Metal Casting and Solidification

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