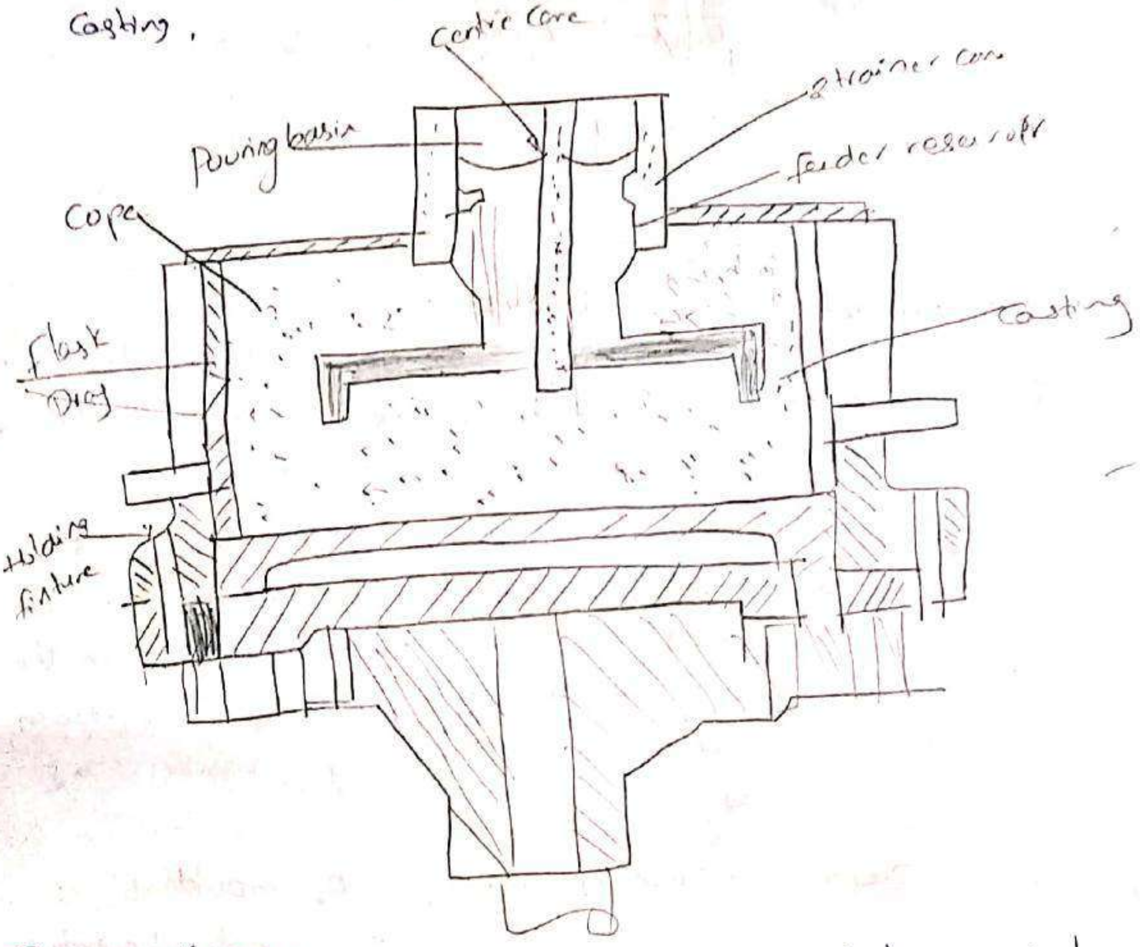
Limitations:-

⇒ only certain shapes which are axi-symmetric and having concentric holes are suitable for the centrifugal castings.

② The equipment is expensive and thus is suitable only for large quantity production.

(2) Semi-centrifugal castings:-

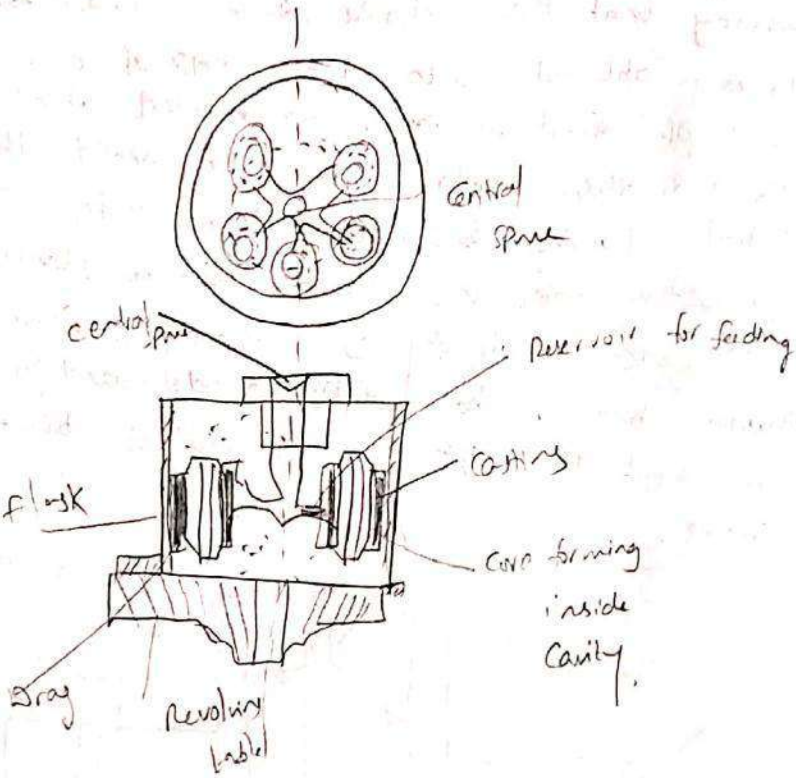
It is used for jobs which are more complicated than those possible in true centrifugal casting, but are axi-symmetric in nature. It is not necessary that these should have a central hole, which is to be obtained with the help of a core. The moulds made of sand or metal are rotated about a vertical axis and the metal enters the mould through the central pouring basin as shown in fig. For larger production rates, the moulds can be stacked one over the other, all feeding from the same central pouring basin. The rotating speeds used in this process are not as high as in case of true-centrifugal casting.




(3) Centrifuging:-

In order to obtain higher metal pressure during solidification, when casting shapes are not axis-symmetrical, the centrifuging process is used. This is suitable only for small jobs of any shape. A number of such small jobs are joined together by means of a radial runners with a central sprue on a revolving table as in fig. The jobs are uniformly placed on the table around the periphery so that their masses are

Properly balanced. The process is similar to semicentrifugal casting.




## Carbondioxide ($CO_2$) Moulding:-

1. $CO_2$ moulding also known as sodium silicate process is one of the widely used process for preparing moulds and cores.
2. In this process, sodium silicate is used as the binder. But sodium silicate activates or tend to bind the sand particles only in the presence of carbondioxide gas. for this reason, the process is commonly known as $Co_2$ process.

### Steps involved in making $Co_2$ mould:-

1. Suitable proportions of silica sand and sodium silicate binder (3-5% based on sand weight) are mixed together to prepare the sand mixture.
2. Additives like aluminium oxide, molasses etc; are added to impart favorable property and to improve collapsibility of sand.
3. The pattern is placed on a flat surface with the drag box enclosing it. Parting

Sand is sprinkled on the pattern surface to avoid sand mixture sticking to the pattern.

The drag box is filled with the sand mixture and rammed manually till its top surface. Rest of operations like placing sprue and riser pin and ramming the cope box are similar to green sand moulding process.

Fig shows the assembled cope and drag box with vent holes. At this stage, the $CO_2$ gas is passed through the vent holes for a few seconds.

Sodium silicate reacts with $CO_2$ gas to form silica gel that binds the sand particles together. The chemical reaction is given by:

$$Na_2SiO_3 + CO_2 \rightarrow Na_2CO_3 + SiO_2$$

The sprue, riser and the pattern are withdrawn from the mould, and gates are cut in usual manner. The mould cavity is finished and made ready for pouring.

Adv:- 1. Instantaneous strength development. The development of strength takes place immediately after $CO_2$ gas is completed.

2. Since the process uses relatively safe $CO_2$ gas, it does not sand disposal problems or any other while mixing and pouring. Hence the process is safe to human operators.

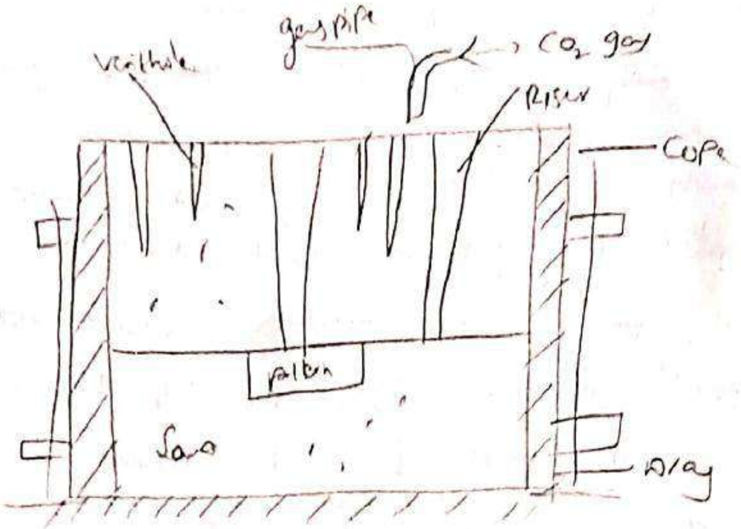
3. Very little gas evolution during pouring of molten metal.

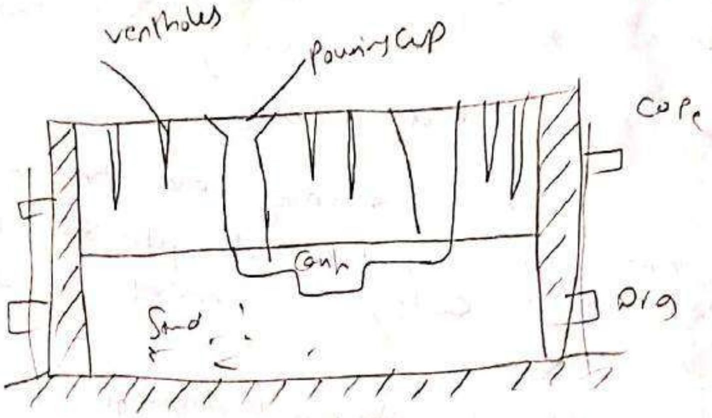
Disad:-

1. Poor collapsibility of moulds is a major disadvantage of this process. Although some additives are used to improve this property for ferrous metal casting and it cannot be used for non-ferrous applications.

2. The sand mixture has the tendency to stick to the pattern and has relatively poor flowability

3. Over gassing and under gassing adversely affects properties of sand.



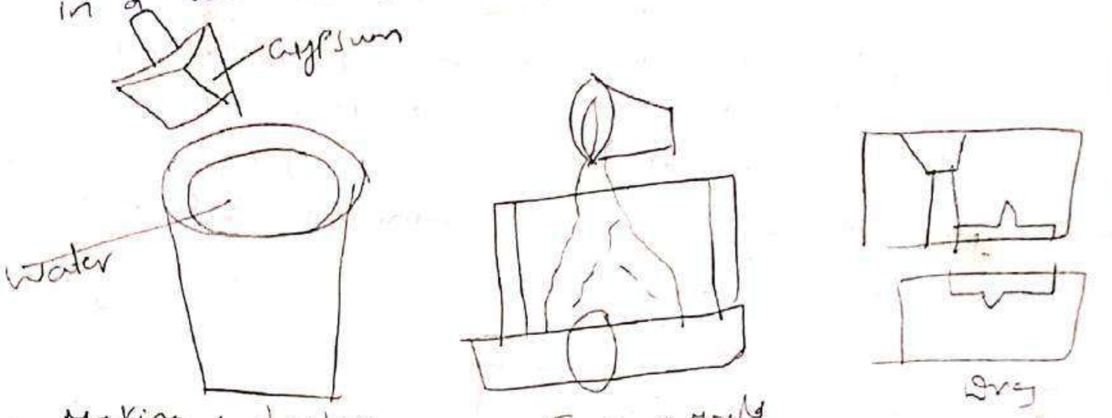

## Plaster - Mould Casting:-

→ Plaster - mould casting is a metal working casting process similar to sand casting except the moulding material is plaster of paris (Gypsum - or calcium sulphate).

→ with the addition of talc and silica flour to improve strength and to control the time required for the plaster to set. These components are mixed with water, and the resulting slurry is poured over the pattern. After the plaster sets, usually within 15 minutes, the pattern is removed and the mould is dried to remove the moisture.

The moulds are then assembled to form the mould cavity and preheated to about 120°c for 16 hours.

Next, the molten metal is poured into the m[old]. Because plaster moulds have very low permeability, gases evolved during solidification of the metal cannot escape. Consequently, the molten metal is poured either in a vacuum or under pressure.




Making of plaster slurry — Ceramic mould making — final part mould

Adv: -

① High dimensional accuracy ② Smooth surface ③ Low porosity ④ Mould easily repairable.

Disadv:-

① Limited to non-ferrous metallic castings ② Dimensional castings ③ Time consuming.

Ceramic - Mould casting: - The ceramic mould casting is similar to the plaster mould process with the exception it uses refractory mould materials suitable for high-temp applications. This process is also called cope-and drag investment casting.

The slurry is a mixture of fine grained zircon ($ZrSiO_4$) aluminium oxide and fused silica which are mixed with bonding agents and poured over the pattern which has been placed in a flask. The pattern may be of wood or metal.

After setting the moulds (ceramic facings) are removed, dried, burned off to remove volatile matter, and baked. The moulds are clamped firmly and used as all ceramic moulds. In shaw process, the ceramic facings are backed by fireclay to give the moulds strengths. The facings are then assembled into a complete mould, ready to be poured.

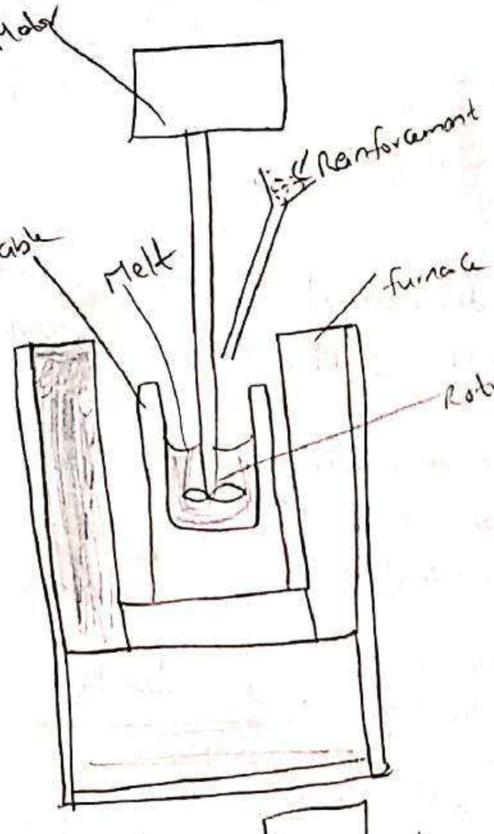
The high-temp resistance of the refractory moulding materials allows these moulds to be used in casting ferrous & other high-temp alloys, stainless steels.

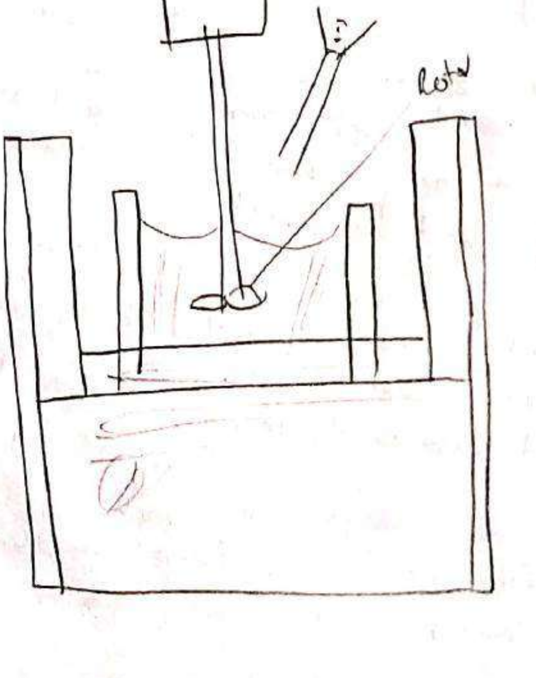
These castings have good dimensional accuracy and surface finish over a wide range of sizes and intricate shapes, but the process is somewhat expensive.

Typical parts made are:-

(1) Impellers, Dies for metal working; Moulds for making plastic or rubber components etc,

Stir casting:-



# SREENIVASA INSTUTUTE OF TECHNOLOGY AND MANAGEMENT STUDIES

## CHITTOOR, ANDHRA PRADESH- 517127

**AN ISO 9001:2015 CERTIFIED INSTITUTION**

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## DEPARTMENT OF MECHANICAL ENGINEERING

NOTES FOR

# MANUFACTURING TECHNOLOGY

# UNIT-II

## WELDING AND CUTTING

## Differences b/n TIG & MIG

| TIG | MIG |
|---|---|
| (1) Non-consumable Electrode is used | (1) Consumable Electrode is used |
| (2) Produce high quality weld | (2) It does not produce high quality weld |
| (3) No weld cleaning is necessary | (3) weld cleaning is necessary |
| (4) Gas used for TIG welding is argon | (4) Gas used for MIG welding is helium, oxygen, nitrogen. |
| (5) High skilled operator is required | (5) High skilled operator is not required |
| (6) Process is slow compared to other process | (6) process is faster than TIG welding |
| (7) It provides lower deposition rate | (7) It provides higher deposition rate |
| (8) It is suitable for welding in all position | (8) It is suitable for welding thin sheets. |

Charact,

## UNIT-2

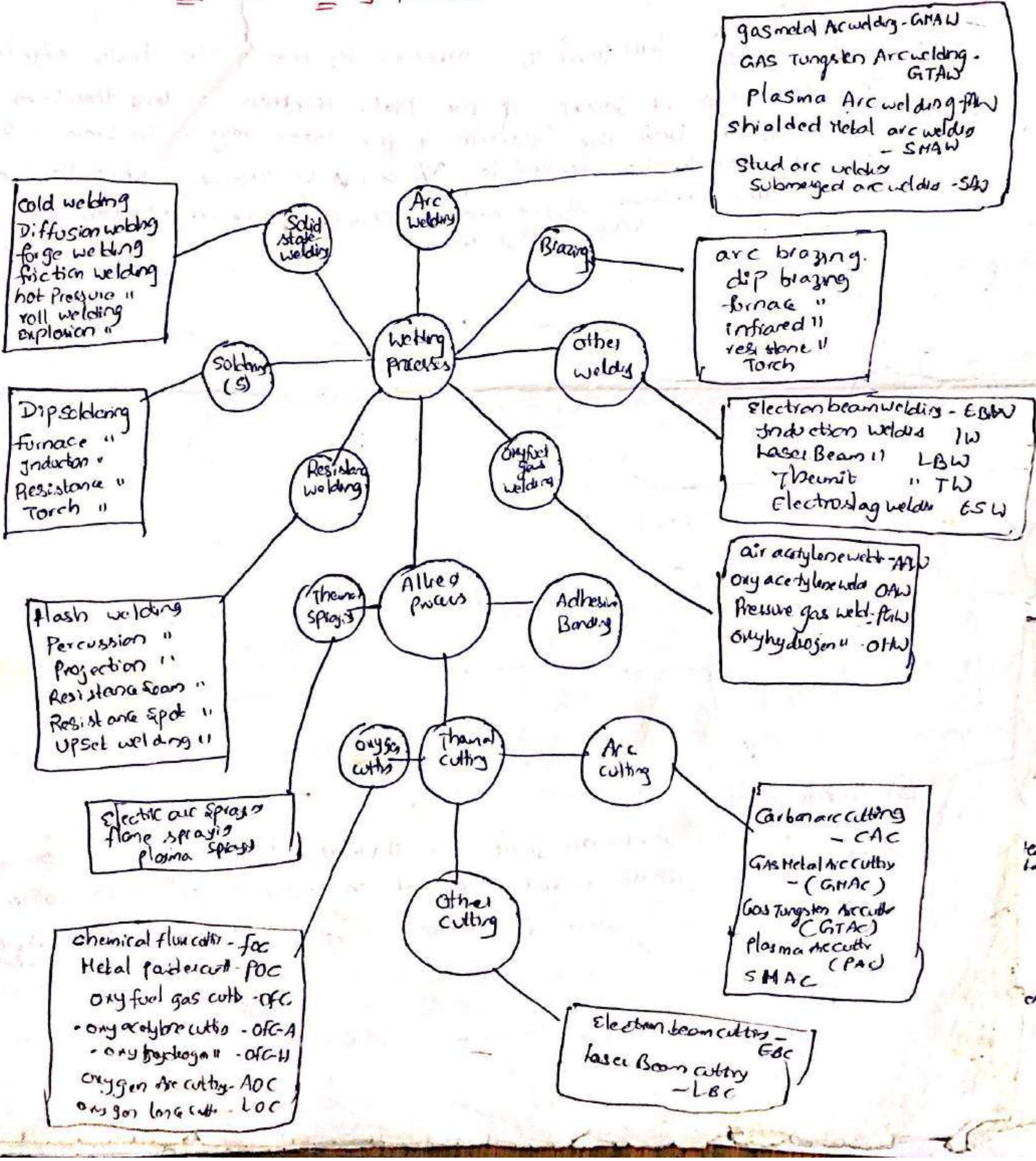
## WELDING AND CUTTING

**Welding** - It is the method of joining metals by application of heat, with out the use of solder or any other metal or alloy having a lower melting point than the metals being joined.

(or)

Welding is defined as "a localised coalescence of metals, where in coalescence is obtained by heating to suitable temp, with or with out the application of pressure and with or with out the use of filler metal".

### Classification of welding process:-

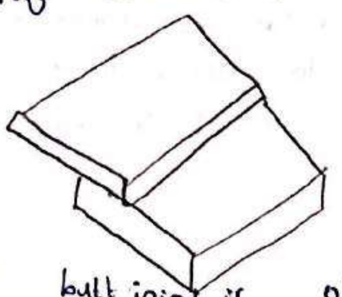


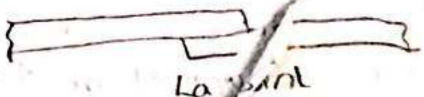
Types of welded joints:-

① Lap joint:- The lap joint is obtained by overlapping and then welding the edges of the plates.

② The lap joints may be single traverse, double traverse & Paral

3. These joints are employed on plates having thickness ≤3.



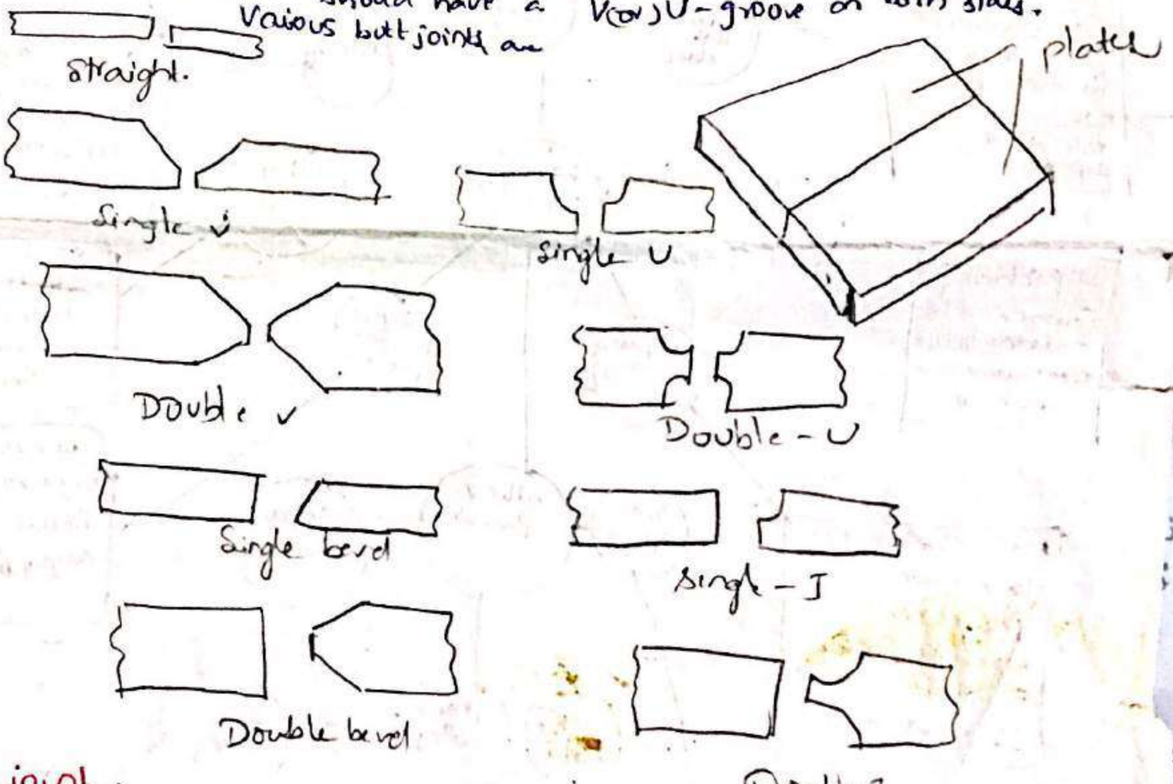



② Butt joints.-

The butt joint is obtained by placing the plates edge to edge as shown in fig.

In this type of joints if the plate thickness is less than 5mm bevelling is not required. When the thickness of the plates ranges b/n 5mm-12.5mm the edge is required to be bevelled to V (or) U-groove while the plates having thickness above 12.5mm should have a V(or)U-groove on both sides.

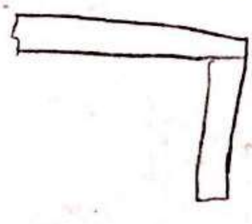
Various butt joints are




③ Corner joint.

① A corner joint is obtained by joining the edges of two plates whose surfaces are at an angle of 90° to each other.

② It is used for both light and heavy gauge sheet metal.



## Characteristics of weld joints:-

Parallel 5.3 A properly made weld should have the following characteristics. A weld not properly welded is a defective weld.

1. The weld should not crack in the bend test.
2. It should not contain slag imbedded in the weld.
3. Its appearance should be ripple like and not spongy.
4. It should not have cavities, and the grain size should be uniform.
5. The weld should have even width.
6. Over current tries to dissolve scum in the weld while under current tries to give cracks in the weld.
7. If electrode distance from the weld is varying this will cause the unevenness of the weld.

## Defects in welding:-

1. Undercut 2. Porosity and blow holes 3. Slag inclusion 4. Cracks 5. Lamellar tearing.

1. **Undercut:-** This appears like a small notch in the weld interface. This is generally attributed to the improper welding technique or excessive welding current. This is mainly caused by the incorrect manipulation of the electrode while depositing the bead, particularly in horizontal & vertical welding. It can be reduced by

2. **Porosity:-** Porosity in welding is caused by the presence of gases which get entrapped during the solidification process. The main gases that causes porosity are Hydrogen, oxygen & Nitrogen.

Hydrogen is the main cause of porosity in the weld pool. The source of $h_2$ could be the electrode coatings such as cellulose dissociation of water, which is present as moisture pick up of electrodes, left over wire drawing lubricant on the electrode wire.

$O_2$ generally reaches the weld pool oxide of base metal or filler metal. $N_2$ generally enters the weld pool through atmospheric nitrogen or the contaminated shielding gases.

Porosity if present in large would reduce the strength of the joint.

3. **Slag inclusions:-** Inclusions are the slag or non-metallic particles and are derived from the environments around the weld metal. Basic slags are more viscous, and are more difficult to remove from the molten metal.

Slow cooling of the molten weld metal pool helps in the elimination of inclusions.

The factors cause slags are

1. High viscosity of weld metal 2. Rapid solidification 3. Insufficient welding heat 4. Improper manipulation of the electrode.

(4) Cracks:- In steel welds cracks are most serious defects.
cracks may be formed due to various causes including unequal physical properties of the parent and weld metals, high conditions & faulty welding.

(1) Hot cracking:- Generally occurs at high temperature & size very small to visible. The crack in most parts is intergranular, magnitude depends upon the strains involved in solidification. The more likely to form during the root pass when the mass of the metal is very large compared to weld metal deposited. It can be by preheating the base metal, increase the cross section area of the.

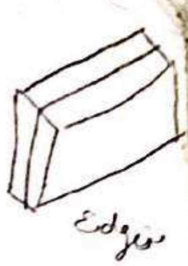
(2) Cold Cracking:- These cracks are formed near the weld area are due to excessive cooling rates & absorbed hydrogen. since these appear long time after the welding operation when the material is cold. They constitute a great danger in the low alloy & high carbon steel.

(5) Lamellar Tearing:- It is generally seen in at the edge of the heat affected zone. It appears as a long and continuous usual separation line b/n the base metal and the heat affected zone. This is caused by the present of elongated inclusions such as Mn, Fe, S in base metal.

Edge joint:- th ① It is T-joint:- plates each ② these ③ the Termin ① Bo ② ③

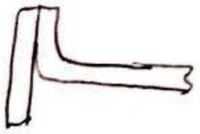
(5) Edge joint:- This joint is obtained by joining two parallel plates

② It is economical for plates having thickness < 6 mm.



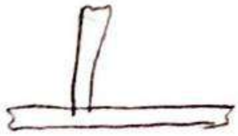

(6) T-joint:-

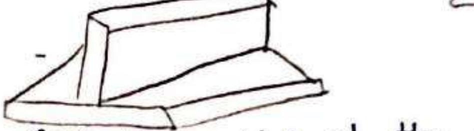
It is obtained by joining two plates whose surfaces are approximately at right angles to each other



② These joints are suitable up to 3 mm thickness.

③ These are widely used to weld thin walled structures.





## Terminology:-

① Backing:- It is the material support provided at the root side of a weld to aid in the control of penetration

② Base Metal:- The metal to be joined or cut.

③ Bead (or) weld bead:- Bead is the metal added during a single pass of welding. The bead appears as a separate material from the base metal.

④ Craters:- In arc welding, a crater is the depression in the weld metal pool at the point where the arc strikes the base-metal plate.

⑤ Deposition Rate:- The rate at which the weld metal is deposited per unit time is the deposition rate and is express as kg/h.

⑥ Fillet weld:- The metal fused into the corner of a joint made of two pieces placed at approx 90° to each other.

⑦ Penetration:- It is the depth up to which the weld metal combines with the base metal, as measured from the top surface of the joint.

⑧ Puddle:- The portion of the weld joint that melted by the heat of welding.

⑨ Root:- It is the point at which the two pieces to be joined by welding is nearest.

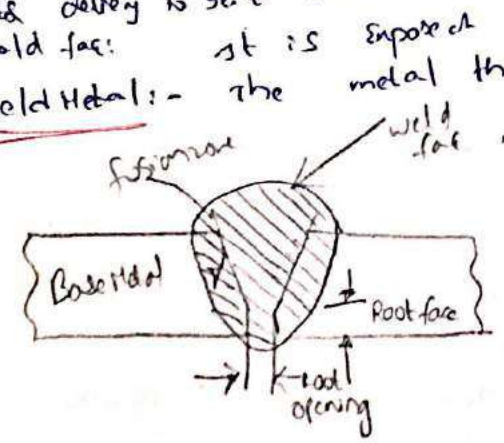
⑩ Tack weld:- A small weld, generally used to temporarily hold the two pieces together during actual welding,

⑪ Toe of weld:- It is the junction b/n the weld face & basemetal.

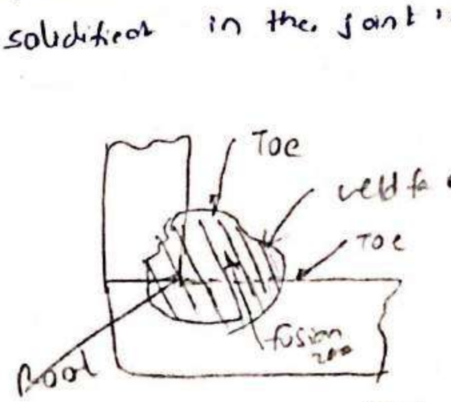
⑫ Torch:- In gas welding, the torch mixes the fuel and $O_2$ and controls its delivery to get the desired flame.

⑬ Weld face: It is exposed surface of the weld.

⑭ Weld Metal:- The metal that is solidified in the joint is called weld metal.




(7) Butt weld



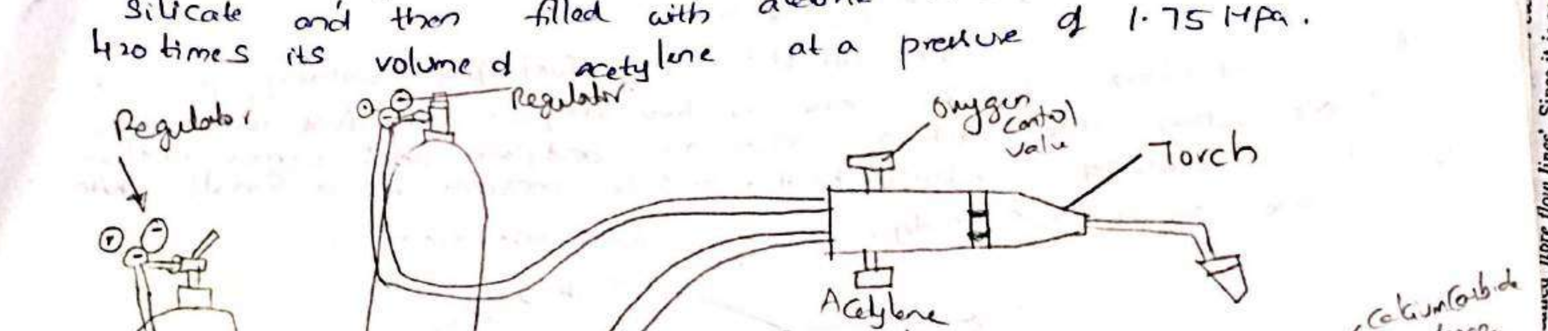

(6) fillet weld

The oxygen is normally stored in strong cylinders at a pressure ranging from 13.8 MPa to 18.2 MPa.

Acetylene is normally made available in the following two forms:

(1) Acetylene storage cylinder (2) Acetylene generator.

Free acetylene is highly explosive, if stored at a pressure more than 200 kPa where it becomes very unstable and is likely to Explode. Hence, acetylene needs to be carefully stored on a strong cylinder filled with 80 to 85%. porous material such as calcium silicate and then filled with acetone which can absorb up to 420 times its volume of acetylene at a pressure of 1.75 MPa.




Acetylene would be released from acetone at a slow rate and thus would not form any pockets of high pressure acetylene. The rate of release depends upon on the temp of gas. Hence, the rate of consumption of acetylene should be under the rate of release, which is normally about $1/7$th of the capacity of the cylinder per hour. However, if acetylene is drawn at a rapid rate, acetone may also come out along with the acetylene.

It is possible to have an acetylene generator in the place of an acetylene cylinder. Acetylene is normally produced by a reaction b/n Calcium Carbide & water which is shown.

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 .$$

A schematic way of acetylene generator is shown in fig. It consists of a cylinder, which is partially filled by water. The calcium carbide is stored in a hopper near the top of the generator. A pressure regulated valve controls the flow of calcium carbide into water, depending upon the pressure of the acetylene in the generator. The acetylene gas is taken out through a pipe as shown in fig.

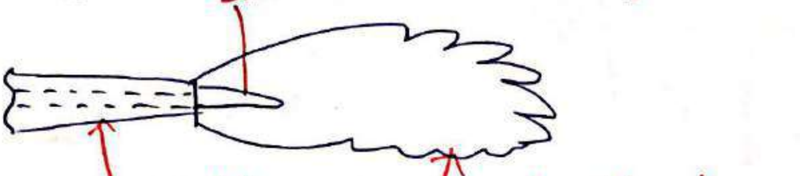
The oxygen & acetylene from the two cylinders are brought through seperate hose pipe to the welding torch as shown in fig.

Oxy-fuel

## Gas welding:-

The gas welding is also called as Oxy-fuel gas welding (OFW) derives the heat from the combustion of a fuel gas such as acetylene in combination with oxygen. The oxy-acetylene welding process can be used for welding almost all metals and alloys. The advantage of using acetylene instead of other fuels, with oxygen is that it produces a comparitively higher temp. flame.

In all the oxy-fuel gas welding processes, the combustion takes place in two stages. The first reaction takes place when the fuel gas such as acetylene and oxygen mixture burn releasing intense heat. This is present as a small white cone as shown in fig.




for the oxy-acetylene welding, the following reaction takes place in this zone

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 + 448\ kJ/mol.$$

The Carbon Monoxide (CO) and hydrogen produced in the first stage further combine with the atmospheric and give rise to the outer bluish flame with the following reaction.

$$4CO + 2H_2 + 3O_2 \rightarrow 4CO_2 + 2H_2O + 812\ kJ/mol.$$

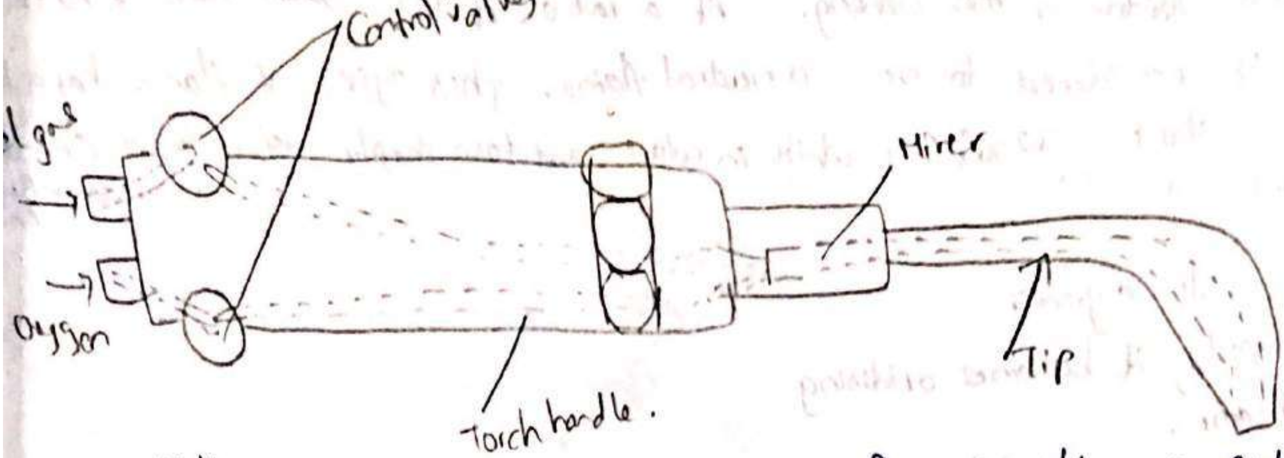
Though higher amount of heat is produced in the secondstage since it is distributed over a large area, the temp achieved is small (1200-2000°c) in the flame. The inner white cone temp is of the order of 3100°c, which is used for directly melting the steel joint.

### Oxy-Acetylene welding Equipment:-

The principle of oxy-acetylene welding is the ignition of oxygen and acetylene gases, mixed in a blow pipe fitted with a nozzle of suitable diameter. This flame is applied to the edges of the joint and to a wire filler of the appropriate metal which is there by melted and run into the joint.

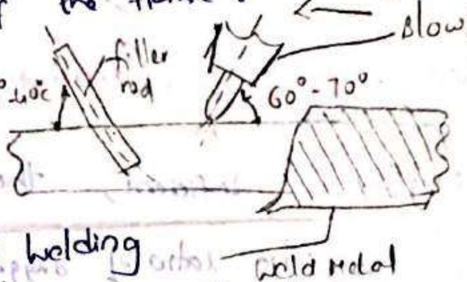
A typical oxy-acetylene welding outfit is shown in fig. It contains the supply units for oxygen and acetylene with associated regulators and the torch, which mixes the two gases before they are ignited.

In the torch, the two gases are mixed & then flowed out through the nozzle at the torch tip.




Methods of welding:- ① Leftward or forward weldin ② Rightward or backward.

① Leftward welding:- After suitable preparation of the joint the weld is commenced at the right-hand side of the joint and blow pipe is given a steady forward movement with a slight side ways motion zigzagging along the weld towards the left as shown in fig. The blow pipe is kept at an angle of 60° to 70° to the surface of the work so that the flame plays ahead of it, and the filler rod held at angle of 30° to 40° is held just ahead of the flame.




② Rightward or backward Welding:- In this welding technique the flame is directed towards the completed part of the joint and welding proceeds from left to right as shown in fig. The filler rod is given a circular movement as it is fed into the flame.

This is used mostly for thicker materials, steel.

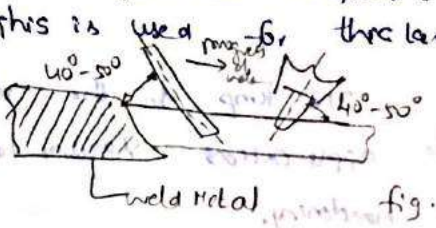
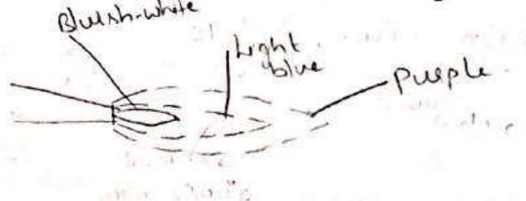



fig. Rightward welding

Types of flames:-

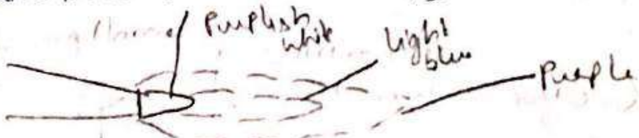
3 Basic types of oxyacetylene flames used in this welding are:- ⓐ Neutral flame ⓑ Oxidizing flame ⓒ Carburising (or) reducing flame.

ⓐ Neutral flame:-



The proportions of acetylene and oxygen in the gas mixture is an important factor in this welding. At a ratio of 1:1, when there is no ... it is considered to be a neutral flame. This type of flame has about 3250°C is white in color and has a sharply defined central cone.

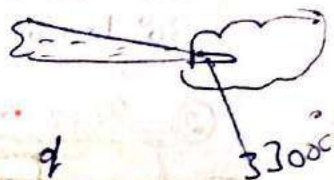
b) Oxidizing flame:




With a greater oxygen supply, it becomes oxidising flame.

The ratio of oxygen to acetylene varies from about 1.2 to 1.5. It is used to weld copper, brass, bronze etc.

This flame is harmful, especially for steels, because oxidizes the steel. Only in the welding of copper & copper alloy based alloys is an oxidising flame desirable, because in those cases a thin protective layer of slag forms over the molten metal.




c) Reducing flame (or) Carburizing flame:

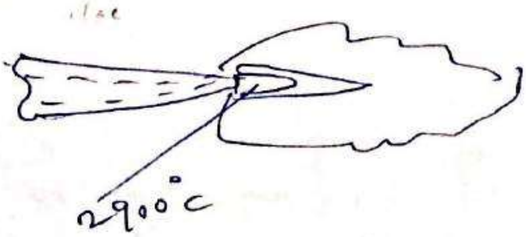
If the ratio of oxygen is deficient, the flame becomes a reducing flame.

→ The ratio of oxygen to acetylene is 0.9 to 1.

Has a Temp of 3150°C.

The temp of the reducing flame is low, so it is suitable for applications requiring low heat such as brazing, soldering & flame-hardening.


(or)

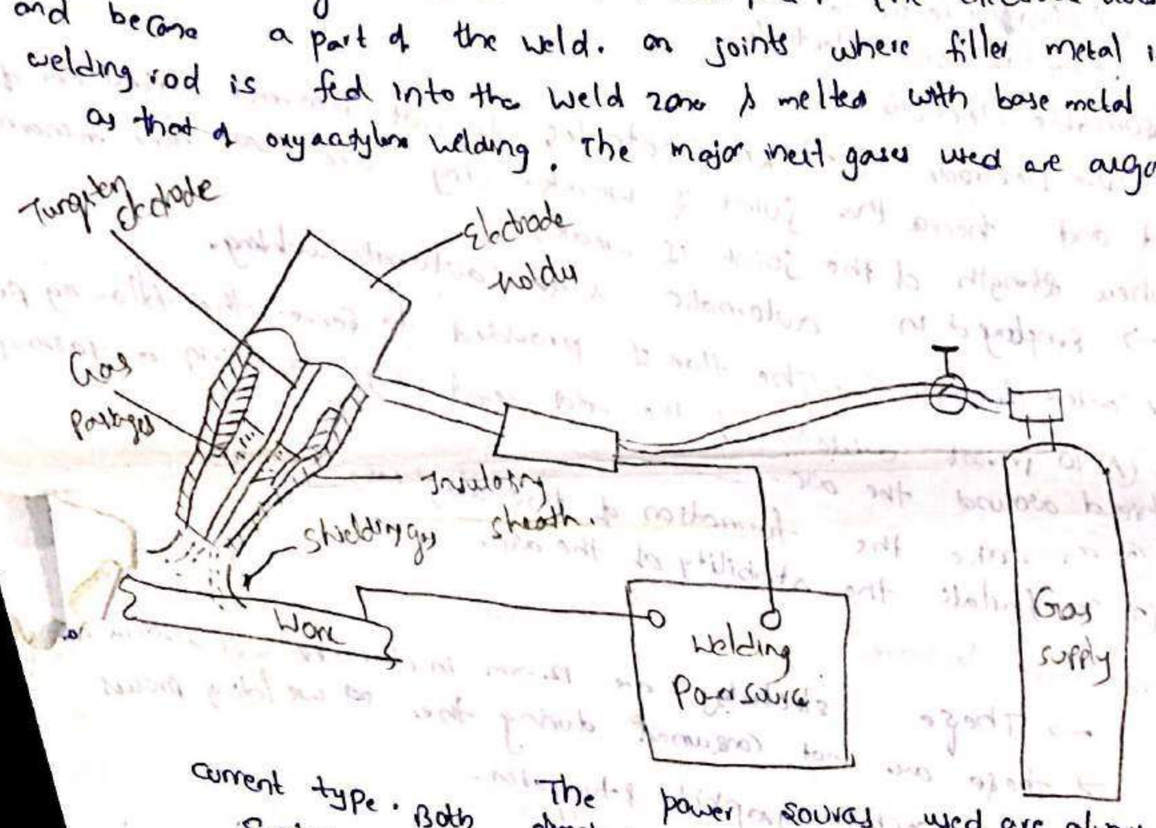


## Tungsten Inert Gas Welding (TIG):-

This welding process is also called as Gas Tungsten Arc Welding. It uses non-consumable electrode. The electrode may also contain 1 to 2% thorium oxide mixed along with the core tungsten or tungsten with 0.15 to 0.40% zirconium oxide.

It consists of a welding torch at the centre of which is the tungsten electrode. The inert gas is supplied to the welding zone through the annular path surrounding the tungsten electrode to effectively displace the atmosphere around the weld pool.

In this process the heat necessary to melt the metal is provided by a very intense electric arc which is struck between a virtually non-consumable tungsten electrode & metal work piece. The electrode does not melt and become a part of the weld. On joints where filler metal is required, a welding rod is fed into the weld zone & melted with base metal in the same as that of oxyacetylene welding. The major inert gases used are argon & helium.




The power sources used are always the constant current type. Both direct current (dc) and alternating current (ac) power supplies can be used for TIG welding. When dc is used, the electrode can be negative (DCEN) or positive (DCEP). When DCEN more heat is generated near the work piece and consequently the electrode does not get heated to a great extent. But when DCEP is used, a large amount of heat is liberated at the electrode itself there by limiting the maximum current that can be carried by an electrode.

Advantages:-

① TIG welds are stronger, more ductile and more corrosion resistant than welds made with ordinary shielded arc welding.
② Since no granular flux is required, it is possible to use a wide variety of joint designs.

3. there is little weld spatters that damage the surface of the metal as in traditional shielded arc welding.

Applications:-

① The TIG process lends itself ably to the fusion welding aluminium and its alloys, stainless steel, Magnesium alloys, nickel base alloys, copper base alloys, low alloy steels.

② TIG welding can also be used for combining of dissimilar metals, & welded

Electrodes:-

The electrodes are of two types:-

① Consumable electrode
(i) Bare electrode
(2) flux coated electrode

(i) Consumable Electrode:-

(i) Bare Electrode:- → These electrodes do not prevent oxidation of the weld and hence the joint is weak. They are used for minor repairs where strength of the joint is weak.

→ employed in automatic & semi automatic welding.

(2) flux coated electrode:- The flux is provided to serve the following purpose by creating a gaseous ...ction of the weld bead

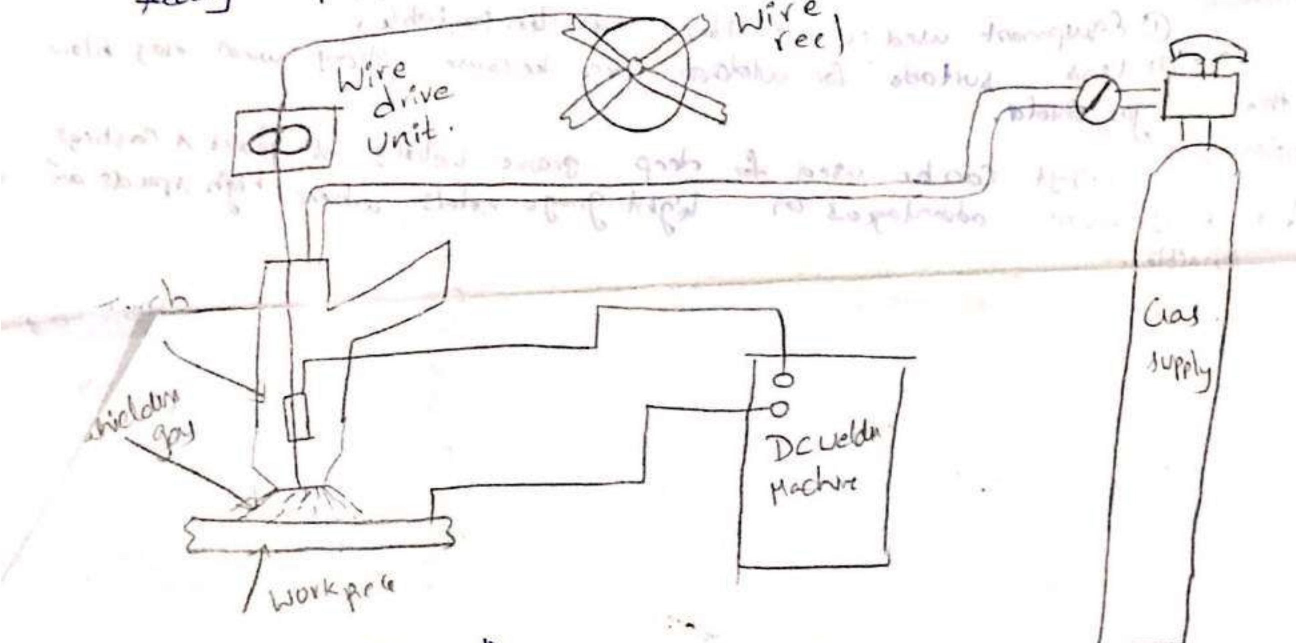
Metal Inert Gas

in ...
is

## Metal Inert Gas Welding (or) Gas-Metal-Arc welding (GMAW):- (MIG)

MIG (or) GMAW, utilises a consumable electrode and though Gas Tungsten Arc welding (or) TIG can be used to weld all types of metals, it is more suitable for thin sheets. When thicker sheets are to welded, the filler metal requirement makes GTAW difficult to use.

The typical set up for GMAW (or) MIG process is shown in fig. The consumable electrode is in the form of a wire reel, which is fed at a constant rate, through the feed rollers. The welding torch is connected to the gas supply cylinder, which provides the necessary inert gas. The electrode and the workpiece are connected to the welding power supply. The power supplies are always of the constant-voltage type only. The current from the welding machine is changed by the rate of feeding of the electrode wire.




Normally, dc arc-welding machines are used for GMAW with Electrode positive (DCEP). The DCEP increases the metal deposition rate and also provides for a stable arc and smooth electrode metal transfer.

① Metal Transfer:- In GMAW process, the filler metal is transferred from electrode to the joint. Depending upon the current & voltage used for given electrode, the Metal transfer is done in diff ways. They are
① short circuit (or) dip transfer ② globular transfer ③ Spray transfer

The short circuit metal transfer occurs with relatively low current settings of the order 75 to 175 A for an electrode dia of 0.9 mm, fig shows the manner in which the sequence of metal transfer takes place takes in S.C

(a) Arc ignity (b) wire end melts (c) Short circuit (d) Pinching of electrode end.

Adv:-

(1) It provides higher deposition rate (2) It is faster than shielded metal arc welding due to continuous feeding of filler metal (3) Welds produced are of better quality (4) There is no slag formation. (5) Deeper penetration is possible (6) More suitable for welding of thin sheets.

Limitations:-

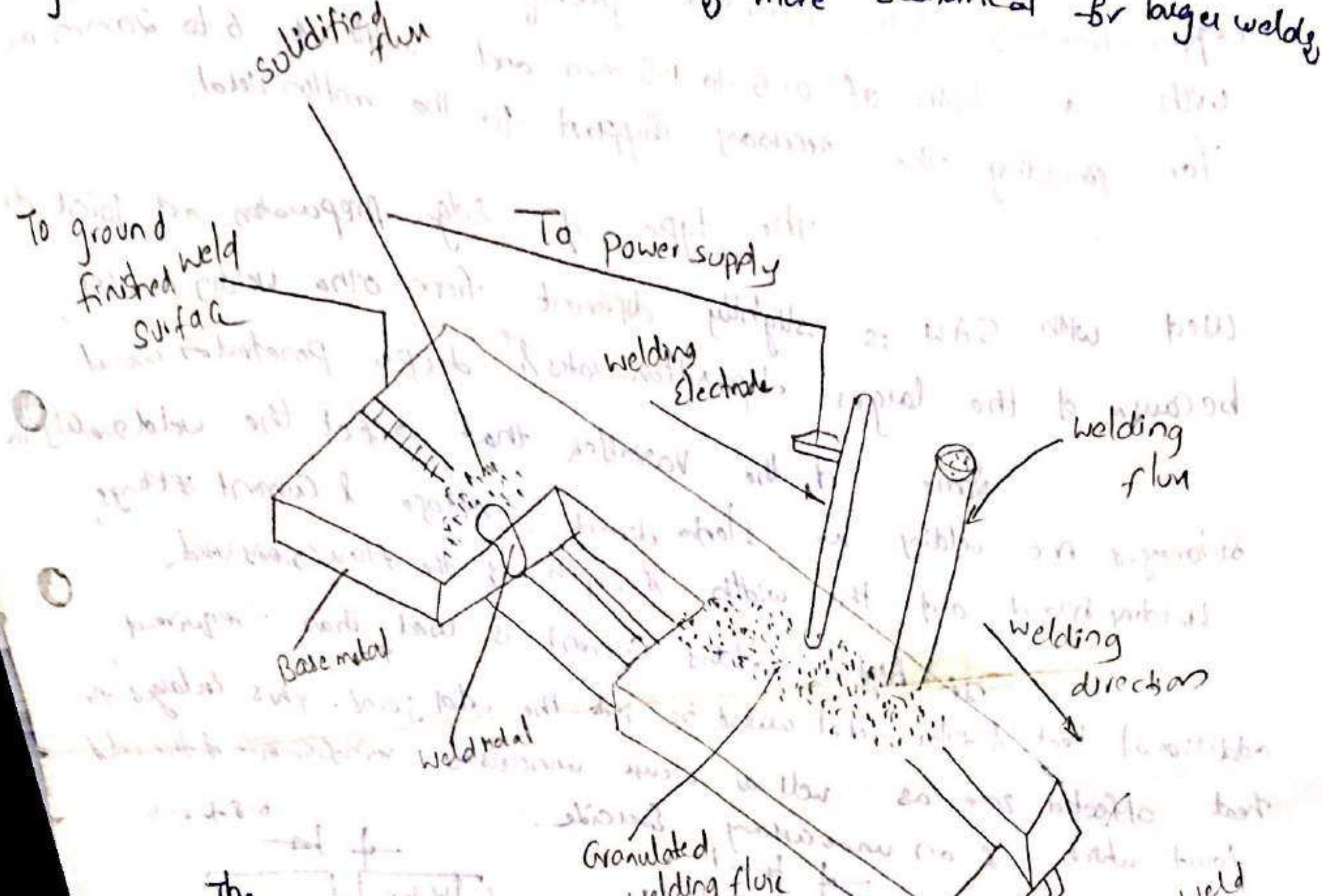
(1) Equipment used is costlier and less portable.

(2) Less suitable for outdoor work because strong wind may blow away the gas shield.

Applications:- (1) It can be used for deep groove welding of plates & castings, but it is more advantageous on light gauge metals, where high speeds are

# Submerged Arc welding (SAW):-

aster welding jobs. It is possible The SAW is used for doing
(12 mm) as well as very high currents (4000A) to use larger welding electrodes,
Metal - deposition rates of the order of 20kg/h or more can be So that very high -
achieved with this process. Also, very high welding speeds (5m/min)
are possible in SAW. Some SAW machines are able to weld plates of
thickness as high as 75mm. It is more Economical for larger welds
only.




The arc is produced while the consumable electrode wire which is
continuously fed into the weld zone. as The welding zone is completely covered by
means of a large amount of granulated flux, which is delivered ahead of the
welding electrode by means of a welding flux feed tube. The arc occuring between
the electrode and the workpiece is completely submerged under the flux
and not visible from outside. A part of the flux melts and forms the
slag, which covers the weld metal as shown in fig.

The Power sourced used with SAW can be either A.C or
D.C. Since the arc is completly submerged in the flux there is no spatter
of the molten metal. since this process uses loose granulated flux to cover the
joint, it is not possible to carry out in any position other than the
flat or down hand position. The electrode wires normally used and size
1.6, 2, 2.5, 3.15, 4, 5, 6.3 & 8 mm. The wires should be smooth with no
surface imperfections or contaminants.

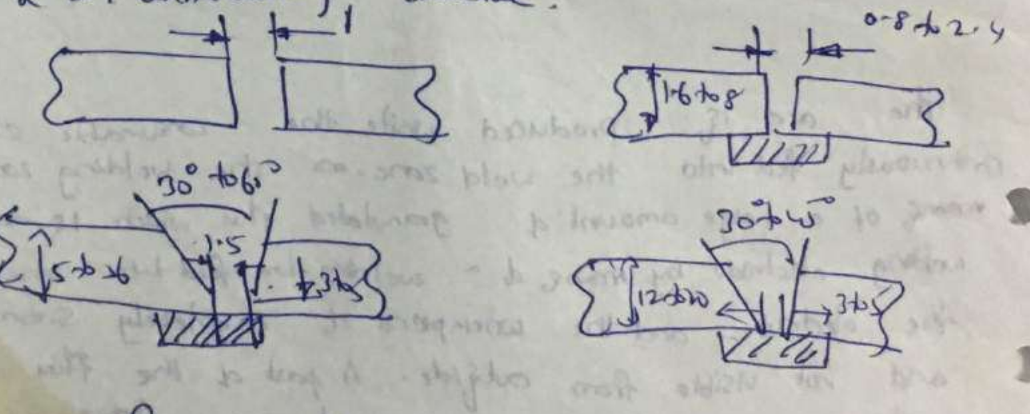
Being a large volume process, the SAW process produces large molten weld metal pool which takes sometime for solidification. The backing plates are normally used. The backing plates can be with or without grooves. The most commonly used are copper plates, which can be cooled by running water, when necessary.

For welding plates that are less than 3mm, copper-backing plates without grooves are used. For thick plates, grooves with a depth of 0.5 to 1.5 mm and width of 6 to 20mm are used for providing the necessary support to the molten metal.

The type of edge preparation and joint design used with SAW is slightly different from other welding processes because of the larger deposition rates & deeper penetrations involved.

Some of the variables that affect the weld quality in submerged arc welding are electrode diameter, voltage & current settings, welding speed and the width & depth of the flux covering used.

If higher welding current is used than required, additional heat & filler metal would be into the weld joint. This enlarges the heat affected zone as well as causes unnecessary reinforcement of the weld joint which is an unnecessary exercise.



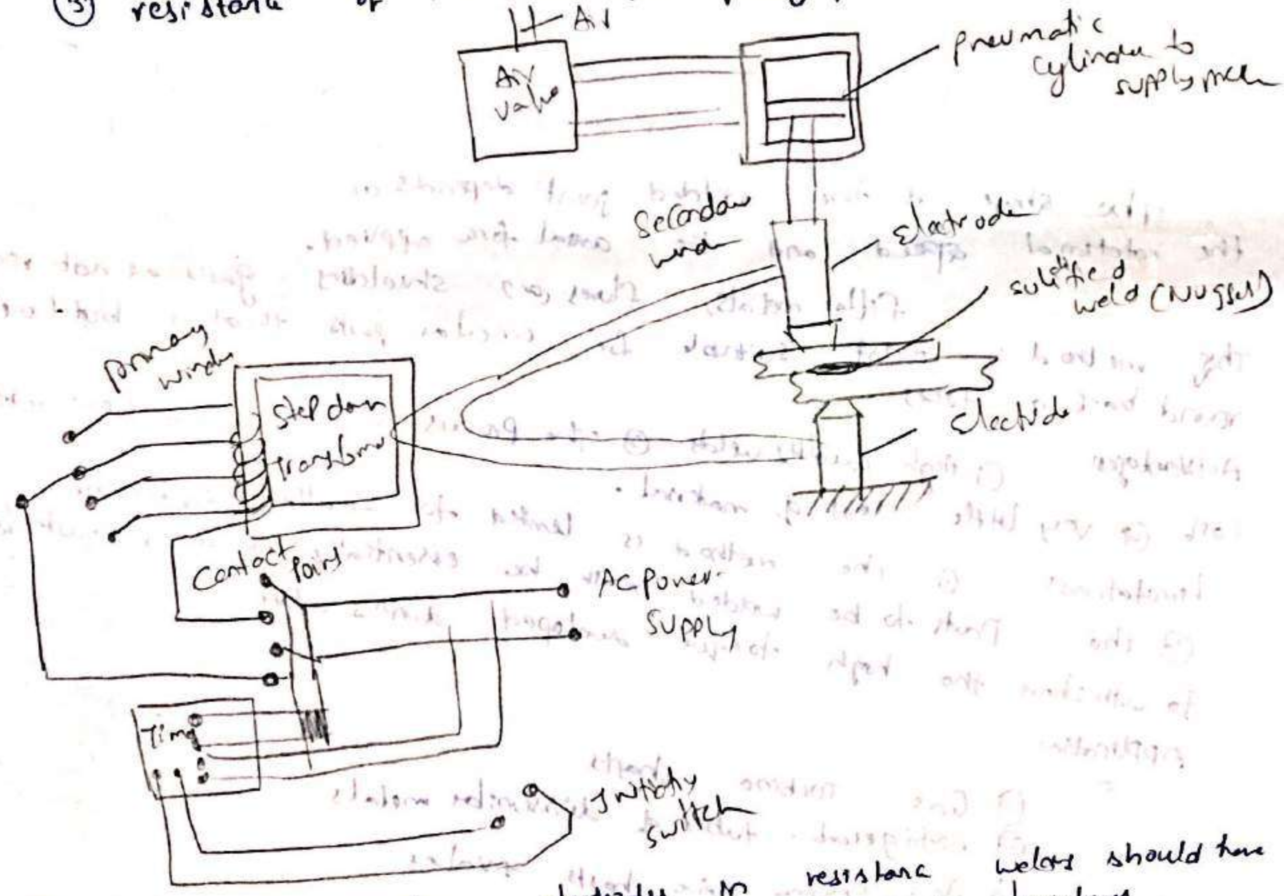

Some typical edge preparations for Submerged Arc welding.

Q. 8. The welding processes are generally fusion welding process where only heat is applied in the joint. In this, the resistance welding process is a fusion where the both heat and pressure are applied on the joint but no filler metal or flux is added.

It is the method of uniting two pieces of metal by the passage of a heavy electric current while the surfaces are pressed together.

Principles:- In RW, a low voltage (1V) and very high current (15000 A) is passed through the joint for a very short time (0.25 s). This high amperage heats the joint, due to the contact resistance at the joint & melts it. The pressure on the joint is continuously maintained and the metal fuses together under this pressure. The heat generated in resistance welding can be expressed as $H = KI^2Rt$. where H = Total heat generated in the work, J. I = electric current A. t = Time for which the electric current is passing through the joint.

Successful operation of a resistance welding process depends upon proper control of following factors (1) welding current (2) welding pressure (3) resistance of the work piece plates.



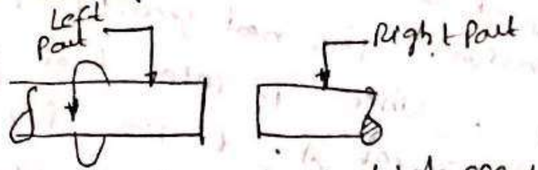

Electrodes:- The electrodes in resistance welders should have higher electrical conductivity as well as higher hardness.
→ Steel though strong, do not have conductivity required for electrodes. Hence, copper in alloyed form is generally used for making electrodes
→ Copper cadmium (0.5 to 1%) alloys have the highest electrical conductivity with moderate strengths & are used for welding non-ferrous materials.

Adv:- (1) It can be used any where (2) Low set-up cost (3) Not ... Operation (4) most suitable for welding of thick sections.

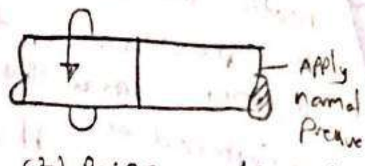
Limitations:- (1) only thick sections can be welded (2) High set-up ...

Applications:- (1) this is widely employed in shipping, steel ... (2) It can be used for welding non-ferrous parts.

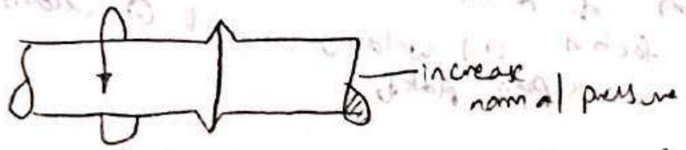
FRICTION welding:- In this welding process, often termed as "in...", the two surfaces to be welded are rotated relative to each... under light normal pressure. when the interface temp increases due to frictional rubbing and when it reaches the required welding temp sufficient normal pressure is applied & maintained until the two pieces get welded.



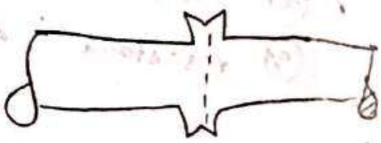
(1) Rotate left part at high speed.



(2) Bring right part in contact & apply axial force



(3) flash begins to form when axial force is increased


(4) Stop rotating left when flash is formed.

The shape of the welded joint depends on the rotational speed and the axial force applied.

Filler metals, fluxes or shielding gases are not required. This method is most suitable for circular parts that is butt welding of round bars & tubes.

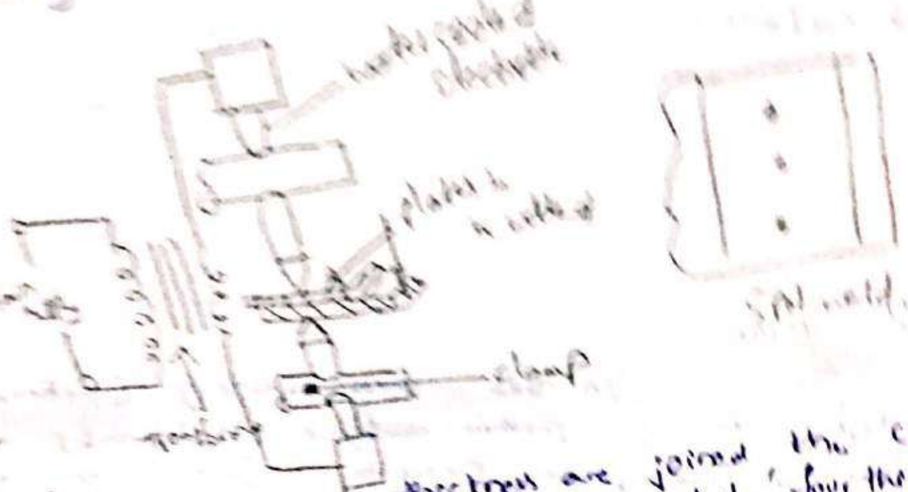
Advantages:- (1) High quality welds (2) The process is clean (3) Low initial capital cost (4) very little loss of material.

Limitations:- (1) The method is limited to smaller components. (2) The parts to be welded must be essentially round & must be able to withstand the high torque developed during welding.

Applications:-

1. Gas Turbine shafts
2. Refrigerator tubes of dissimilar metals
3. Aero-Engine drive shafts & valves
4. steering columns.

[illegible]




When sheets of unequal thickness are joined the current and pressure setting for the thinner sheets are used. Similarly, four thickness may be welded, using the same settings as for two thickness.

Currents usually range from 3000 A to 40,000 A.

Steel, brass, copper & light alloys can be joined by this method.

Applications – It is widely used for fabricating sheet metal products. Examples of its application range from attaching handles to stainless steel containers to rapid spot welding of automobile bodies using multiple.

Advantages –
(1) High production rate (2) Economical process (3) High skill not required (4) Most suitable for welding sheet metals. (5) Minimum distortion & warping or distortion of parts.

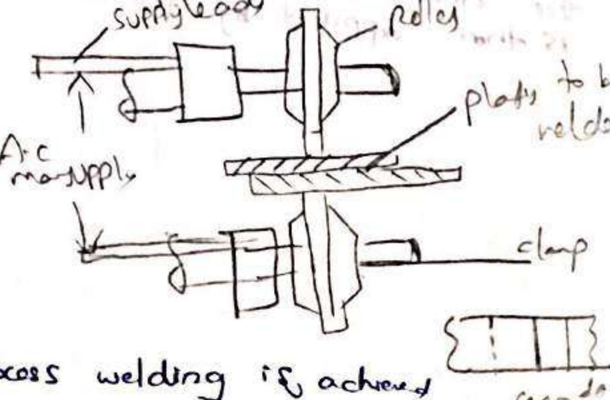
Limitations –
(1) Suitable for thin sheets only
(2) High equipment cost.

Resistance seam welding - Seam welding is analogous to spot welding, difference is the electrodes are in the form of rollers and the work direction perpendicular to roller axis. The current is interrupted times a minute to give a series of overlapping spot welds. The usually done under water to keep the heating of the welding rollers work to a minimum and thus to give lower roller maintenance distortion of the work.

Welding current ranges from 2000A to 5000A. While the force applied to the rollers as high as 5KN to 6KN.

Typical welding speed is 1.5m/min for thin sheet.

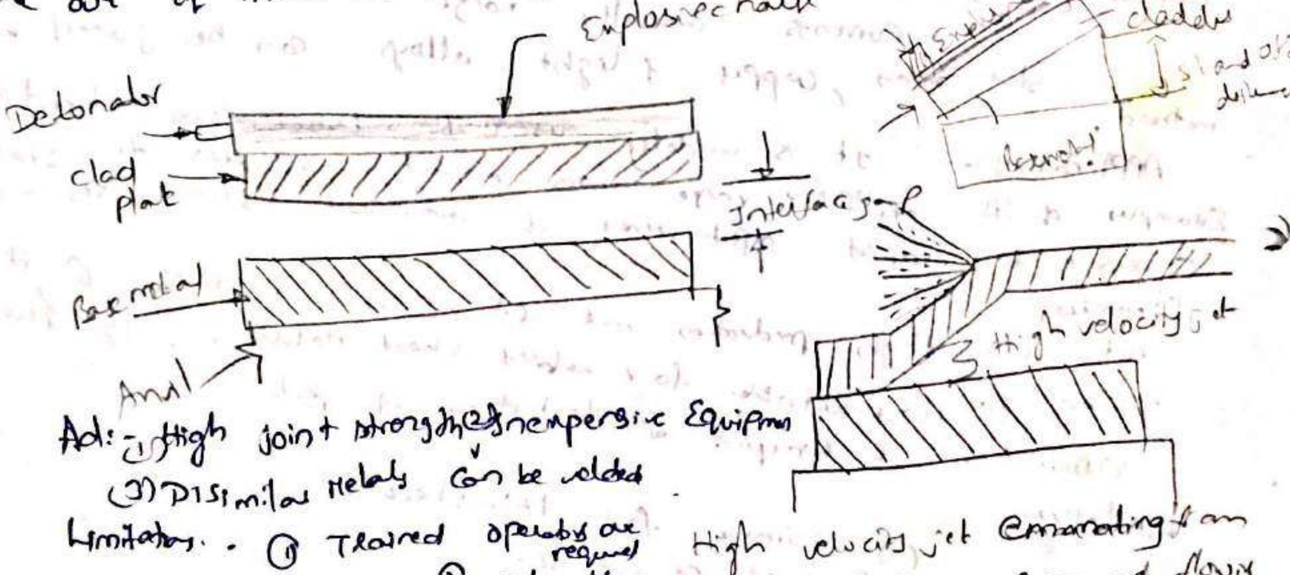
Applications - It is employed on many types of pressure (light or leak) tanks for oil switches, transformers, refrigerators, evaporators & condensers, paint & varnish container.




Plasma Arc ... matter ... of gas is ... the ... It is the arc ... shielding in the ... Constrain ... all

## Explosive WELDING:-

In this process welding is achieved through very high contact of pressure developed by detonating a thin layer of Explosive placed over one of the pieces to be joined. The detonation imparts high kinetic energy to the piece which on striking the other piece causes plastic deformation & squeezes the contaminated surface layers out of interface resulting in a high quality welded joint.




Adv: (1) High joint strength (2) Inexpensive Equipment
(3) Dissimilar metals can be welded.

Limitations. (1) Trained operators are required
(2) Inherently dangerous pro

High velocity jet emanating from the striking point and flows into the space b/n the plates

Plasma Arc Welding:-

plasma is often considered the fourth state of matter. plasma is the state of matter when the part of the gas is ionised making it a conductor of electric current. It is the state of the matter present in between the electrodes in any arc. It also uses a non-consumable tungsten electrode and a shielding gas such as argon, like TIG process. The main diff is in the construction of the torch.

In plasma Arc welding the plasma arc is tightly constrained as shown in fig. A small amount of the pure argon gas flow is allowed through the inner orifice surrounding the tungsten electrode to form the plasma gas. Because of the squeezing action of the constraining nozzle the arc in PAW is concentrated & straight. This increases the heat contained per unit volume of the arc plasma. The plasma gas is forced through the torch surrounding the cathode. The main function of the plasma gas is shielding the body of the torch from the extreme heat of the cathode.

To initiate the arc in PAW, a low current pilot arc is obtained b/n the electrode and the constricting nozzle which ionises the plasma gas flowing through the nozzle.

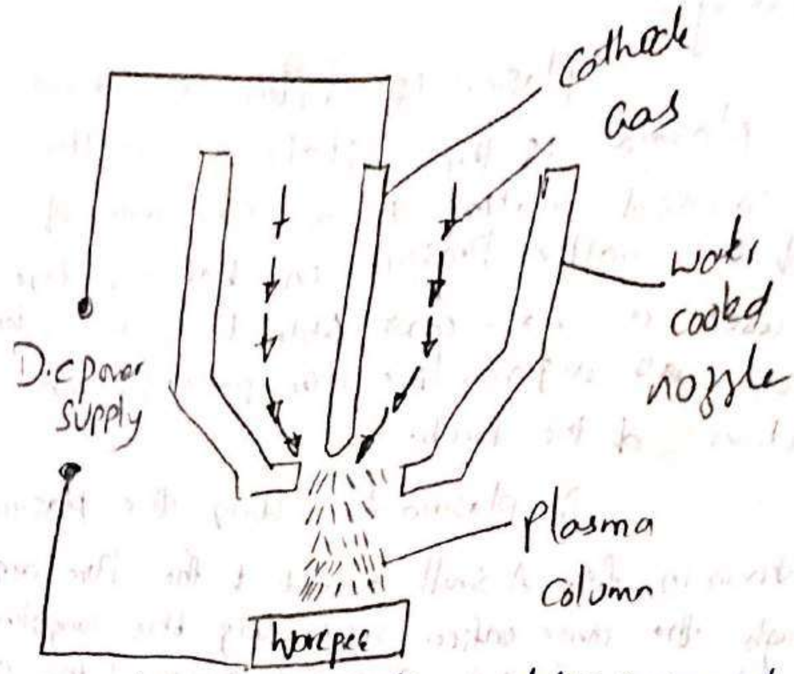
The plasma gas flowing through the constriction reaches a very high temp & provides a low resistance path to initiate the welding arc b/n the electrode and the work piece. this is termed a transferred arc. The equipment necessary for PAW includes a conventional DC power supply.

The two main types of torches for welding and cutting with plasma arc are: ① Transferred arc ② Non-transferred arc.

① Transferred arc / plasma jet torch is similar to TIG torch, except that it has the water-cooled nozzle b/n the electrode & work. this nozzle constricts the arc, increasing its pressure.

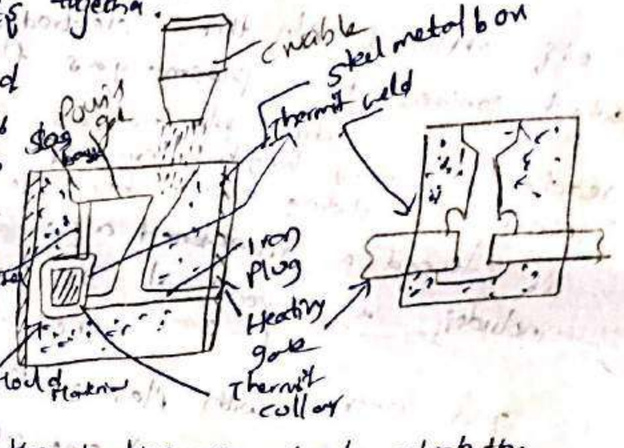
The plasma, caused by the collision of gas molecules with high-energy electron, is then put through the nozzle ~~acts as the anode. This type of plasma jet is completely independent of the~~ work piece, with the power supply forming the main current path b/n electrode & work piece.

② The Non-transferred arc torch extends the arc from the electrode, or the cathode to the end of the nozzle. The nozzle act as the anode. These type of plasma jet is completely independent of the work piece.




The disadvantages are however that the welding equipment is expensive and also the nozzle surrounding the electrode needs a frequent replacement.

THERMIT WELDING:-
It is the method of uniting iron or steel parts by surrounding the joint with the steel at a sufficient high temp to fuse the adjacent surfaces of the parts together.




(1) Here a wax pattern of desired size & shape is prepared around the joint a region where the weld is to be affected.
(2) The wax pattern is then surrounded by sheet iron box and space b/n the box & pattern is filled and rammed with sand.
(3) After cutting, pouring & heating gates and risers a flame is directed into the heating oven due to which the wax pattern melts and drains out the heating is continued to raise the temp of parts to be welded.
(4) The thermit mixture (finely divided aluminium iron oxide) is packed in the crucible of conical shape formed from a sheet iron casting lined with heat resisting cement & is ignited with magnesium (nearly 3000°C) molten iron and a slag of Aluminium oxide.

Reaction is $8Al + 3Fe_3O_4 \rightarrow 4Al_2O_3 + 9Fe + heat$.

(5) The molten iron is then run into the mould which fuses with the parts to be welded & forms a thermit collar at the joint. The welds thus obtained are metallurgically very sound & strong.

# ...ing and Brazing:-

...ing: Soldering is a method of joining similar or disimilar metals by means of a filler metal whose liquidus temp is below 450°c. The fusible metal is called 'solder'.

It is a quick method of making joints in light articles made from steel, copper and brass and for wire joints such as occur in electrical work.

Though soldering obtains a good joint between the two plates, the strength of the joint is limited by the strength of the filler metal used. The soldered joints are not suitable for high-temp service because of the low melting temp of the filler metals used. The joint design used for soldering is similar to that of brazing since the filler metals enters the soldered joint by capillary action.

A soldered joint is weaker compared to that of brazed joint. As a result, other means of mechanical fastening is used in addition to soldering to provide the necessary joint strength. The soldering joints also need to be cleaned to provide chemically clean surfaces to obtain a proper bond. Solvent cleaning, acid pickling and even mechanical cleaning are applied before soldering.

To remove the oxides from the joint surfaces and to prevent the filler metal from oxidising, fluxes are generally used in soldering. Rosin and rosin plus alcohol based fluxes are least active type and are generally used for electrical soldering work.

The organic fluxes such as zinc chloride & ammonium chloride are quick acting and produce efficient joints. Because of their corrosive nature, the joint should be thoroughly cleaned of the entire flux residue from the joint. These are to be used for only non-electrical soldering work.

The filler metals used are normally called as solders which are essentially alloys of lead & tin. The eutectic alloy (62% Tin + 38% lead) has lowest at 183°c.

The various soldering methods are:

① Soldering iron methods ② Dip soldering ③ wave soldering ④ Torch Method ⑤ Induction Method.

① Soldering iron is a copper rod with a thin tip, which can be used for flattening the soldering material. It is also used to heat the solder and the parts to be joined.

Soldering irons are of 2 types

① Those heated by heater or by either solid or gaseous fuel
② those heated electrically.

An ordinary soldering iron consists of a copper point or 'bit', usually of square or rectangular cross section usually of mild steel and a wooden handle. The point is of a size chosen to suit the class of work, its purpose is to absorb heat while in the fire and to give out this heat when applied to to ~~iron~~ job, thus heating the two parts & melting the solder.

When applying the iron it must be held in position for a sufficiently long time to ensure that the work is heated to temp, it is then drawn slowly over the surface so that it will heat the adjoining area & melt the solder.

② In dip soldering a large amount of solder is melted in a ... which is closed. The parts that are to be soldered are first cleaned properly and dipped in a flux bath as per requirement. These are then ... into the molten solder pool and lifted when the soldering complete.

Wave soldering is a variant of this method, where the part to be soldered ex., an electronic printed circuit Board (PCB) not dipped into the solder tank, but a wave is generated in the tank so that the solder comes up and makes the necessary joint. This is normally a continuous process with the PCB's being continuously moving on top of the solder tank and the waves become continuously generated.

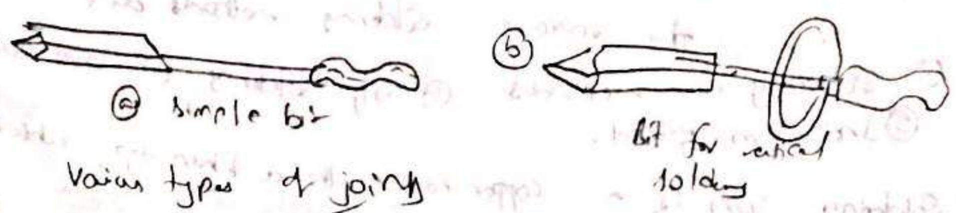
**Advantages:-**

(1) Low cost ② simplicity and cheapness of the equipment ③ Good & effective ... in fabrication as compared to other process like riveting, spotwelding etc.

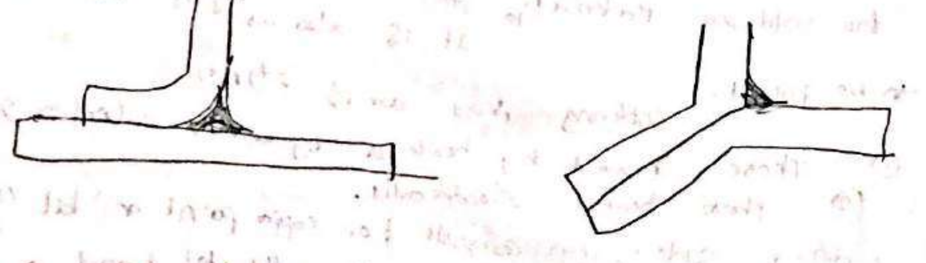
**Applications:-**

① Connections in wireless set, ~~...~~ (radio), T.V sets etc.
② Wiring joints in electrical connections, battery & other terminals.
③ Radiator brass tubes for motor car.
④ copper tubing carrying liquid fuel gas or air used in engine.

~~Brazing:~~ Soldering bits




Various types of joints



Brazing is coalescence of a joint with the help of a filler metal whose liquidus temp is above 450°C and is below the solidus temp of the base metal. The filler metal is drawn into the joint by means of a capillary action. Because of the low temp used, there is less distortion in brazed joints. Also in many cases, the original heat treatment of the plates being joined is not affected by the brazing heat. The joint can be quickly finished without much skill. Because of simplicity of process, it is often an economical joining method with reasonable joint strength.

Brazed joint is generally not useful for high temp because of the low melting temp of the filler metal. The colour of the filler metal in the brazed joint also may not match with base metal.

The filler metal reaches the joint by capillary action. So it is essential that the joint is designed properly. Another important factor to be considered is the temp at which the filler metal is entering the joint. While designing a brazed joint, care is to be taken to see that the difference in the coeff of thermal expansion of two pieces to be joined are properly considered.

In brazing, joints need to be extremely clean. Any grease or oil present in the joint prevents the flow of filler metal. Oxides & salts present are removed by acid pickling.

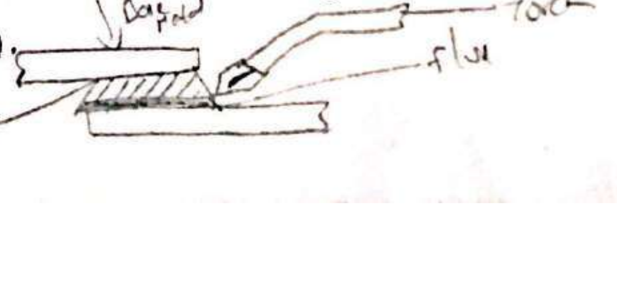
Fluxes are added to the brazed joint to remove any of the oxides present or prevent the formation of the oxides so that the base metal & filler metal remain pure during the joining.

The fluxes generally used are combination of borax, boric acid, chlorides & flourides. The fluxes used for ferrous materials are mixtures of borax & boric acid in a paste form. (75% borax & 25% boric acid).

Alkaline biflourides are used for brazing of stainless steel, al & copper alloys. A special flux containing sodium cyanide is used in brazing tungsten to copper.

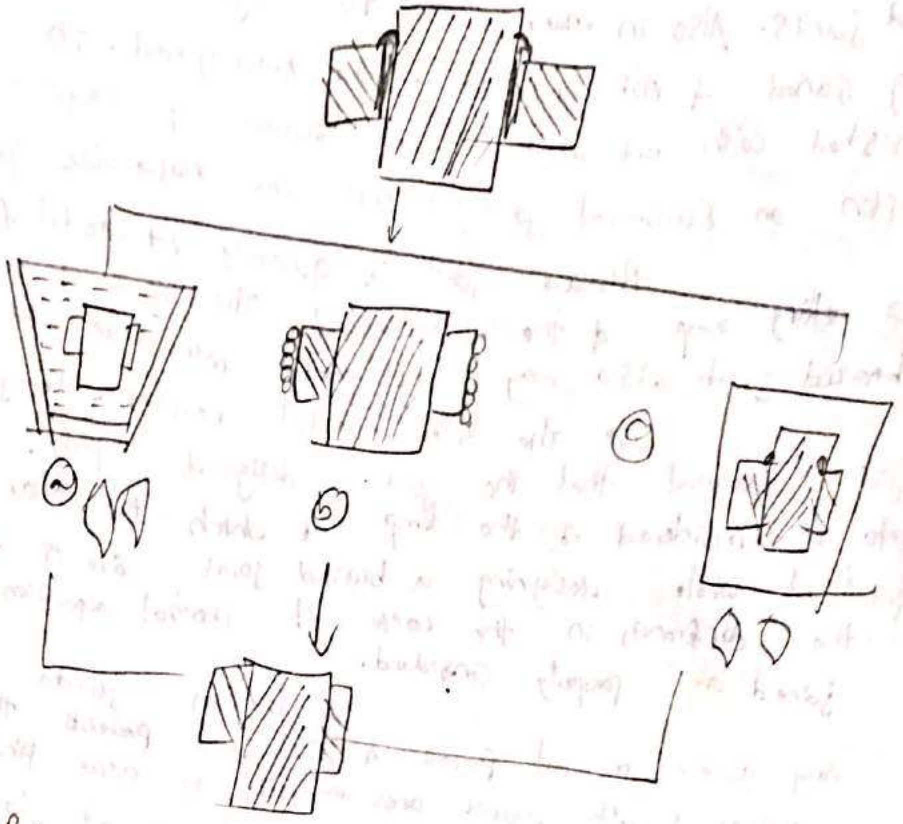
Depending on the type of base metals brazed, a no. of filler metals are available.

In Dip Brazing a molten salt bath is used to supply heat to the base metal as shown in fig. A brazing joint is prepared & dipped into the bath for quick melting of brazing alloy. When the assembly is taken out of the bath, the joint cools and joint strength is obtained.



In Induction brazing, heat is obtained from high frequency induced in the work by means of the electrical coils.

In furnace brazing, a furnace with a controlled atmosphere, which is either neutral or reducing is used.




(a) Dip Brazing (b) Induction brazing (c) furnace brazing.

...uctive and Non-Destructive testing of welds:-

(Quantitative)

The common methods of testing welded joints destructively are:- ① Tension Test ② Bending Test ③ Hardness Test ④ Impact Test. (Workshop)

⑤ Toughness Test ⑥ fatigue Behaviour (Laboratory)

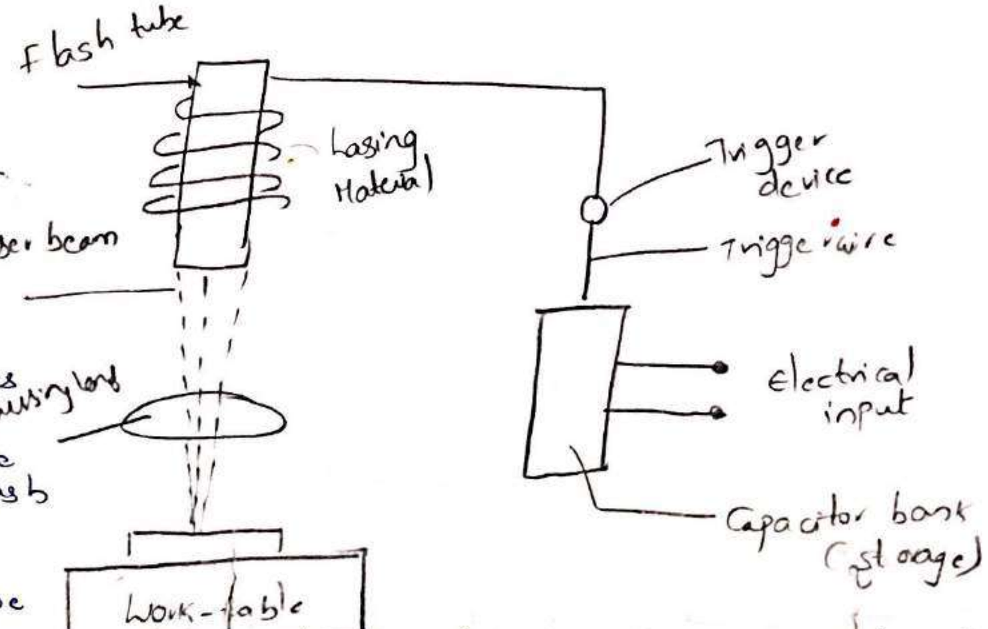
Non-destructive Tests (Qualitative)

(1) visual Examination
(2) Liquid penetrant test
③ ultrasonic inspection
④ Radiography.
⑤ thermal Testing.

Generally inspecting testings are of Qualitative tests that is Non-destructive and Quantitative tests that is destructive tests.

## Laser Beam Welding:-

The laser welding Process is the focusing of a monochromatic light into Extremely Concentrated beams. It employs a carefully focussed beam of light that Concentrates tremendous amount of energy on a small area to Produce fusion.




When Capacitor bank is triggered energy is injected into the wire that surrounds the flash tube. This wire establishes an imbalance in the material inside the flash tube. Thick Xenon often is used in the material for the flash tube, producing high power levels for very short period of time. The flash tubes or lamps are designed for operation at a rate of thousands of flashes per second. By operating in this manner, the lamps become an efficient device for Converting electrical energy into light energy, the Process of pumping the laser. The laser is then activated. The beam is emitted through the Coated end of the lasing material. It goes through a focussing device where it is Pin-pointed on the work piece. Fusion takes place and the welding accomplished.

CW $CO_2$ laser can produce deeper welds at higher rates of speed.

**Advantages:-**

1. This process can be used to weld dissimilar metals.
2. Welds can be made with a high degree of precision.
3. High depth to width ratio of weld.
4. High production rate.

**Limitations:-**

1. High energy losses
2. Highly skilled operation
3. High Equipment cost.
4. Eye protection required.

# SREENIVASA INSTUTUTE OF TECHNOLOGY AND MANAGEMENT STUDIES

## CHITTOOR, ANDHRA PRADESH- 517127

**AN ISO 9001:2015 CERTIFIED INSTITUTION**

**(AUTONOMOUS and ACCREDITED BY NAAC & NBA, PERMANENTLY AFFLIATED TO JNTU ANANTHAPURAMU)**

## DEPARTMENT OF MECHANICAL ENGINEERING

NOTES FOR

# MANUFACTURING TECHNOLOGY

# UNIT-III

## BULK FORMING

UNIT-3

# ROLLING, EXTRUSION AND DRAWING PROCESSES

The materials which are covered under the scope of material science are available either from nature or industry. However these materials cannot be used in raw form for useful purposes. They have to be shaped and formed into articles through different manufacturing processes.

Mechanical working processes are used to achieve optimum mechanical properties in the metal. Metal working reduces any internal voids or cavities present and thus makes the metal dense. The impurities in the metal also get elongated with the grains and in the process get broken and dispersed through out the metal. This decreases the harmful effect of impurities and improves mechanical strength.

When materials are subjected to external loads, they get deformed. The deformation may be elastic, plastic or fracture depending upon the load and the properties of the material. Elastic deformation is said to have occured when the material returns to its original shape on removal of load and when it does not return to its original shape on removal of load but retain its new configuration, the material is said to have deformed plastically. Further deformation causes the material to fracture resulting in seperation of a part of material from the body of material.

UNIT- 3

Differences

## COLD AND HOT WORKING:-

cold working:- When plastic deformation of metal is carried out at temp below the recrystallisation temp, the processes performed on metals are termed as cold working.

The various cold working processes are:

(1) Drawing (2) Bending (3) squeezing (4) shearing (5) shot peening.

### Advantages of cold working:-

1. Handling of material is easy.
2. Good surface finish and better dimensional accuracy.
3. Energy saving since heating is not required
4. Strength, fatigue and wear properties are improved.
5. Minimum contamination because of low working temp
6. Economical for smaller sizes.
7. Highly suitable for mass production and automation, because of low working temp.
8. Thin gauge sheets can be produced,

### Disad:-

1. Deformation energy required is high, so rugged and more powerful equipment is required, thus equipment cost is high.
2. Severe stresses are set up, this requires stress relieving which increases the cost.
3. cold working for large deformation requires several stages with interstage annealing, which increases production cost.
4. During cold working residual stresses are set up. As their presence is undesirable a suitable heat treatment is generally necessary to neutralise these stresses and restore the metal to its original structure.

Differences between cold working and Hot working

| Coldworking | Hot working |
|---|---|
| (1) coldworking is done at a temp below the value required for recrystallization. | 1. Hot working is done at a temp above recrystallization temp, so it can be regarded as a simultaneous occur of deformat. |
| (2) Hardening is not eliminated as working is done at a temp below recrystallization. | (2) Hardening due to plastic deformation is completely eliminated by recovery and recrystallization. |
| (3) Cold working decreases the value of elongation, reduction of area and impact values | (3) Mechanical properties like elongation reduction of area and impact values are improved. |
| (4) Crystallization does not take place, so refinement of crystals does not occurs | (4) Refinement of crystals occurs |
| (5) uniformity of material is lost and properties are affected a lot | (5) promotes uniformity of material by facilitating diffusion of alloys constitutes and breaks brittle film of hard constituents or impurity |
| (6) chances of crack propogation is more | (6) Cracks and unoxidised below holes are sometimes welded up, alternatively serious cracks are shown up at early stage |
| (7) Internal and residual stresses are produced | (7) Internal and residual stress are not produced |
| (8) Energy required for plastic deformation is more | (8) Energy required for plastic deformation is less because at high temp, metals become soft and ductile |
| (9) More stress is required for deformation | (9) Less stress is required for deformation |
| (10) No oxidation of metal occurs during working and hence pickling is not required | (10) Heavy oxidation occurs during working and pickling is required to remove the oxide |
| (11) Embrittlement does not occur due to less diffusion and no reaction of oxygen at low temp | (11) Reactive metals get severely embrittled by oxygen and hence must be protected from the action of oxygen by using inert atmos |

Hot working:- when plastic deformation of metal is carried out at temp above the recrystallisation temp, the processes performed on metals are termed as Hot working.

The various hot working processes are:-

① Rolling ② forging ③ Pipe welding ④ Hot spinning

Adv:-

① High production rate ② very high reduction is possible without fear of fracture. ③ Metal is made tougher because pores get closed and impurities are segregated. ④ Deformation energy required is low, hence, less powerful equipments are required. ⑤ Structure can be altered to improve the final properties. ⑥ since hot working promotes diffusion of constituents, segregation can be reduced or eliminated

Dis:-

① Handling of material is not so easy.
② Heat resistant tools are required which are Expensive.
③ High temp may produce undesirable reactions
④ Surface finish is poor because of scale formation.
⑤ Metallurgical structure may be non-uniform.

performed carried

(12) Surface finish is good

(12) Surface finish is not so good due to oxidation at high temp

(13) It is easy to control the dimensions within the tolerance limit

(13) It is difficult to control the dimensions because of contraction occur during cooling

(14) Handling of Materials is easy

(14) Handling of materials is difficult.

Difference between ingot, bloom, slab & billet:-

Ingot:- Ingots are very large casting products, greater in size and shape than blooms, billets and slabs. Ingot generally has rectangular / square cross section, but it is not necessary that it should be uniform through out its length.

Bloom:- Bloom has rectangular / square cross section. The cross section area of bloom is always greater than 230 cm². Blooms are used as rolling material in the manufacturing process of rails, seamless pipes etc.

Billet:- 1. Billet is also a casting product. Billets are made with the help of machine called as CCM.

2. Billet has a square cross section area, but cross section area of billet should be same throughout its length. The cross section area of billet is always < 230 cm². Billets are used in the manufacturing process of steel Rebars.

Slab:- A slab has a rectangular cross section, slab has thickness lesser than bloom.

weight of ingot > wt of bloom > billet > slab.

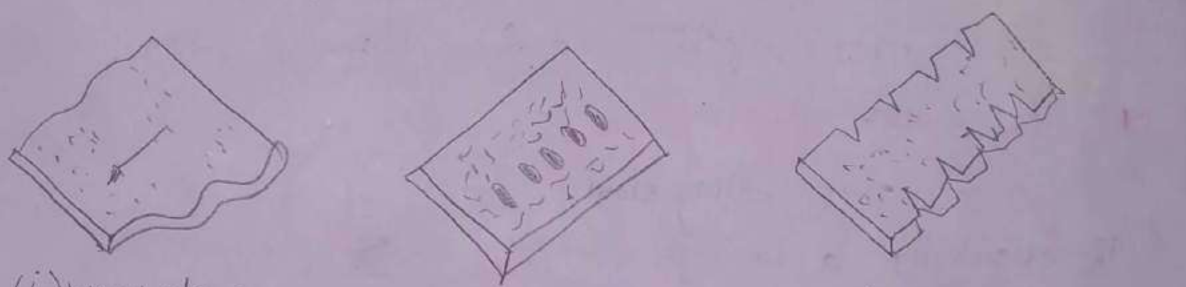
## Defects in Rolling:-

The various defects are
① Surface defects ② Structional defects

① Surface defects: These defects may result from:
(1) Inclusions and impurities in the material ② Scale, rust, dirt
(3) Roll marks.

In hot rolling blooms, billets and slabs, the surface is usually preconditioned by various means such as by torch to remove scale.

② Structural defects: These defects distort or affect the integrity of the rolled product.



(i) wavy edges (ii) zipper cracks (iii) Edge cracks

(i) Wavy Edges:- These are caused by bending of the rolls, the edges of the strip are thinner than the centre. Because the edges elongate more than the centre and are restrained from expanding freely, they buckle.

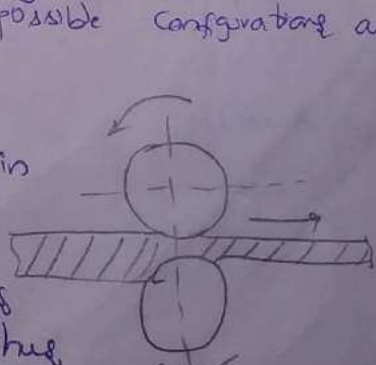
(ii) & (iii) Zipper cracks and Edge cracks:- Zipper cracks in the centre of strip and Edge cracks are usually caused by low ductility & barreling

### Rolling Stand Arrangement:-

The arrangement of rolls in a rolling mill also called rolling stand, varies depending on the application. The names of the rolling stand arrangements are given by the number of rolls employed. The various possible configurations are presented

① Two-high Roll Mills:-

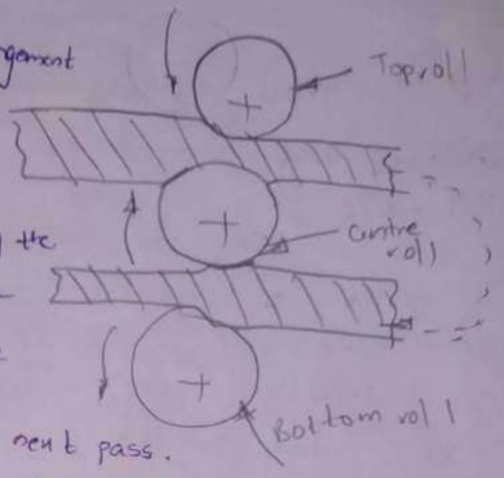
Both the rolls rotate in opposite directions to one another as shown in fig. Their direction of rotation is fixed and cannot be reversed. Thus the work can be rolled by feeding from one direction only.



The space between the rolls can be adjusted by ra[ising] the upper roll. The position of the lower roll is fixed.

(3) Three-high rolls :-

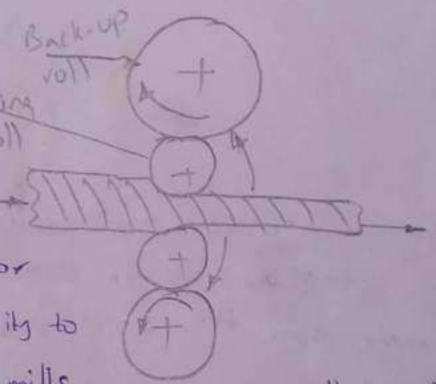
This stand arrangement is used for rolling of two continuous passes in a rolling sequence without reversing the drives. After all the metal has passed through the bottom roll set, the end of the metal is entered into the other set of rolls for the next pass.




This rolls allangement is used for blooming, rolling.

(4) four-high rolls :-

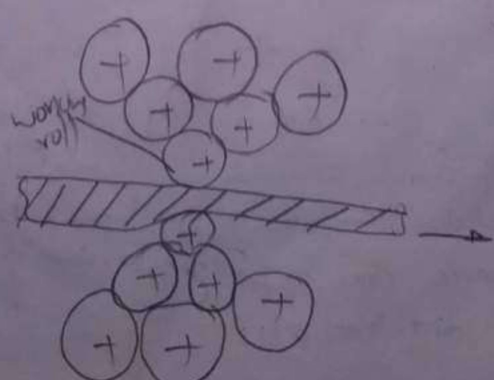
This rolling stand is essentially a two-high rolling mill, but with small-sized rolls. The other two rolls are back-up rolls for providing the necessary rigidity to the small rolls.



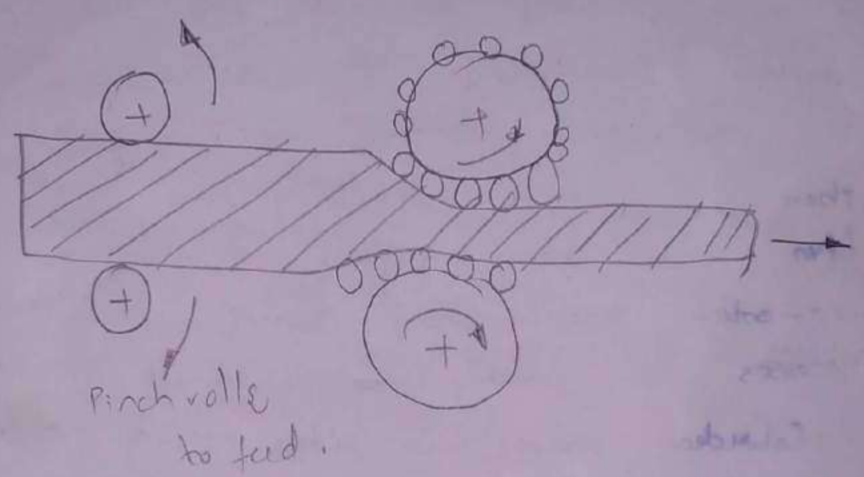

These mills are generally employed for subsequent rolling of slabs. The common products of these mills are hot or cold rolled sheets, plates.

(5) cluster rolls :- It consists of two working rolls of smaller diameter and four or more back-up rolls of large diameter. The number of back-up rolls may go as high as 20 or more, depending upon the amount of support needed for the working rolls during the operation.

This type of mill is genrally used for cold rolling.

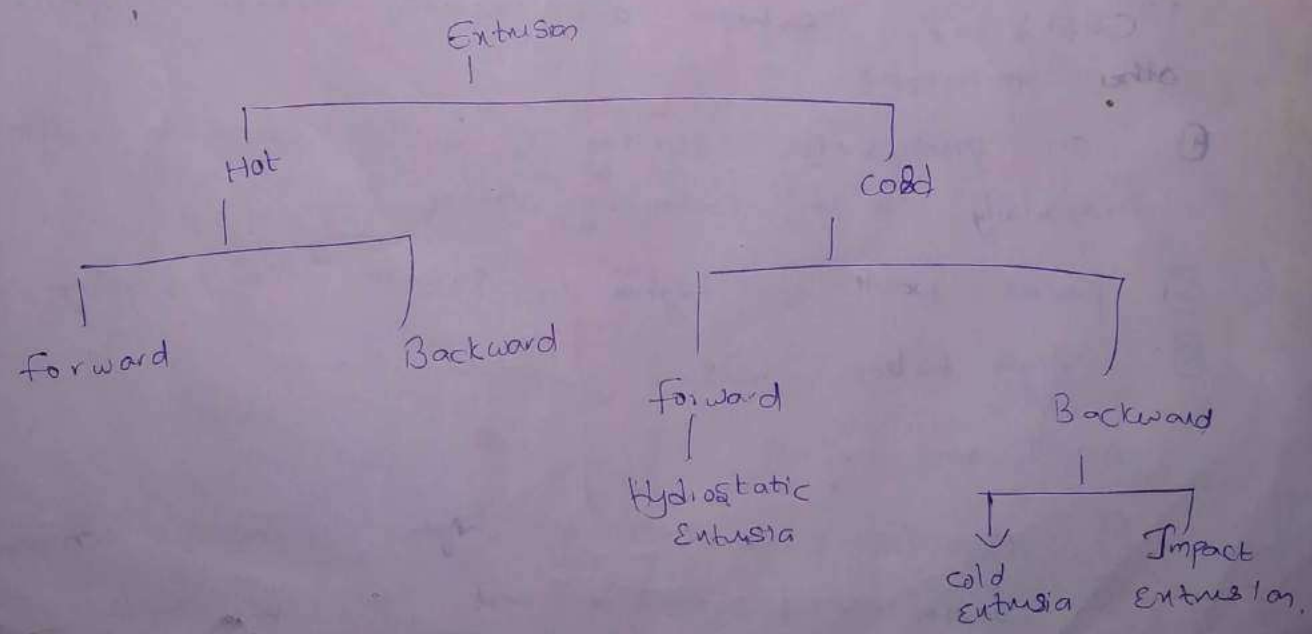


**Planetary mill:-** for the rolling arrangements require large reduction, a number of free rotating wheels instead of a single small roll, are fixed to a large back-up roll in the planetary rolling mill arrangement shown in fig.




**Extrusion:-**

Extrusion is the process of confining the metal in a closed cavity and then allowing it to flow from only one opening so that the metal will take the shape of the opening. The operation is identical to the squeezing of tooth paste out of the tooth paste tube.



Advantages of Extrusion

① Shapes can be extruded, those if produced by other methods shall entail more cost comparitively.

② Thinner walls can be obtained by increasing the forming pressure.

③ The extrusion dies are less expensive comparitively.

④ Extrusion process allows low cost in process redesign.

⑤ The dimensional tolerances are very good.

⑥ There is more flexibility in design for adjacent thin and heavy sections as well as for difficult re-entrant angle. Sharp corners, not practicable in other processes can readily be obtained by extrusion.

Extruded shapes can often replace weldments.

Extrusion is an ideal process for obtaining rods from metal having poor ductility.

Limitations:-

① As compared to roll forming extruding speed is slow.

② The sizes of dies and presses that can be economically built is a limiting factor.

③ Costs of extrusion are generally greater as compared to other techniques.

④ In productivity extrusion is much inferior to rolling, particularly to its continuous varities.

⑤ Process waste is higher in extrusion than in rolling.

⑥ High tooling costs.

Applications:

① Manufacture of parts of high dimensional accuracy.

② Manufacture of sections and pipes of complex configuration.

③ Medium & small batch production.

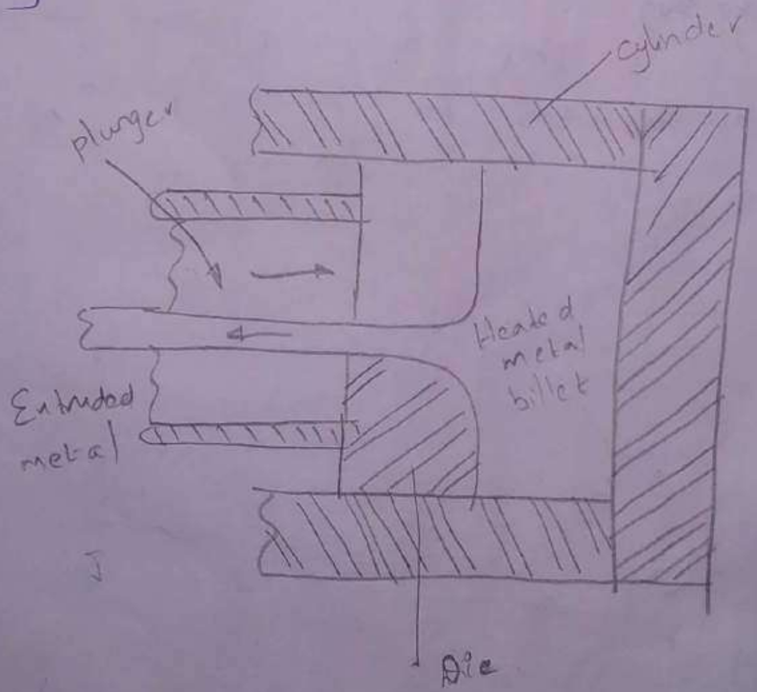
④ Working of poorly plastic and non-ferrous metals and alloys.

## Backward Hot Extrusion:-

In order to completely overcome the friction, the backward hot extrusion as shown in fig is used. In this, the metal is confined fully by the cylinder. The ram which houses the die, also compresses the metal against the container, forcing it to flow backwards through the die in the hollow plunger or ram. It is termed backward because of the opposite direction of the flow of metal to that of ram movement. Thus, the billet in the container remains stationary and hence no friction. Also, the extrusion pressure is not affected by the length of the billet in the extrusion press since friction is not involved.

The surface quality achieved is generally good since there is no heat cracking due to the friction bet^n the billet and the extrusion cylinder interface.

The disadvantage of backward extrusion is that the surface defects of the billet would end up in the final product unlike direct or forward extrusion where these are discarded in the extrusion container. Though advantageous this process is not extensively used because of the problem of handling extruding metal coming out through the moving ram.



## Cold Extrusion

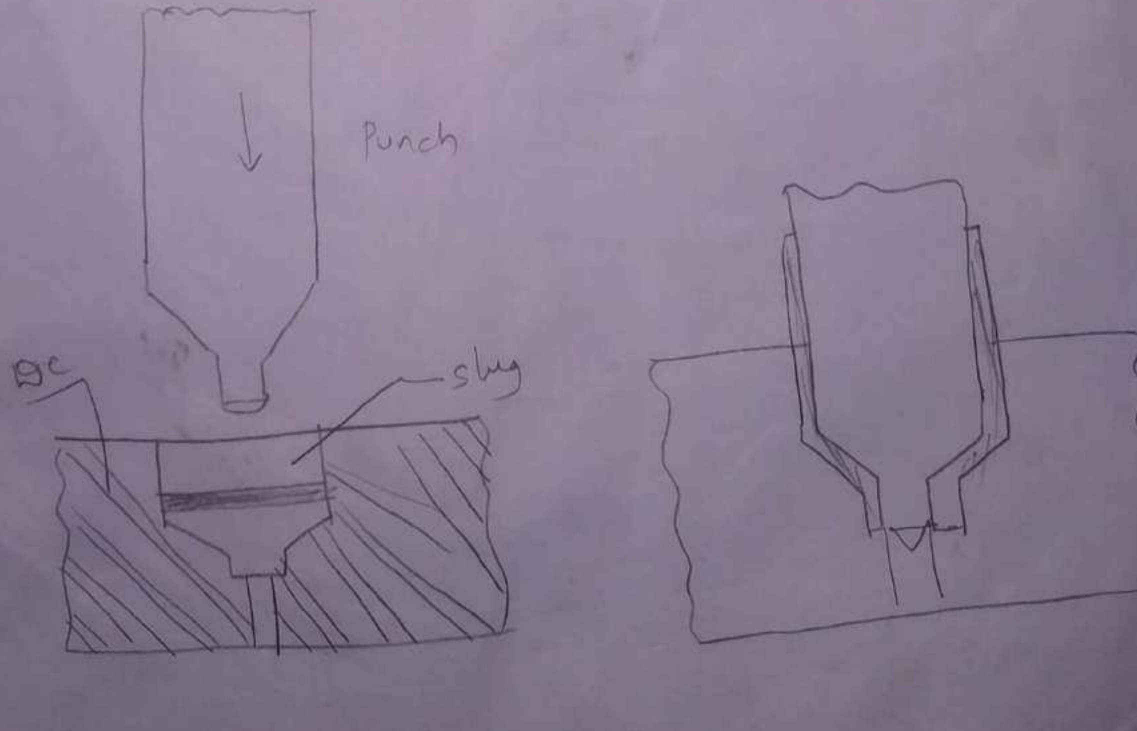
### (1) Forward cold Extrusion:-

The forward cold extrusion is similar to that forward hot extrusion process except for the fact that the extrusion ratios possible are lower and extrusion pressures are higher than that of hot extrusion. It is normally used for simple shapes requiring better surface finish and to improve mechanical properties. Ex of the applications are cans, shock absorber cylinder etc.

### (2) Impact Extrusion:-

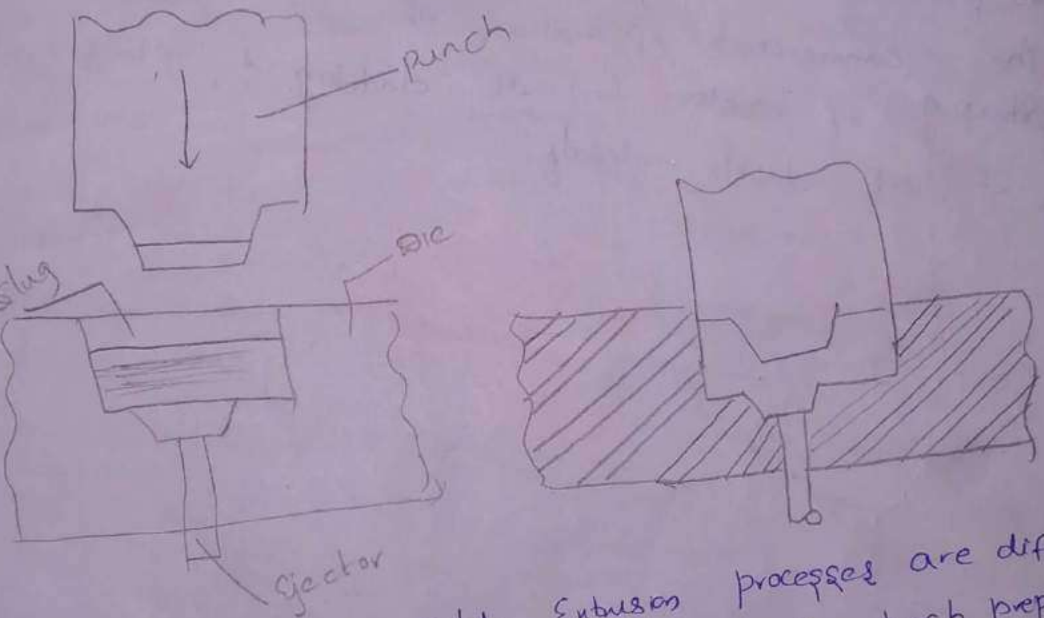
The backward cold extrusion is much more commonly particularly with softer materials such as aluminium and its alloys. In backward cold extrusion called the impact extrusion, the set up consists of a die and a punch as shown in fig. The slug for making the component is kept on the die and the punch strikes the slug against the die. The metal is then extruded through the gap between the punch and die opposite to the punch movement as in fig. Because of the impact force, the side walls go straight along the punch though they are not confined. The hight of the side walls is controlled by the amount of metal in the slug.

This process is more commonly used for making the collapsible tubes for housing pastes, liquids etc.



## Cold Extrusion forging:-

The cold Extrusion is similar to impact Extrusion but with the main difference that the side walls are much thicker and their height is similar. This also contains a die and punch set as shown in fig. The punch slowly descends over the slug kept on the die, thus forging same metal between the punch and the die and the rest being extruded through the clearance between the punch and die side walls. The side walls thus generated are short and thick with any profile in the end unlike the impact extrusion. Afterwards, the component is ejected by means of the ejector pin provided in the die.

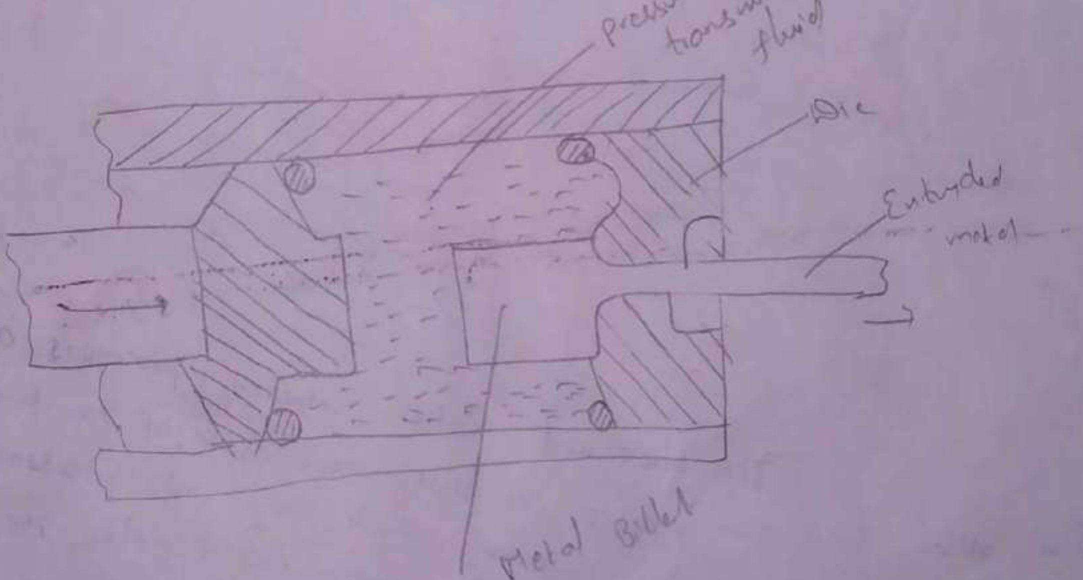



The backward cold-Extrusion processes are different from other Extrusion processes in that, each stroke of the punch prepares a directly usable single component which may not necessarily have a uniform cross section over its entire length. Also, these are limited to smaller sizes and for non-ferrous alloys only.

Hydrostatic Extrusion:-

Another extrusion process that is being used for special applications is the hydrostatic extrusion. In this, the metal billet is compressed from all sides by a liquid rather than ram. The presence of liquid inside the container eliminates the need for any lubricant and also, the material is more uniformly compressed from all sides through out the deformation zone. Because of this, highly brittle materials such as grey cast iron can also be extruded.

A typical hydrostatic extrusion operation is shown in fig. Some of the pressure-transmitting fluids used are Castor oil with 10% alcohol, SAE 30 mineral lubricating oil, glycerine, ethyl glycol and iso pentane. The hydrostatic pressure range is from 1110 to 3150 Mpa. The commercial applications of the process are limited to the extrusion of reactor-fuel rods, cladding of metals and making wires of less ductile materials.



Hot Extrusion processes:-

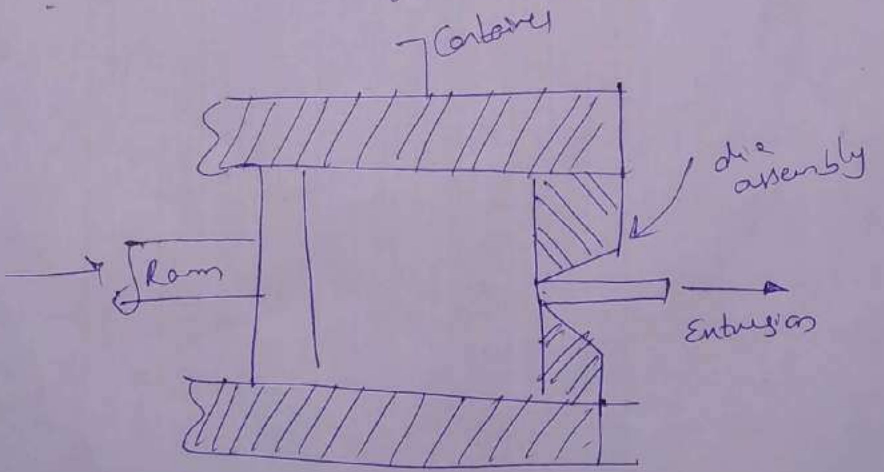
(1) forward (or) Direct Extrusion process:-

In this process a billet (piece of metal worked to a suitable shape) of the material to be extruded is placed in a container. At one end of the container is fixed a die while from the other end the metal is forced to flow through the die by hydraulically driven ram.

Much work must be supplied to overcome the resistance and high frictional forces b/n the billet and wall of the container and to produce the required rate of deformation. In forward extrusion, the problem of friction is prevalent because of the relative motion b/n the heated metal billet and cylinder walls. The problem of friction is particularly severe in case of steels because of their higher extrusion temp. To reduce this friction lubricants are to be used.

At low temp, a mixture of oil and graphite is generally used. Molten glass is generally used for extruding steels.

To reduce the damage to equipment, extrusion is finished quickly and the cylinder is cooled before further extrusion



## Principle and Mechanism of Rolling:-

The process is illustrated in fig. The rolls are in contact with the passing metal piece over a sufficient distance, represented by the arc LM. The angle LOM subtended at the centre of the roll by the arc LM is called the 'angle of contact' or the 'maximum angle of bite'. It is the friction between the surfaces of the metal piece and the rolls which provides the required grip of rolls over the metal piece to draw the latter through them.

The pressure exerted over the metal by the roller is not uniform throughout, it is minimum at both the extremities L and M and maximum at a point known as no-slip point or the point of maximum pressure. At this point the surfaces of the metal and the roller move at the same speed. Before reaching this point i.e, from L to S, the metal moves slower than the roll and the frictional force acts in the direction to draw the metal moves slower than the roll and the frictional force acts in the direction to draw the metal piece into the rolls. After crossing the neutral point S, i.e, from S to M, the metal moves faster than the roll surface, and the friction opposes the travel tending to hold the metal track. This results in setting up of stresses with in the metal to obstruct its reduction.

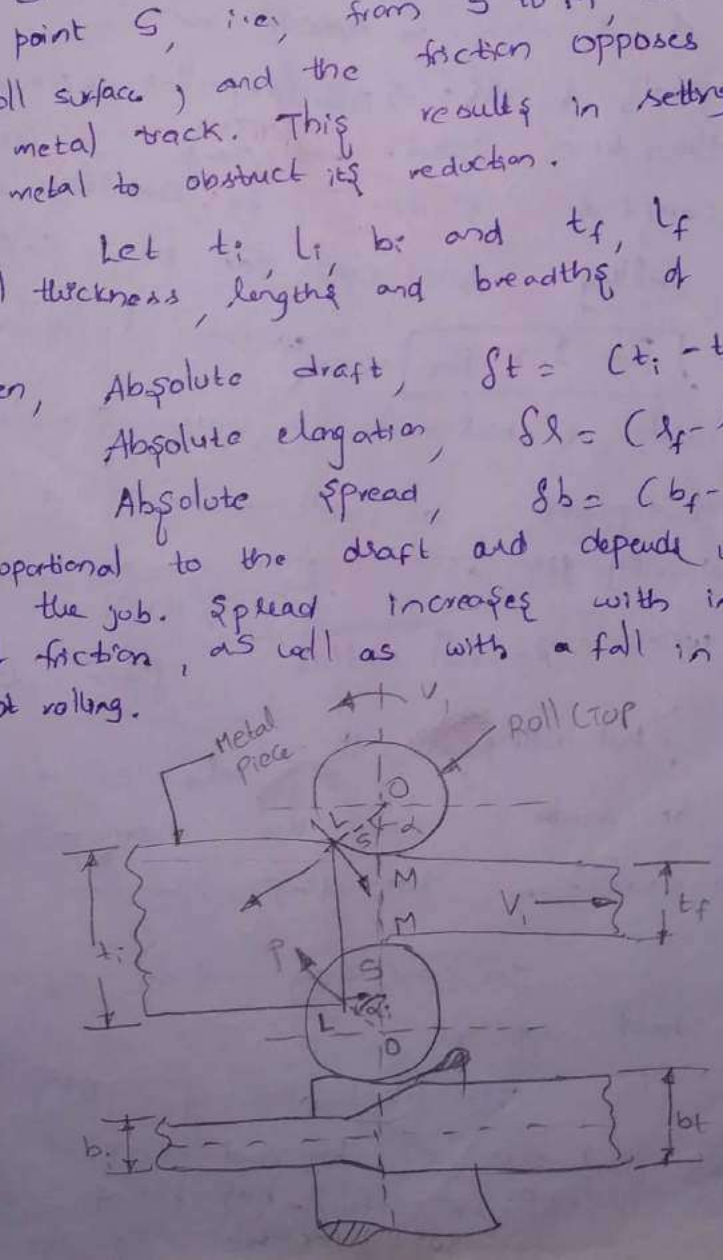
Let $t_i$, $l_i$, $b_i$ and $t_f$, $l_f$ and $b_f$ be the initial and final thickness, lengths and breadths of the metal piece respectively.

Then, Absolute draft, $\delta t = (t_i - t_f)$ mm

Absolute elongation, $\delta l = (l_f - l_i)$ mm

Absolute spread, $\delta b = (b_f - b_i)$ mm.

Spread is proportional to the draft and depends upon the thickness and width of the job. Spread increases with increase in roll diameter and coeff of friction, as well as with a fall in temp of metal in course of hot rolling.




Metal rolling process

Relative draft, $R_t = \frac{\delta t}{t_i} = \left(\frac{t_i - t_f}{t_i}\right) \times 100$.

Elongation Coeffiaent, $\nu = \frac{l_f}{l_i}$.

At the moment of bite, two forces act on the metal from the side each roll, radial or normal force 'p' and the tangential forced frictional force $\mu p$ where where $\mu$ is coeff of friction b/w the metal and roll surfaces. The part would be dragged in if the resultant of horizontal component of the normal force 'p' and tangential force $\mu p$ is directed in that direction.

In the limiting case

$$p \sin \alpha = \mu p \cos \alpha$$

$$\mu = \tan \alpha \quad \therefore \boxed{\alpha = \tan^{-1} \mu}$$

when $\alpha > \tan^{-1} \mu$, the metal would not enter the space b/w the rolls automatically that aided.

The maximum permissible angle of bite depends upon the value of '$\mu$' which in depends upon:

- Materials of rolls; → Job being rolled; → Roughness of their surfaces
- Rolling temp, speed. → Process variables in rolling process: (1) Temp → (2) Roll gap or draft.
→ (3) Coeff of friction → (4) Dimensions of sheet.

The rolling load (P) can be calculated as:

$$\boxed{P = l \cdot b \cdot P_m}$$ where $l$ = Roll-strip contact length,

b = Breadth of sheet and $P_m$ = Mean specific pressure.

Since $l$ depends on roll diameter and angle of bite, it is approximately given as, $l = \sqrt{R \cdot \delta t}$

where R = roll radius, $\delta t$ = draft $= t_i - t_f$.

* In hot rolling, the value of $\alpha$ and hence of '$\mu$' should be greater since the maximum possible reduction is desired. Usually in hot rolling, lubrication is not necessary.

In cold rolling, since the rolling loads are very high. $\mu$ should not be much.

The usual values of biting angles are:

2°–10° = for cold rolling of oiled sheet and strip
15°–20° = for hot rolling of sheet & strip
24°–30° = for hot rolling of heavy billets/blooms.

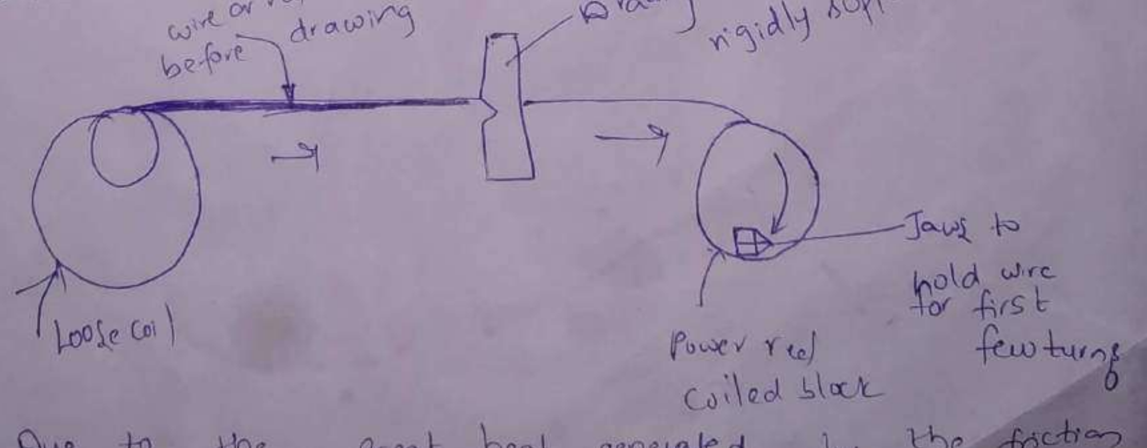
## Wire Drawing:-

Wire drawing is the process of reducing diameter of metal rods by drawing them through conical openings in die blocks.

Wire drawing is fundamentally a simple process. Steel, iron or non-ferrous rod is converted into wire by drawing it through a conical hole having an included angle of 8-24°. In continuous wire-drawing the wire passes through a succession of holes of decreasing size in dies made of steel, tungsten carbide, ruby or diamond, the reduction in cross-sectional area usually being about 30%.

The rods used for wire-drawing are first pickled in acid to remove any scale and then electrically butt welded. The end of the rod is tapered sufficiently to fit the first dies by passing it through a pointing machine, which generally takes the form of two motor-driven rollers having a number of grooves of decreasing size between which the rod is rolled. The rod may be coated with iron hydroxide, copper or tin, applied during or after pickling. The rod is then fed into the wire drawing machine, which may be fitted with six or more dies, through which the wire is drawn by means of number of power-driven pulleys or rotating drums.

Although the principle is similar in each case, the machines differ in design, and for practical purposes are broadly divided into non slip and slip types.




Due to the great heat generated by the friction of the wire in the dies, both the dies and drums are continuously cooled by circulating water through them.

Lubrication is often ensured by passing the rod through dry soap on its way to the die.

A different method of overcoming the cooling and lubrication problem is to employ a wet-drawing machine.

Ruby or diamond dies are also employed but their use generally being confined to the drawing of fine wires of <3mm in dia. The jewels are first trimmed and then drilled with small drills which are fed with diamond powder & oscillated for several hours.

UNIT-4

FORGING AND SHEET METAL PROCESSES

Forging is the operation where the metal is heated and then a force is applied to manipulate the metal in such a way that the required final shape is obtained.

Advantages and disadvantages of forging:-

1. Forging improves the structure of metal and hence its mechanical properties.
2. Forgings are easily welded.
3. Rapid duplication of components.
4. Ability of the forging to withstand unpredictable loads.
5. Metal removing in machining is minimum.
6. The forging can withstand unpredictable loads.
7. The surface of the forging is relatively smooth.
8. Superior machining qualities.
9. Minimum weight per unit strength and better resistance to shock.

Disadvantages:-

1. The initial cost of dies and cost of their maintenance is high.
2. In hot forging, due to high temp of metal, there is rapid oxidation or scaling of the surface resulting in poor surface finish.
3. Forging operation is limited to simple shapes and has limitations for parts having undercuts etc.
4. Forgings are usually costlier than castings.

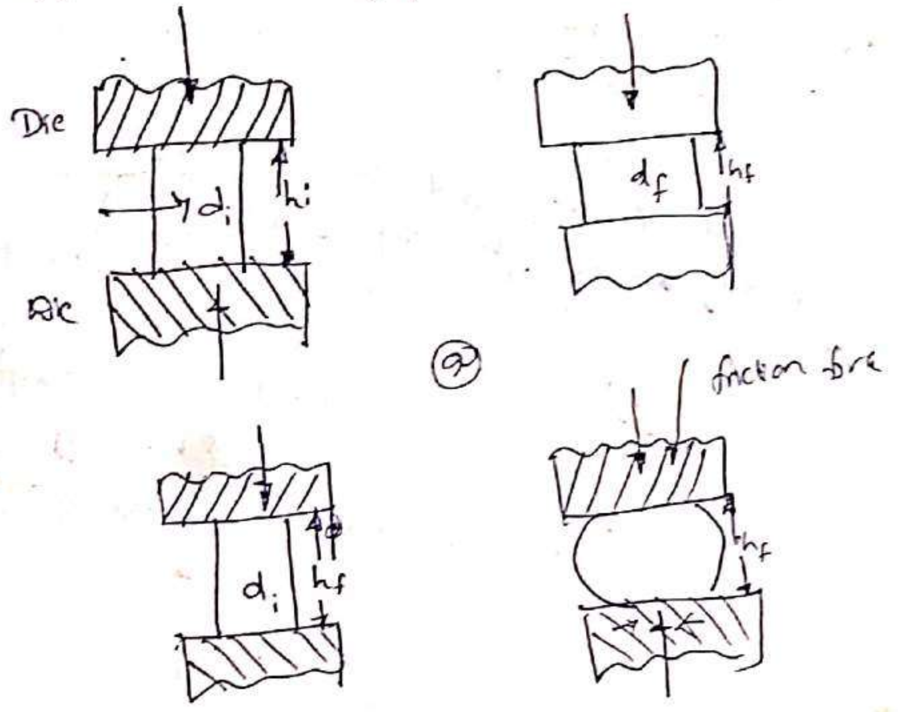
Basic categories of forging:-

① open-die forging ② Impression die-forging ③

① open-die forging:- This type of forging is distinguished by the fact that the metal is never completely confined as it is shaped by various dies.

Open-die forging, in its simplest form generally involves placing a solid cylindrical workpiece between two flat dies and reducing its height by compressing it. This process is known as upsetting. under ideal conditions, a solid cylinder deforms as shown in fig.(a) this is known as homogeneous deformation.

fig (b) shows deformation in upsetting with friction as the die-workpiece interfaces, the specimen develops a barrel shape.




Adv:-

① simple to operate ② simple for low production volume ③ Inexpensive tooling & equipment ④ wide range of workpiece sizes can be used.

Limit

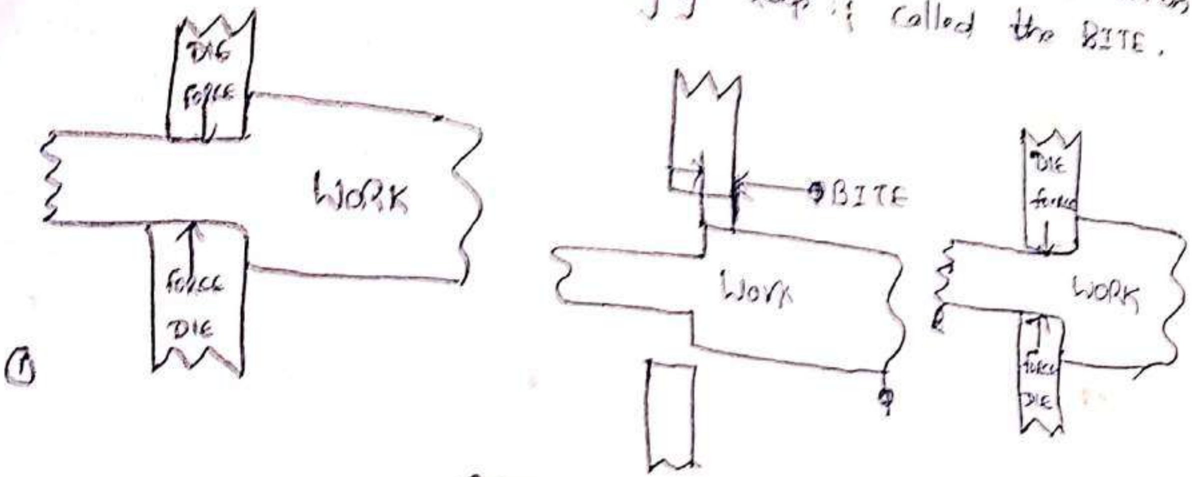
① suitable for simple shapes only. ② Can be employed for short run production only ③ Material utilisation is poor ④ Skilled workers are required. ⑤ Since machining is often required, final cost of production may be higher than other forging methods.

marks which have spec... cannot be o...

(1) Open die forging categorized in 3 methods;

(i) Cogging is a forging process in which flat (or) slightly contoured die are used to compress a work piece, reducing its thickness and increasing its length.

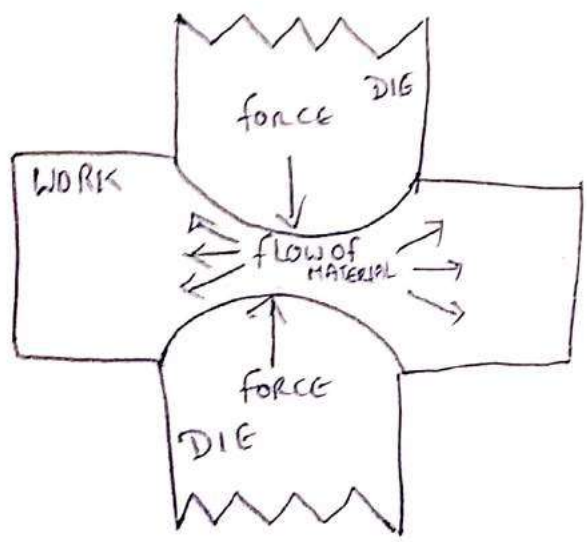
The distance travelled by die in forward direction on the workpiece between each forging step is called the BITE.




Cogging operation.

(ii) FULLERING:- In fullering, open die with convex surfaces are used to deform the work piece.

The result is to cause material to flow out of one area and to both sides. Fullering is mostly used as an earlier step to prepare the work piece for further forging processes.




FULLERING

The removed portion is called a blank.

Reduced to simplest terms, a set of blanking tools consists of a bed and punch. The latter is attached to the ram of the machine and the former is clamped to the bed to the press. When the tools are set, the punch should first enter the bed without touching the sides in such a manner as to damage the cutting edge.

The clearance between the cutting edge is regulated to suit the thickness of the metal to be cut with the tools in position, the punch should be adjusted to enter the bed for the minimum distance necessary to give complete shear. If it is permitted to enter too far, the punch is subjected to unnecessary wear. With tools in position and properly set, the tail end of the downward stroke of the ram forces the punch to carry the material it covers into the bed. The surrounding metal cannot enter, hence is sheared off. In order to obtain a blank free from burr, that is with a clean sheared edge, particular attention should be given to the clearance and condition of the cutting edges.

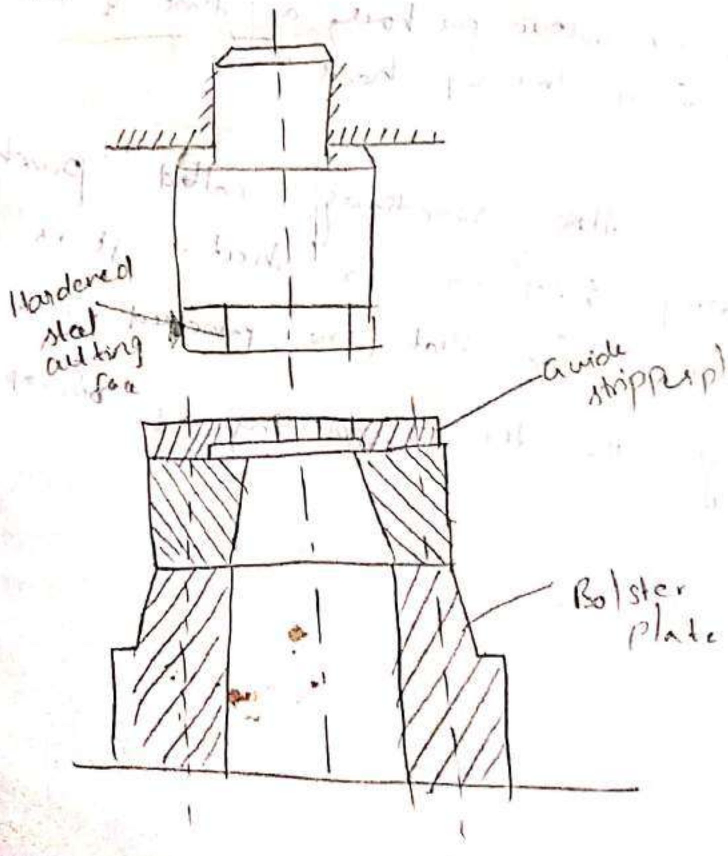
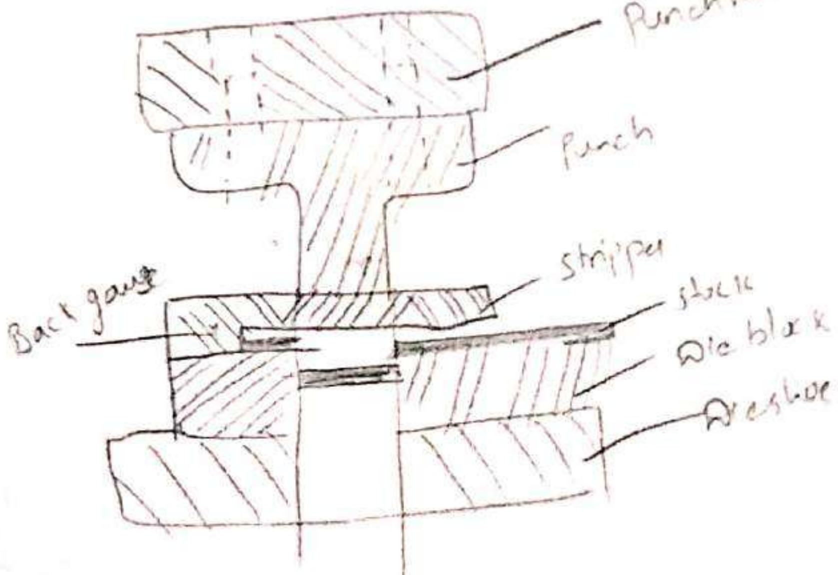


fig. shows a typical lay out for a small set of blanking. The punch is of the built-up type having a low-carbon shank, which is fitted in the press ram and a hardened cutting edge held by screws on to the base. The aim of having a built-up punch of this type is two fold. It gives a strong edge that will withstand the abrasive action for a considerable period without loosing its size, and it permits a great economy in the use of expensive alloy steel. In this particular design the cutting edge is held in position by means of a spigot and hollow head-screws.

To assist the clamping and make up the "Shunt height" of the press, the bed is mounted on a bolster plate. It is located by means of strong dowels and clamped in position with hollow-head screws.

In order to guide the material a guide plate fitted with a stop is attached to the face of the blank bed. The guide plate also acts as a stripper and takes the scrap webbing off the punch. It aids in getting a good blank, and a reasonable output per hour, as time is not wasted in having to pull the scrap clear by hand.

Piercing:- Also sometimes called punching the piercing is making holes in a sheet. It is identical to blanking except the fact that the punched-out portion coming out through the die in piercing is scrap.



# SREENIVASA INSTUTUTE OF TECHNOLOGY AND MANAGEMENT STUDIES

## CHITTOOR, ANDHRA PRADESH- 517127

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## DEPARTMENT OF MECHANICAL ENGINEERING

NOTES FOR

# MANUFACTURING TECHNOLOGY

# UNIT-IV

## SHEET METAL FORMING

## Sheet Metal operations:-

Sheet metal forming is the process of converting a flat sheet of metal into a part of desired shape with out or excessive localized thinning. The process may be simple, such as a bending operation, or a sequence of very complex operations such as those performed in high-volume stamping plants.

Sheet metal:- Sheet Metal is simply metal formed into a thin and flat piece called a "sheet Metal".

→ In prehistoric times, metal sheets were used to make armor of soldiers, swords etc;

→ Before the discovery of Glass, it was also used to make common home articles like plates, bowls, liquid jars etc; Later on the sheet metal found its way in the making of vehicles, blades of helicopters.

### Sheet Metal characteristics:-

① Elongation:- This is the characteristic of the sheet metal to stretch with out necking and failure.

② Strength:- The ability of a material to stand up to forces being applied with out bending, breaking or deforming it in any way.

③ Elasticity:- The ability of a material to absorb force it in different directions, returning to its original position.

④ Plasticity:- The ability of a material to change in shape permanently.

⑤ Ductility:- The ability of a material to change shape (deform) usually by stretching along its length.

⑥ Toughness:- A characteristic of a material that does not break when receiving a blow or under a sudden shock.

Defects in forging:-

(1) Cold shut:- This usually occurs at the corners and at right angles to the surface.

This is caused mainly by the improper design of the die where in the corner and fillet radii are small as a result of which the metal does not flow properly into the corner and ends up as a cold shut.

(2) Unfilled section:- It is similar to misrun in casting and occurs when metal does not completely fill the die cavity.

It is usually caused by using insufficient metal or insuffient heating of the metal.

(3) Flakes:- Basically these are internal ruptures.

These are caused by improper cooling of large forging and can be remedied by following proper cooling practice.

(4) Scale Pits:- These are irregular depressions on the surface of the forging.

These are primarily caused because of the improper cleaning of the stock used for forging.

(5) Improper grain flow:- This is caused by the improper design of the die which makes the flow of metal not following the final intended directions.

(6) Internal cracks:-

These can result from too drastic a change in the shape of the raw stock at too fast a rate.

(7) Die-shift:-

This defect is caused by the misalignment of two die halves, making the two halves of the forging to be of improper shape.

(8) Burnt and over heated metal:-

This defect is caused by improper heating conditions and soaking the metal too long.

The ability of a material to conduct electricity

**Conductivity:-**

**Tensile strength:-** The ability of a material to stretch without breaking.

**Grain size:-** Determines surface roughness on stretch sheet metal. It affects material strength.

## Applications of sheet Metal:-

In Automobiles:- The sheet metal is deformed into the desired and brought into the required form to get auto body pressings like bumpers, doors etc;

2. It is used for making the entire fuselage wings.

3. It is used for making many parts like washing machine body & covers, clock cages, fan blades, cooking utensils etc.

## formability of sheet Metal:-

The ability of the sheet metal to undergo the desired shape change without such failure as necking or tearing.

## Testing Methods for FORMABILITY:-

We can determine the formability of sheet metal by following tests.

① Ductility Test ② DENT TESTER ③ TENSILE TEST
④ CUPPING TEST

**① TENSILE TEST:-** Tensile testing is the most basic mechanical test for sheet metal. This test is relatively simple & inexpensive. It also follows established standards to ensure uniformity of application and results suitable for comparison.

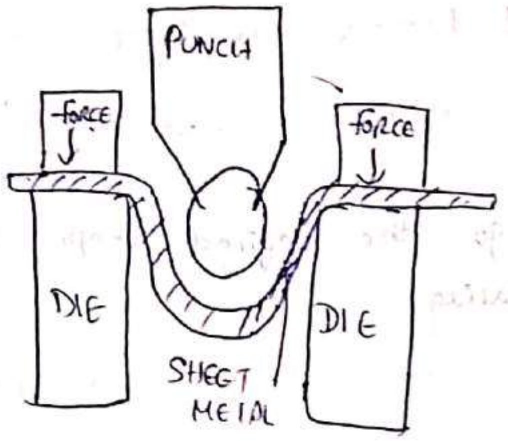
Simply put a standardized sample in tensile test apparatus and pull it along a single axis until it fails. We measure the material as it is pulled to determine the materials elongation, tensile strength, yield strength.

Scanned by CamScanner

(2) CUPPING TEST:-

The first test is the cupping test for checking the formability of sheet metals. In which test a sheet metal specimen is clamped between two circular dies, and a steel ball or round punch is pushed into the sheet metal until a crack begins to appear on the stretched specimen.

Formability of sheet metal is directly proportional to the punch depth "d". This test is insufficient in simulating exact conditions of actual sheet-forming operations.




## SHEARING OPERATIONS:-

Straight line shears are used for general purpose shearing work, for example in cutting the small pieces from a larger sheet. But the more useful are the die-shearing operations where the shears take the form of the component to be made. The upper shear is called the punch and the lower shear is called a die.

The two widely used processes are blanking and piercing.

### (1) Blanking:-

Blanking is a process of cutting or shearing a blank from sheet or strip material.

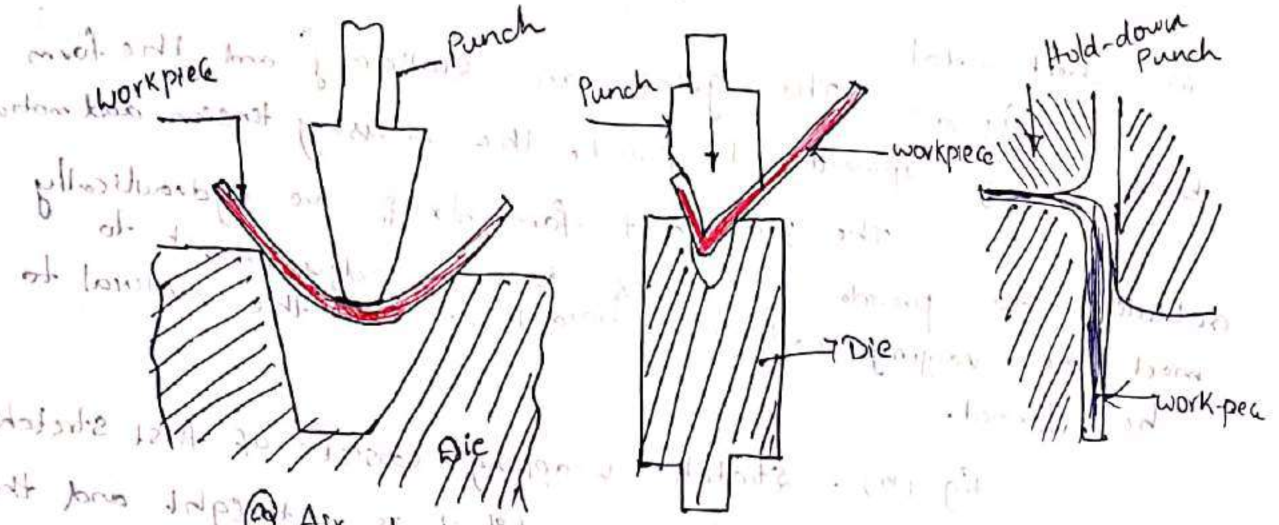
(Or)

It is a process in which the punch removes a portion of material from the stock, which is a strip of sheet metal of the necessary thickness and width. The

## Bending:-

Bending is the operation of deforming a flat sheet around a straight axis where the neutral plane lies. It is a very common forming process for changing sheet and plate into channel, drums, tanks etc.

The types of bending dies/methods as shown in figure.




(a) Air-bending (b) Die-bending

In V-bending fig (a, b) a wedge-shaped punch forces the metal sheet or strip into a wedge shaped die cavity. The bend angle may be ~~acute~~ acute, 90° (or) obtuse.

V-dies are the ones that are most generally used.

→ Wiper bending is used for 90° bends only. Here the work is held firmly to the die, and the punch bends the extended portion of the blank.

Presses specifically designed for these operations are called press brakes.

The bending load may be calculated from the knowledge of material properties and die characteristics as follows:

$$P_b = \frac{K L \sigma_y t^2}{b}$$

where $P_b$ = Bending force N.

K = 1.33 for die opening of 8t; 1.20 for die opening of 16t, 0.67 for U bending.

l = length of bent part, mm.

$\sigma_u$ = ultimate tensile strength, MPa. t = material thickness, mm and b = width b/n contact points mm.

Stretch forming:- It is a method of producing contours in sheet metal.

fig (a) The grips are stationary and the form block moves upwards to provide the necessary tension and motion. The jaws and form blocks are hydraulically actuated to provide control of pressure adjustment to meet the varying conditions characteristic of the material to be formed.

fig (b). stretch wrapping consists of first stretching the metal beyond its yield point while it is straight and then wrapping it around a form block. It is particularly suited for long sweep bends on tubes and extruded shapes.

The main adv of this type of forming is that only one die is needed, the die may be made out of inexpensive material.

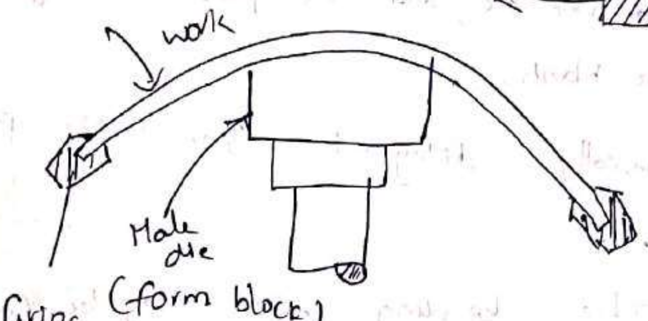



fig (a)

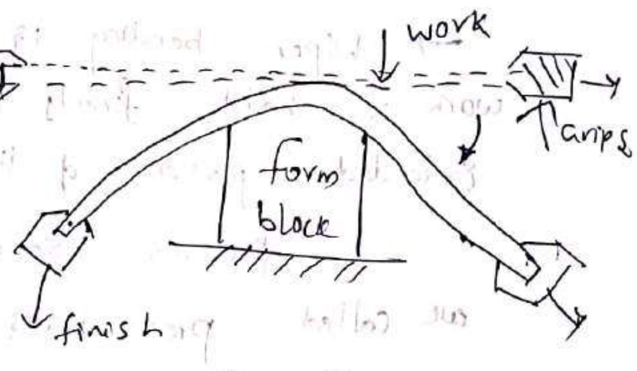



fig (b)

The thickness reduction should not exceed 5% of the original thickness.

The process is applicable to a wider range of materials, because the ductility is the least important shock transmission.

Explosive forming is widely used, high-value forming techniques for large and difficult geometries. This process was mostly used to form large and bulky components, typically for military and aerospace applications.

A few Ex of products manufactured using Explosive forming are : Jet Engine shroud, many unique tubular shapes, Composite tubes, nozzles.

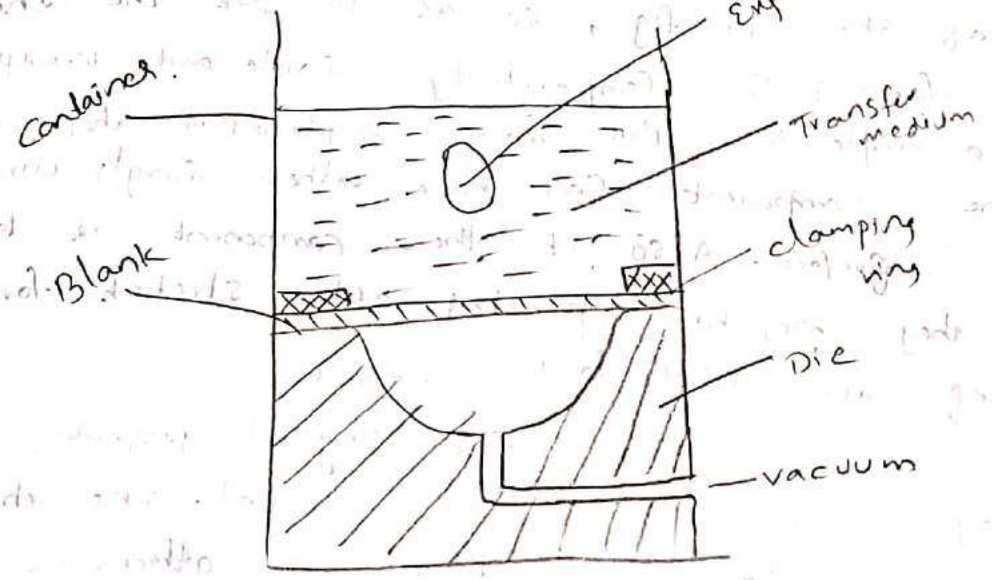
Adv:- (1) Low tooling cost. (2) Simpler tooling as only one-sided tooling is required. (3) unlimited power. (4) suitable for low-quantity production.

Typical alloys that are used for Explosive forming are aluminium alloys, Titanium & Ti alloys and nickel based super alloys.

broportion which is difficult and

Explosive forming:- It is a very high energy - rate manufacturing process also called High Energy Rate forming (HERF). In explosive forming, the Explosive is employed to generate shock waves to directly deform the work piece at very high velocities. There are 2 types of possibilities.

(1) Stand off Method:- In this method, the Explosive is at a specified distance from the work piece while the energy from the Explosive is transmitted through a medium (usually water) to deform the work piece as shown in fig. The working times are normally measured in milliseconds and the work piece velocities are measured in terms of 100 m/s.



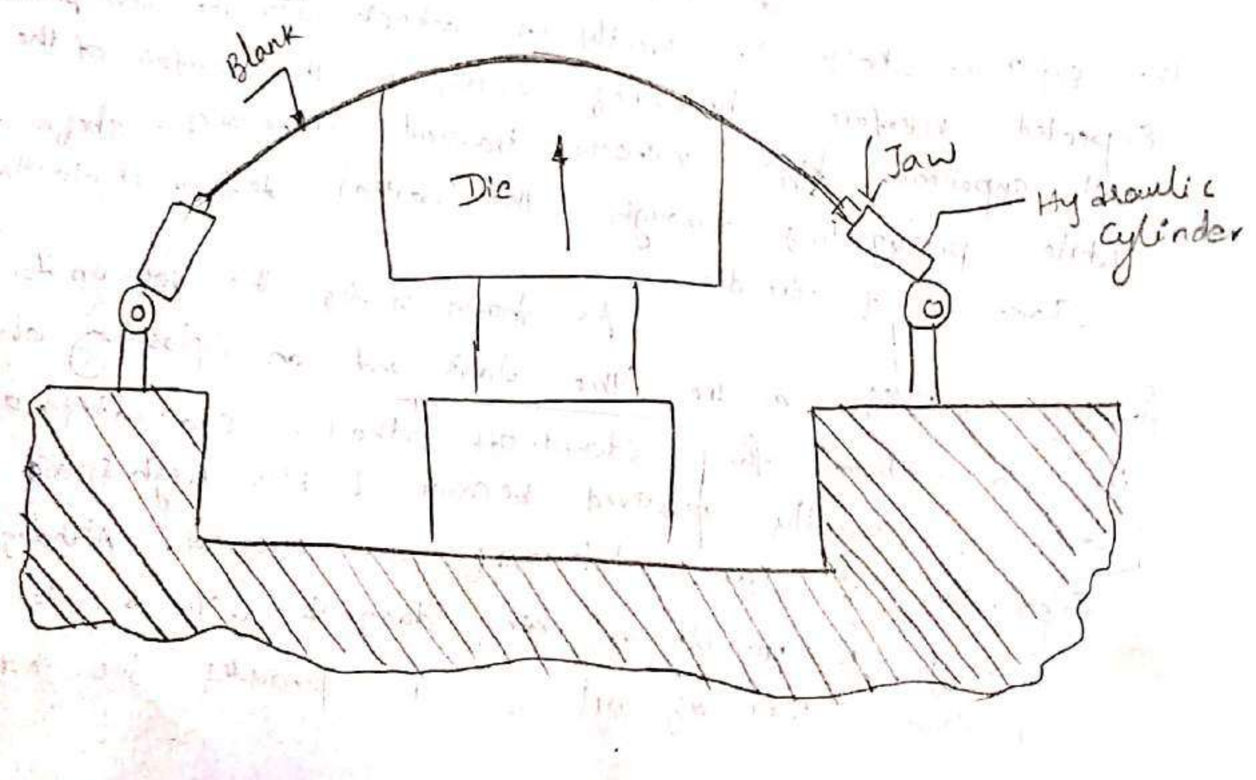

(2) Contact Method:- In contact method, the energy is released while the explosive charge is directly in contact with the work piece. The expected interface pressures acting on the surface of the material will experience high intensity, transient shock waves. These shockwaves while propogating through the material deform it to the required shape of the die.

As shown in fig, the set-up for explosive forming involves a die, the blank and an explosive charge contained in a medium for stand-off method. Evacuation of the die is usually required because of the high speed of operation especially if close tolerances are required. Although explosive forming is possible in air, doing it with a dense transfer medium such as oil or water provides the advantage of factor in stretch forming.

Stretch forming:- In all the processes, the deformations of the metal is done in elastic and plastic range, the spring back is always to be considered. However in stretch forming the complete deformation is carried out in plastic state only. The material is first brought into plastic state by stretching, hence the name stretch forming.

In this process, the sheet is held in the jaws of hydraulic cylinders and is stretched beyond elastic limit. Then the sheet is brought into contact with the die as shown in fig, so as to give the shape of the die. Stretch forming is comparitively simple and inexpensive, because it uses a single die. But many complicated shaps cannot be obtained. But the component can have either singly curved or doubly curved surface. Also, if the component is to have any holes, they may be punched after stretch forming, otherwise the holes are likely to be enlarged.

The physical properties are generally improved by uniform stretching of the metal. The sheet used in stretch forming should have uniform thickness, otherwise the thinner portions are likely to be overstretched.



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## DEPARTMENT OF MECHANICAL ENGINEERING

NOTES FOR

# MANUFACTURING TECHNOLOGY

# UNIT-5

## ADDITIVE MANUFACTURING

# 3D PRINTING CONCEPTS

## UNIT-1

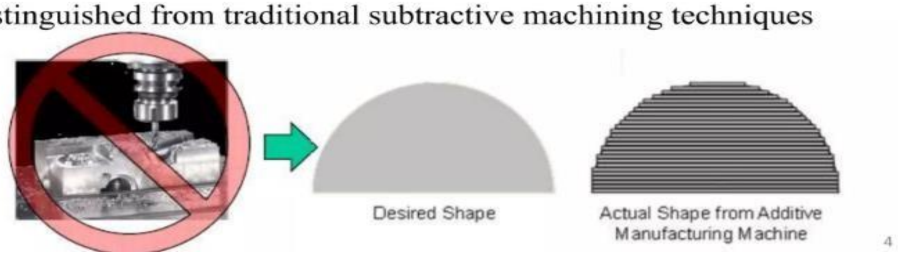
## Introduction

Manufacturing is a process in which raw materials are transformed into finished goods.

- Technology that can make anything.
- Eliminates many constraints imposed by conventional manufacturing
- Leads to more market opportunities.
- Increased applications such as 3D faxing sender scans a 3D object in cross sections and sends out the digital image in layers, and then the recipient receives the layered image and uses an AM machine to fabricate the 3D object.

## Additive Manufacturing?

- ➢ *The process of joining materials to make objects from three-dimensional (3D) model data, usually* ***layer by layer***
- ➢ Commonly known as **"3D printing"**
- ➢ Manufacturing components with virtually no geometric limitations or tools.
- ➢ AM uses an ***additive process***
- ➢ *Design for manufacturing to manufacturing for design*
- ➢ Distinguished from traditional subtractive machining techniques




## ADVANTAGES

- ➢ Freedom of design
- ➢ Complexity for free
- ➢ Potential elimination of tooling
- ➢ Lightweight design
- ➢ Elimination of production steps

## DISADVANTAGES

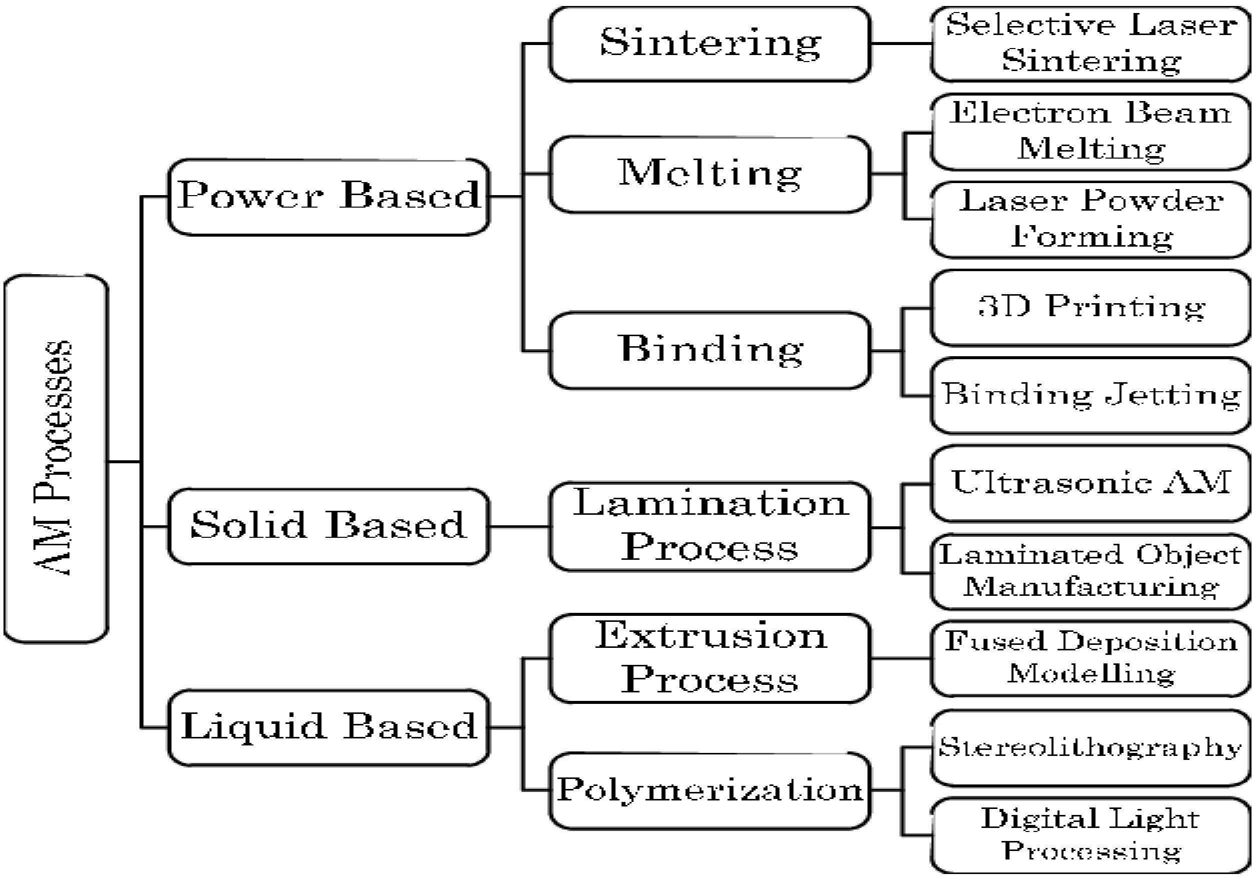
- ❖ Slow build rates
- ❖ High production costs
- ❖ Considerable effort required for application design
- ❖ Discontinuous production process
- ❖ Limited component size.

**Applications**

AM has been used across a diverse array of industries, including;

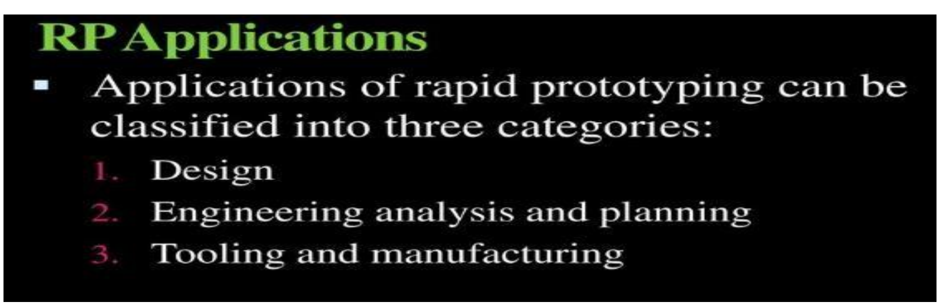
- ✓ Automotive
- ✓ Aerospace
- ✓ Biomedical
- ✓ Consumer goods and many others

## Classification of Additive Manufacturing:




## Rapid Prototyping:

- ➢ Rapid prototyping is the fast fabrication of a physical part, model or assembly using 3D computer aided design (CAD).
- ➢ The creation of the part, model or assembly is usually completed using additive manufacturing, or more commonly known as <u>3D printing</u>.



## RAPID TOOLING

- Rapid Tooling refers to mould cavities that are either directly or indirectly fabricated using Rapid Prototyping techniques.
- These are primarily used to create multiple prototypes. Rapid prototyping techniques are not economical when more than one prototype needs to built for the same component.

## Rapid Tooling Methods

### Indirect RTM Method

Pattern is created by RP and the pattern is used to fabricate the tool

- Examples:
  - Patterns for sand casting and investment casting
  - Electrodes for EDM

### Direct RTM Method

RP is used to make the tool itself

## Importance of Rapid Tooling

- Tooling time is much shorter than for a conventional tool.
- Tooling cost is much less than for a conventional tool.
- Tool life is considerably more than for a conventional tool.
- Tolerances are wider than for a conventional tool.

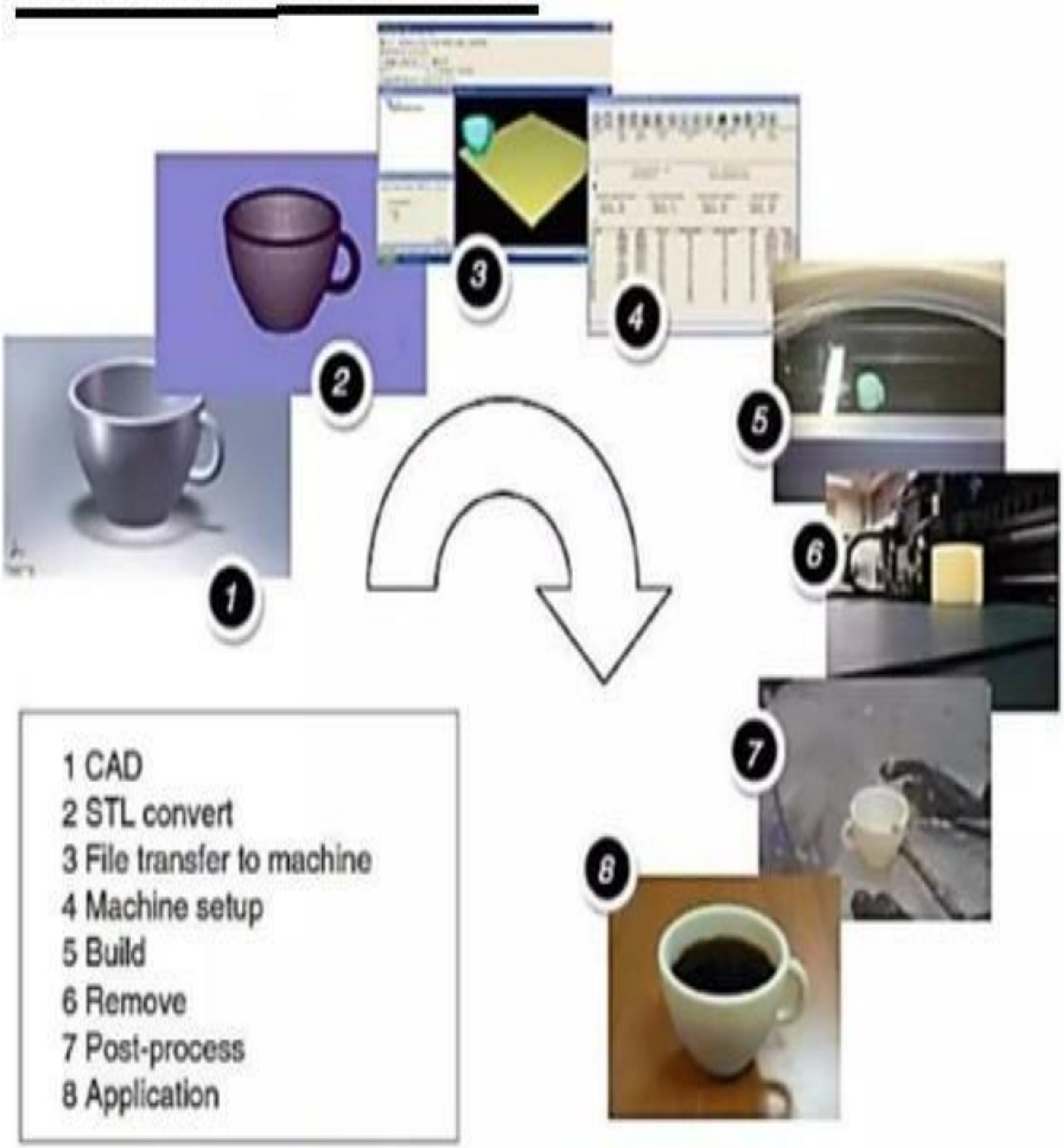
## Rapid Manufacturing:

- Rapid manufacturing is the use of software automation and connected manufacturing equipment to rapidly accelerate the manufacturing process.
- Read how one provider breaks down some of the considerations when applied to 3D printing

- The term rapid manufacturing is used to summarize different methods and manufacturing processes that serve the fast and flexible production of prototypes and series parts.

- The most common rapid manufacturing services include CNC machining, parts finishing, plastic injection molding, metal casting, and sheet metal fabrication.

## The Generic AM Process




Generic process of CAD to part, showing all 8 stages

**Step 1: CAD**

**All AM parts must start from a software model that fully describes the**

**external geometry. This can involve the use of almost any professional CAD solid modeling software, but the output must be a 3D solid or surface representation. Reverse engineering equipment (e.g., laser and optical scanning) can also be used to create this representation.**

## Step 2: Conversion to STL

**Nearly every AM machine accepts the STL file format, which has become a de facto standard, and nowadays nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.**

## Step 3: Transfer to AM Machine and STL File Manipulation

**The STL file describing the part must be transferred to the AM machine. Here, there may be some general manipulation of the file so that it is the correct size, position, and orientation for building.**

## Step 4: Machine Setup

**The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.**

## Step 5: Build

**Building the part is mainly an automated process and the machine can largely carry on without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches, etc.**

## Step 6: Removal

**Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.**

## Step 7: Post-processing

**Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation.**

## Step 8: Application

**Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use. For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding. They may also be required to be assembled together with other mechanical or electronic components to form a final model or product.**

### VAT Photopolymerization

VAT Photo polymerization is an AM process in which **liquid photopolymer resin** is cured (solidified) using a **light source (UV laser or projector)** layer by layer.

### Working Principle:

- A vat is filled with liquid resin.
- UV light selectively cures specific areas based on the CAD model.
- The build platform moves up/down after each layer.
- The process repeats until the part is completed.

### Examples:

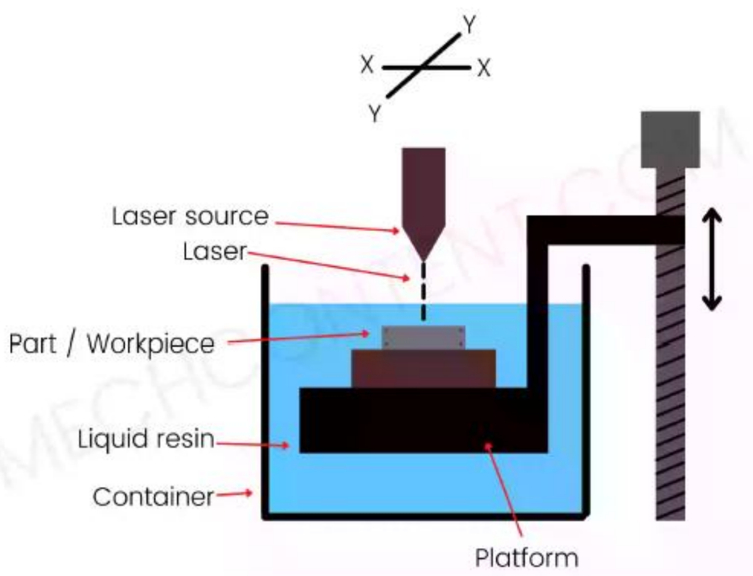
- Stereolithography (SLA)
- Digital Light Processing (DLP)

**STEREOLITHOGRAPHY:**

It is one of the Rapid Prototyping processes in which liquid polymer is used as material for layer by layer 3-D part building with the help of Laser for solidification of liquid resin.

**Working principle:**

In the **Stereolithography process**, as per the action of the laser beam, a layer of liquid resin gets solidified on the platform. This solidification of the liquid layer is used to build the part.




Stereolithography-process

**Construction:**

**Stereo-Lithography** Machine consists of the following components:-

1) **Laser Source**: - Laser source is used to supply a laser to solidify liquid resin to build the part in layers.
2) **Container: -** Container is filled with the liquid resin, when the laser falls on the liquid resin, the liquid resin gets solidified.
3) **Platform**: - Platform helps in the part building. Platform can move in an upward and downward direction. Therefore during part building, the Platform moves downwards so new layers of liquid

resin get solidified on the old solidified layer.

**Stereolithography working process:**

When the laser source gets on, the Laser falls on the liquid resin above the platform. Hence due to the laser, the Liquid resin layer above the platform gets solidified.

Therefore Platform moves downwards and a new solidified layer of liquids forms on the old solidified layer. In such a way, the platform moves downwards, and the Product build son the platform in layers.

**Resins used in stereolithography:**

There are three widely used resin types: polyester, vinyl ester, and epoxy.

**Epoxy resins** are the most commonly used material group in stereolithography. This synthetic resin with good electrical-insulation properties and high heat-resistance is also known as reaction resin.

**Materials used in stereolithography:**

Modern stereolithography machines offer a range of thermoplastic like materials. **Polypropylene, ABS and polycarbonate.**

- **Polypropylene**, a synthetic resin built up by the polymerization of propylene. One of the important family of polyolefin resins, polypropylene is molded or extruded into many plastic products in which toughness, flexibility, light weight, and heat resistance are required.
- **ABS (Acrylonitrile butadiene styrene)** is a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which the material is machined by plastic manufacturers. Better yet, its natural benefits of affordability and machinability do not hinder the ABS material's desired properties:
  - Impact Resistance
  - Structural Strength and Stiffness
  - Chemical Resistance
  - Excellent High and Low Temperature Performance
  - Great Electrical Insulation Properties
- **Polycarbonate** is a tough, transparent plastic material with outstanding strength, stiffness, and impact resistance.

**Advantages of Stereolithography:**

- *Round the clock operation. The SLA can be used continuously and* nattended round the clock.
- **Good user support. The computerized process serves as a good ser support.**
- *Build volumes. The different SLA machines have build volumes* ranging from small to large to suit the needs of different users.
- *Good accuracy. The SLA has good accuracy and can thus be used* or many application areas.
- *Surface finish. The SLA can obtain one of the best surface finishes* amongst RP techno logies.
- *Wide range of materials. There is a wide range of materials, from* general-purpose materials to specialty materials for specific applications.

**Disadvantages of Stereolithography:**

- *Requires support structures. Structures that have overhangs and* undercuts must have supports that are designed and fabricated together with the main structure.
- *Requires post-processing. Post-processing includes removal of* supports and other unwanted materials, which is tedious, time consuming and can damage the model.
- **Requires post-curing. Post-curing may be needed to cure** *the object* completely and ensure the integrity of the structure

**Applications of SLA:**

**The SLA technology provide methods for reducing time to market, lowering product**

**development costs, gaining greater control of their design process and improving product design.**

- **Models for conceptualization (an elaborated concept), packaging and presentation.**
- **Prototypes for design, analysis, verify functional testing.**
- **Parts for prototype tooling and low volume production tooling.**
- **Investment casting, sand casting and molding.**
- **Tools for fixture and tooling design, and production tooling.**

## Extrusion-Based AM Processes

In this process, **material is heated and extruded through a nozzle** layer by layer.

### Working Principle:

- Thermoplastic filament is fed into a heated nozzle.
- Material melts and is deposited on the build platform.
- Layers fuse together upon cooling.

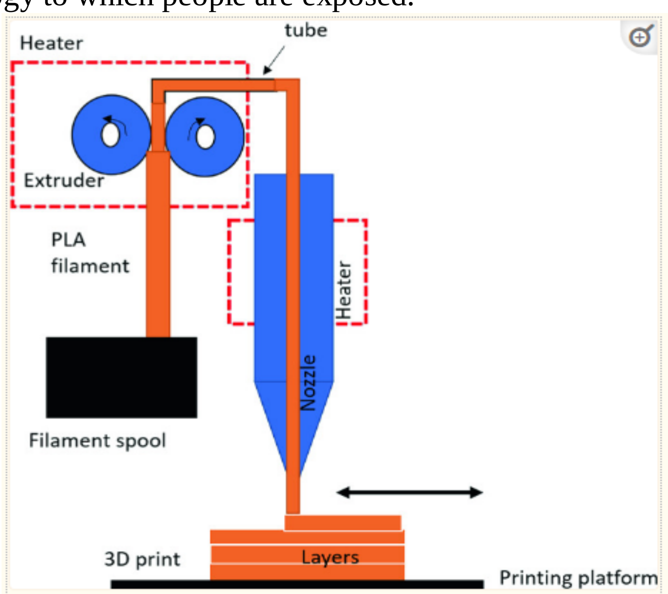
### Example:

- Fused Deposition Modeling (FDM)

**Fused deposition modeling (FDM):**

It is an additive manufacturing technology that creates 3D components using a continuous thermoplastic or composite material thread in filament form. An extruder feeds the plastic filament through an extruding nozzle, which is melted and then selectively deposited layer by layer onto the build platform in a predetermined automated path.

FDM, also known as **Fused Filament Fabrication (FFF)**, is a Material extrusion technology, one of the seven main types of additive manufacturing technologies. FDM is the most widely used 3D printing technique, with the most 3D printer users globally, and is typically the first 3D printing technology to which people are exposed.



## Working process of FDM:

3D printers that run on FDM Technology build parts layer-by-layer from the bottom up by Heating and Extruding thermoplastic filament.

The process is simple:

**Pre-processing:** Build-preparation software slices and positions a 3D CAD file and calculates a path to extrude thermoplastic and any necessary support material.

**Production:** The 3D printer heats the thermoplastic to a semi-liquid state and deposits it in ultra-fine beads along the extrusion path. Where support or buffering is needed, the 3D printer deposits a removable material that acts as scaffolding.

**Post-processing:** The user breaks away support material away or dissolves it in detergent and water, and the part is ready to use.

## Materials used in FDM:

The two most common materials in FDM printing are **ABS (acrylonitrile butadiene styrene)** and **PlA (polylactic acid)**. Both are inexpensire and available in a variety of colors.

- **ABS**, a common household plastic, offers good strength and thermal characteristics, but requires good ventilation as it emits strong odors.It requires a heated build platform to avoid warping.
- **PLA** offers great surface quality, is one of the easiest materials to print and is also biodegradable but lacks impact strength.

## Advantages of FDM 3D Printers:

1. A wide range of FDM printers are available in the market today.
2. The raw material is inexpensive.
3. Durable and maintains dimensional integrity.
4. Wide choice of raw material.
5. Affordable

## Disadvantages of FDM 3D Printers:

1. FDM printers do not offer the high quality, dimensional accuracy or reliable operation that some are other 3D printers offer.
2. Reliability can be an issue with failed parts or clogs in flowing plastic.
3. FDM is not the best choice for printing parts that need to be "close to perfection."

## Application of FDM 3D Printers:

Creating prototypes for Fit, Form and Function testing rapid tooling patterns and mould inserts creating and testing any parts that work under thermal loads production of precise and complex end-use parts

e.g. jigs & fixtures.

**Sectors that use FDM 3D Printers include:**

- Automotive
- Aerospace
- Manufacturing
- Industrial
- Medical
- Architecture
- Consumer Goods
- Education & Research

**Powder Bed Fusion (PBF) AM Processes**

In PBF, **thermal energy (laser/electron beam)** selectively fuses powdered material.

### Working Principle:

- A thin layer of powder is spread.
- Laser or electron beam fuses selected areas.
- Platform lowers and next layer is spread.

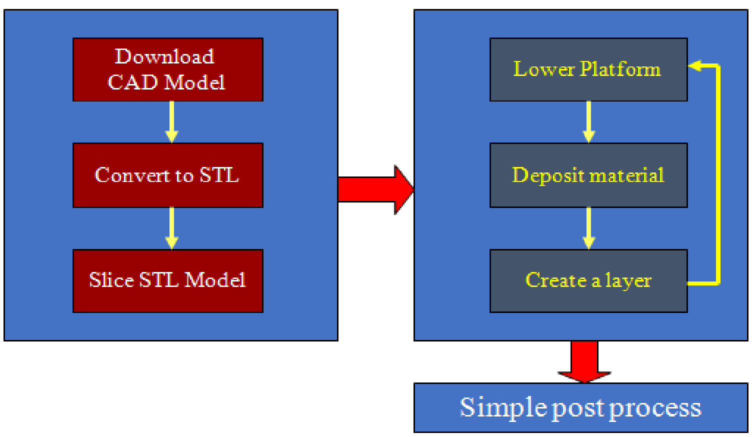
### Examples:

- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)
- Electron Beam Melting (EBM)

## SELECTIVE LASER SINTERING (SLS):

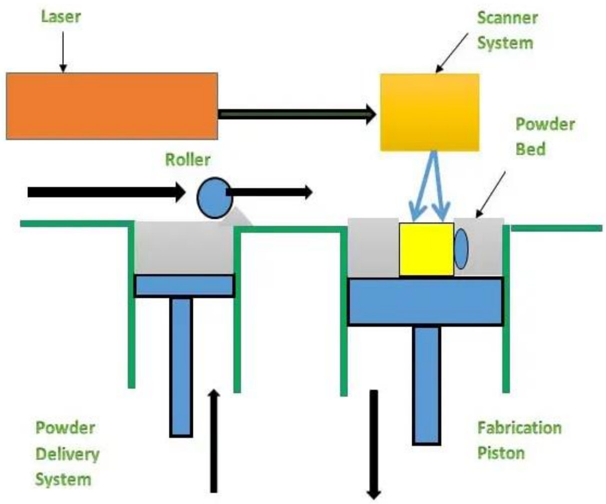
It is a powder-based 3D printing technology that uses a laser to fuse material layers into a final part. The laser traces the pattern of each cross section of a 3D design onto a bed of powder. After one layer is built, the build platform lowers and another layer is built on top of the previous layer. This process continues until every layer is built and the part is complete.

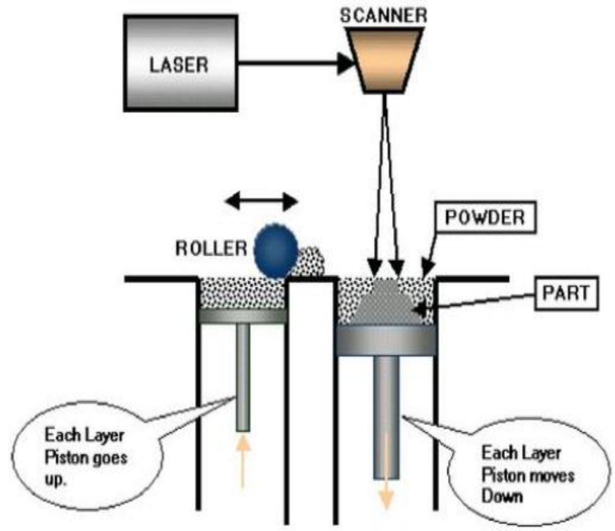
**SLS Process**




## Working of SLS:

- ➢ It is an additive RP techniques.
- ➢ Layer of powder is first deposited on part build cylinders.
- ➢ The laser (C02) traces a two-dimensional cross section of the part.
- ➢ During laser exposure, the powder temperature rises above the glass transition point after which adjacent particles flow together. This process is called sintering.
- ➢ Platform descends down by an amount equal to the thickness.
- ➢ The roller pushes the material on the built platform and the process is repeated again and again.




## Components of SLS:

- **Laser:** This is a powerful laser which is used to melt the particles to fuse them together
- **Scanning System:** This system perfectly directs the laser to the desired location and then traces the geometry for each layer.
- **Build Chamber:** This chamber houses the powdered material
- **Powder Delivery System:** The powder delivery system is responsible for carrying and delivering the powder for each layer of printing.
- **Powdered Material:** This is the actual material in its powdered form. Most common material is Nylon PA12
- **Roller or Leveller:** This transfers new layer of material from the powder delivery system and spreads it evenly on top of the previously printed layer in the build chamber for next printing cycle.

## Material used in SLS:

- Plastic powders
  (Polyamides (PA), polystyrenes (PS),
  thermoplastic elastomers (TPE),
  and polyaryletherketones (PAEK))
- Metal powders (direct metal laser sintering),
- Ceramic powders
- Glass powders

## Applications of SLS:

- Aerospace industry
- Medical and Health care
- Casting Patterns
- Automotive
- Manufacturing
- Industrial …., Etc….,

## Advantages of SLS:

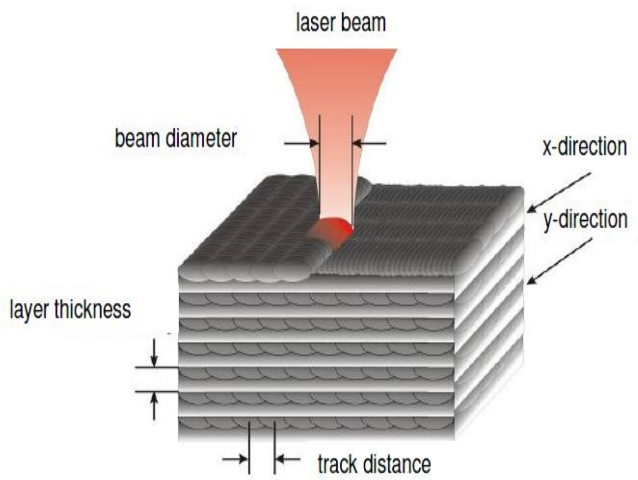
- Fully Automatic
- Good Accuracy
- Work with Varieties of Material
- Simple Finishing Operation

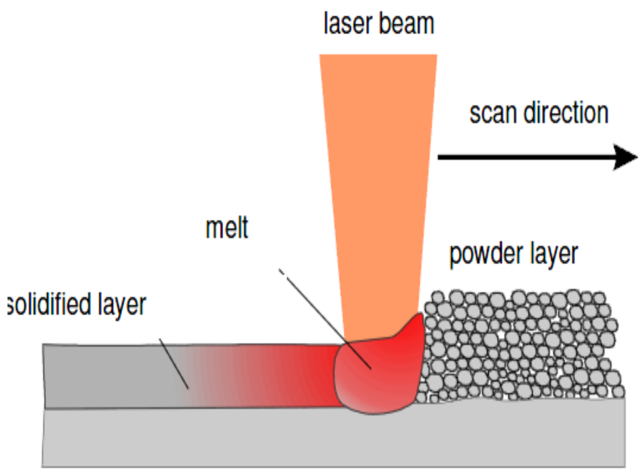
## Disadvantages of SLS:

- Rough Surface
- Shrinkage & Distortion
- Temperature Control is Critical

## SELECTIVE LASER MELTING:

- **Selective laser melting** is an **additive manufacturing** process used to build 3D metal objects using high-power laser beams.
- A thin layer of powder is applied to the build platform in the first construction process step with a squeegee (or a combination of several squeegees).
- A laser melts the metal powder with temperatures of up to 1,250 °C in the laser focus at the coordinates specified by a **CAD** file.
- The construction chamber is filled with an inert gas to prevent oxidation of the metal throughout the construction phase.




## Material used in SLM:

The types of materials that can be processed:

- Stainless steel alloys,
- Nickel-based alloys,
- Tool steel alloys,
- Titanium alloys,
- cobalt chrome, and
- Aluminium alloys.

## Applications of SLM:

Complex geometries & structures in

- Bio – Medical
- Automotive
- Building Modeling
- Food Industry
- Electrical
- Aerospace. Etc ....,

## Advantages of SLM:

- Dense functional parts made of various metallic materials such as tool steel, stainless steel, aluminum, copper, and titanium
- High mechanical load capacity
- Good suitability for injection molds
- Conformal cooling / tempering
- Long durability of the material
- Production of components made of copper with high electrical conductivity
- Good finishing possibilities (such as heat treatment / hardening)

## Disadvantages of SLM:

- **Quality**
    1. Surface quality
    2. Accuracy / distortion
    3. Finish by machining necessary reproducibility
    4. Process control / close loop control necessary
- **Productivity**
    1. Build up rate
    2. Part size
    3. Non productive time

**Direct Energy Deposition (DED) AM Processes**

DED uses **focused thermal energy** to melt material (wire or powder) as it is deposited.

**Working Principle:**

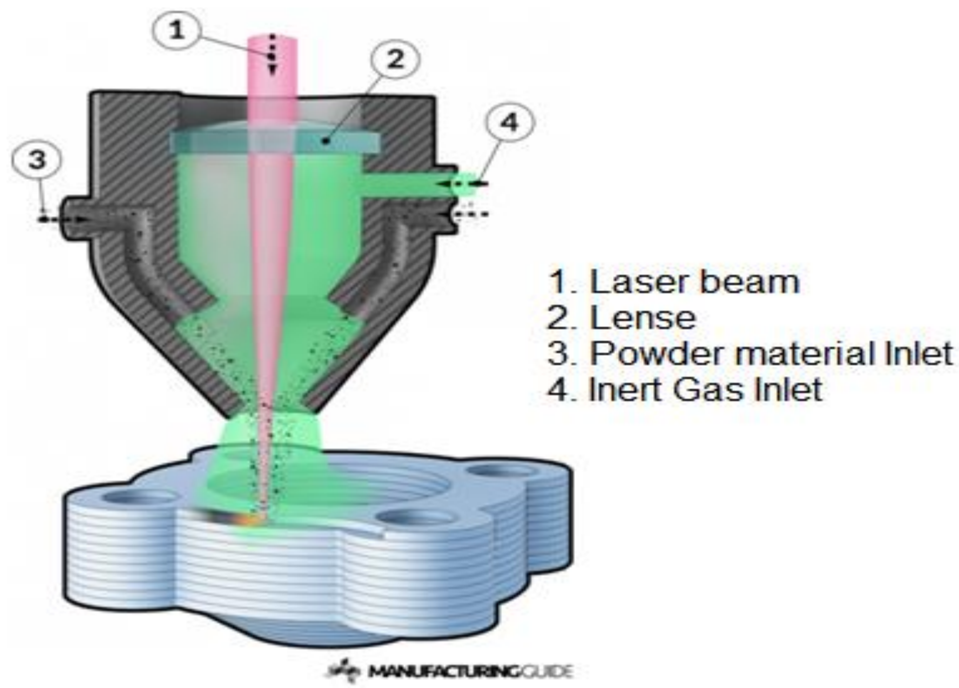
- Material is fed through a nozzle.
- Laser/electron beam melts material.
- Deposited onto existing surface.

**Examples:**

- Laser Metal Deposition
- LENS (Laser Engineered Net Shaping)

## LASER ENGINEERED NET SHAPING(LENS) :

- Additive manufacturing method in which the product is built up layer by layer by continuously feeding of metal powder or metal wire melted in to a laser beam.
- A laser beam created by a laser generator is focused through a lens onto the workpiece.
- Metal powder, or metal wire, is introduced at the focus of the laser beam, where the metal powder and workpiece melt and thus building on the surface.
- An inert gasis supplied to protect both the laser and the melt from contamination during the welding process.
- The cross section of the detail is thus built up step by step until the complete detail is created.
- The method can also be used to repair damaged or worn surfaces and is then often described as laser welding with powder.




## Working Principle :

- Laser engineered net shaping (LENS) uses computer-controlled lasers that, in hours, weld air-blown streams of metallic powders into custom parts and manufacturing molds.
- The technique produces shapes close enough to the final product to eliminate the need for rough machining.

## Advantages:

- Ability to build fully dense shapes.
- Closed loop control of process for accurate part fabrication.
- Ability to tailored deposition parameters to feature size for speed, accuracy, and property control.
- Composite and functionally graded material deposition.

## Disadvantages:

- Less accurate than others.
- Although the process negates the need to hog out large amounts of hard-to-cut material, finish machining is still usually necessary.

## Applications of LENS:

Complex geometries & structures in

- Bio – Medical
- Automotive
- Building Modeling
- Food Industry
- Electrical
- Aerospace. Etc ….,

**Post Processing of AM Parts:**

**Post processing techniques used to overcome AM limitations**

- Support material removal
- Surface texture improvements
- Accuracy improvements
- Aesthetic improvements
- Preparation for use of pattern
- Property enhancement using thermal and non-thermal techniques
- Inspection and testing
- Defects and their causes.

### Post processing of AM parts

**Support Material Removal**

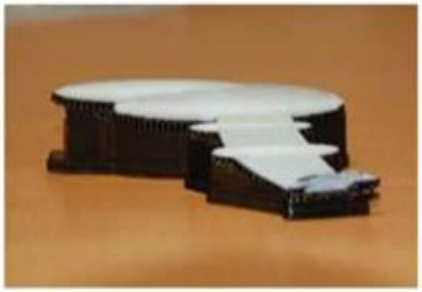
Support material can be broadly classified into two categories:

- Material which surrounds the part as a naturally-occurring by-product of the build process (natural supports)
- Rigid structures which are designed and built to support, restrain or attach the part being built to a build platform (synthetic supports).

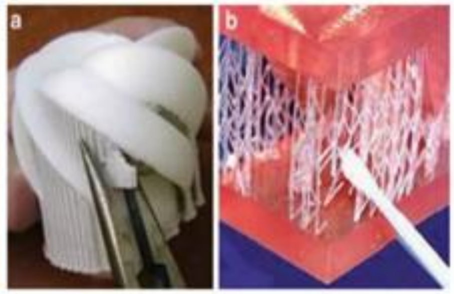
## PRODUCT QUALITY

Post processing of AM parts

### Support Material Removal



Flat FDM-produced aerospace part. White build material is ABS plastic and black material is the water-soluble support material. (Courtesy of Shapeways. Design by Nathan Yo Han Wheatley.)




Breakaway support removal for (a) an FDM part (courtesy of Jim Flowers) and (b) an SLA part (Courtesy Worldwide Guide to Rapid Prototyping web-site.

## Post processing of AM parts

### Accuracy Improvements

- There is a wide range of accuracy capabilities in AM.
- Some processes are capable of sub-micron tolerances, whereas others have accuracies around 1 mm.
- Typically, the larger the build volume and the faster the build speed the **worse** the

  accuracy for a particular process.

Post processing of AM parts

## Aesthetic Improvements

- A difference in surface texture between one region and another may be desired (this is often the case in jewelry).
- Finishing of selected surfaces only is required.
- In cases, where the color of the AM part is not of sufficient quality, several methods can be used to improve the part aesthetics.
- Another aesthetic enhancement (which also strengthens the part and improves wear resistance) is chrome plating.


SLA part (a) before and (b) after chrome plating. (Courtesy of Artcraft Plating)

## Post processing of AM parts Preparation for use as a Pattern Often

- The parts made using AM are intended as patterns for investment casting, sand casting, room temperature vulcanization (RTV) molding, spray metal deposition or other pattern replication processes.
- The accuracy and surface finish of an AM pattern will directly influence the final part accuracy and surface finish.
- As a result, special care must be taken to ensure the pattern has the accuracy and surface finish desired in the final part.
- In addition, the pattern must be scaled to compensate for any shrinkage that takes place in the pattern replication steps.

## Post processing of AM parts

### Property Enhancements using Non-thermal Techniques

- Powder-based and extrusion-based processes often create porous structures.
- The porosity can be infiltrated by a higher-strength material, such as cyanoacrylate (Super Glue). Newer, proprietary methods and materials have also been developed to strengthen various AM parts.
- One of the best known is the RP Tempering process (PAR3 Technology, USA).
- RP Tempering is a collection of materials and treatment operations used to increase the strength, ductility, heat deflection, flammability resistance, EMI shielding or other properties of AM parts
- using nano-composite reinforcements.

## Post processing of AM

### parts Property Enhancements using Thermal Techniques

- Many parts are thermally processed to enhance their properties.
- In beam deposition and PBF techniques for metals, this thermal processing is primarily heat treatment to form the desired microstructures and/or to relieve residual stresses.
- Traditional heat treatment developed for the specific metal alloy being employed are commonly used.
- In some cases, special heat treatment methods have been developed to retain the fine-grained microstructure within the AM part while still providing some stress relief and ductility enhancement.

**Inspection** is normally used to examine a component of a product in relation to the design standards specified for it.

For a mechanical component, this would probably be concerned with the dimensions of the part. These might be checked with several go/no go gages or they might be measured with a micro meter and other instruments.

**Testing**, on the other hand, is normally associated with the functional aspects of the item, and it is often directed at the final product rather than its components. In this usage, testing consists of the observation of the final product during operation under actual or simulated conditions.

## Applications of Additive Manufacturing

### 1. Aerospace

Lightweight parts, complex internal channels

### 2. Automotive

Prototyping and custom components

### 3. Medical

Customized implants and prosthetics

### 4. Construction

3D printed building components

### 5. Tooling

Jigs, fixtures, molds

Here are six ways that additive manufacturing is used in **aerospace applications.**

**1. Build Parts with Complex Geometries**

From helicopter parts to turbine engines, aerospace components require highly complex geometric structures in sometimes very tight spaces.

Using additive manufacturing, it's possible to create intricate parts with less lead time and energy from a wide variety of materials, including metal and carbon fiber.

**2. More Efficient Prototyping**

Manufacturing standards by creating consistent parts - every part must be the same as the part produced before it.

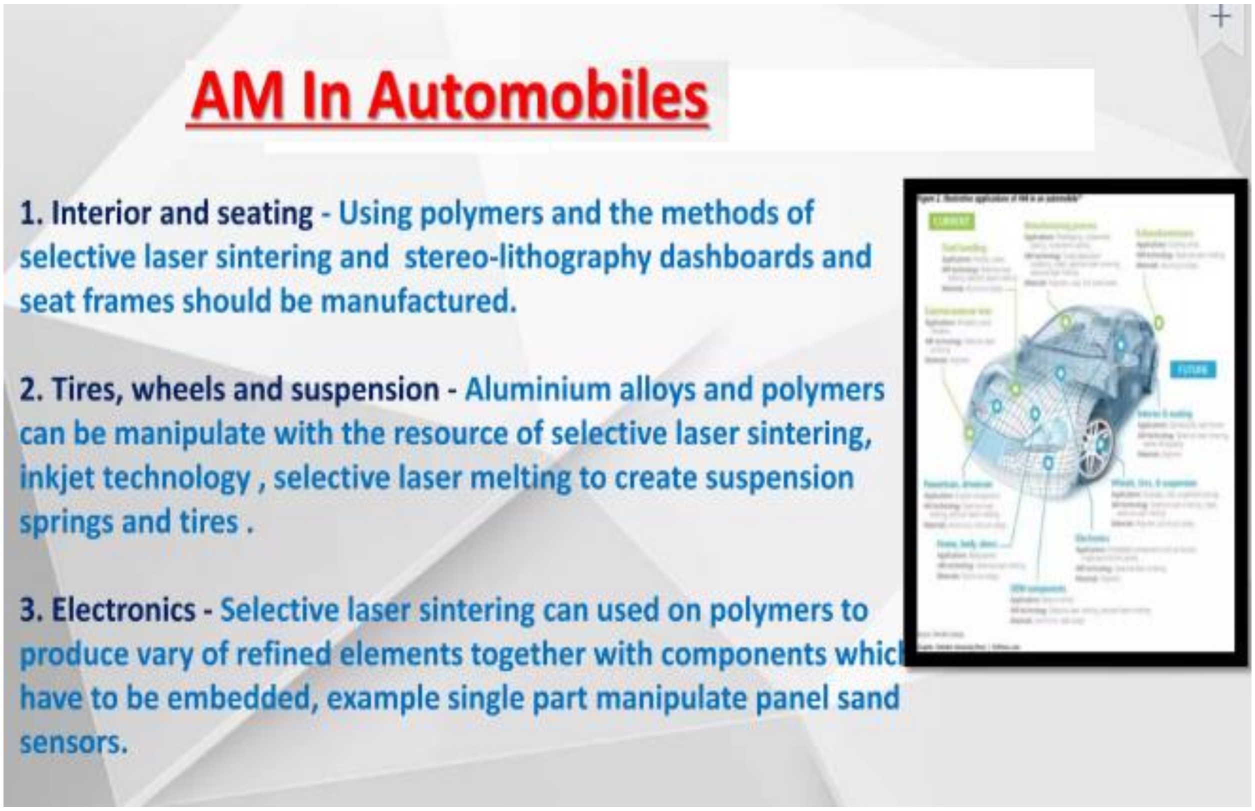
Printing at a larger scale, since 3D printing is a newer technology.

**3. Cost-Effective Production**

Additive manufacturing can not only reduce the time to create prototypes, but it can also reduce the cost.

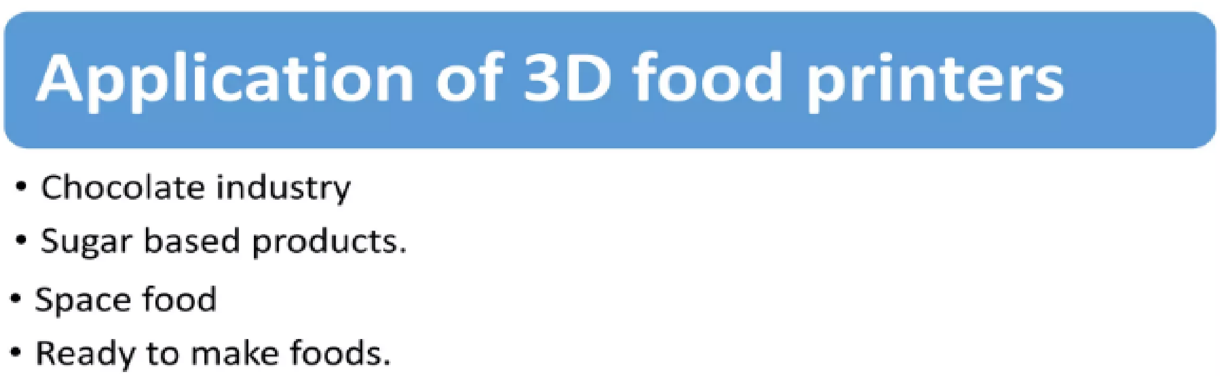
**4. Increase Parts' Internal Strength**

Every time smaller parts are combined to make a larger object, it reduces the structural integrity of the whole. With additive manufacturing, design engineers can create entire parts, including hollow centers and interior components, without weak, vulnerable joints.




**Benefits of AM in electronics:**

- Proper and optimized design.
- Print on non-flat surfaces.
- Light weight and lesser material wastage.



# 3D food printing in space

- Refrigaration & freezing requies lot of energy in space station hence it is usually absent on space flights.
- For this reason food get easily spoiled & astronauts have to consume food within 10 days of flight.
- But 3D food printing can change this scenario by printing food in space station at normal gravity with improved shelf life.
- For deep mars mission this 3D food printing will play important role as it will give proper nutritionally balanced food.

## 3D printed products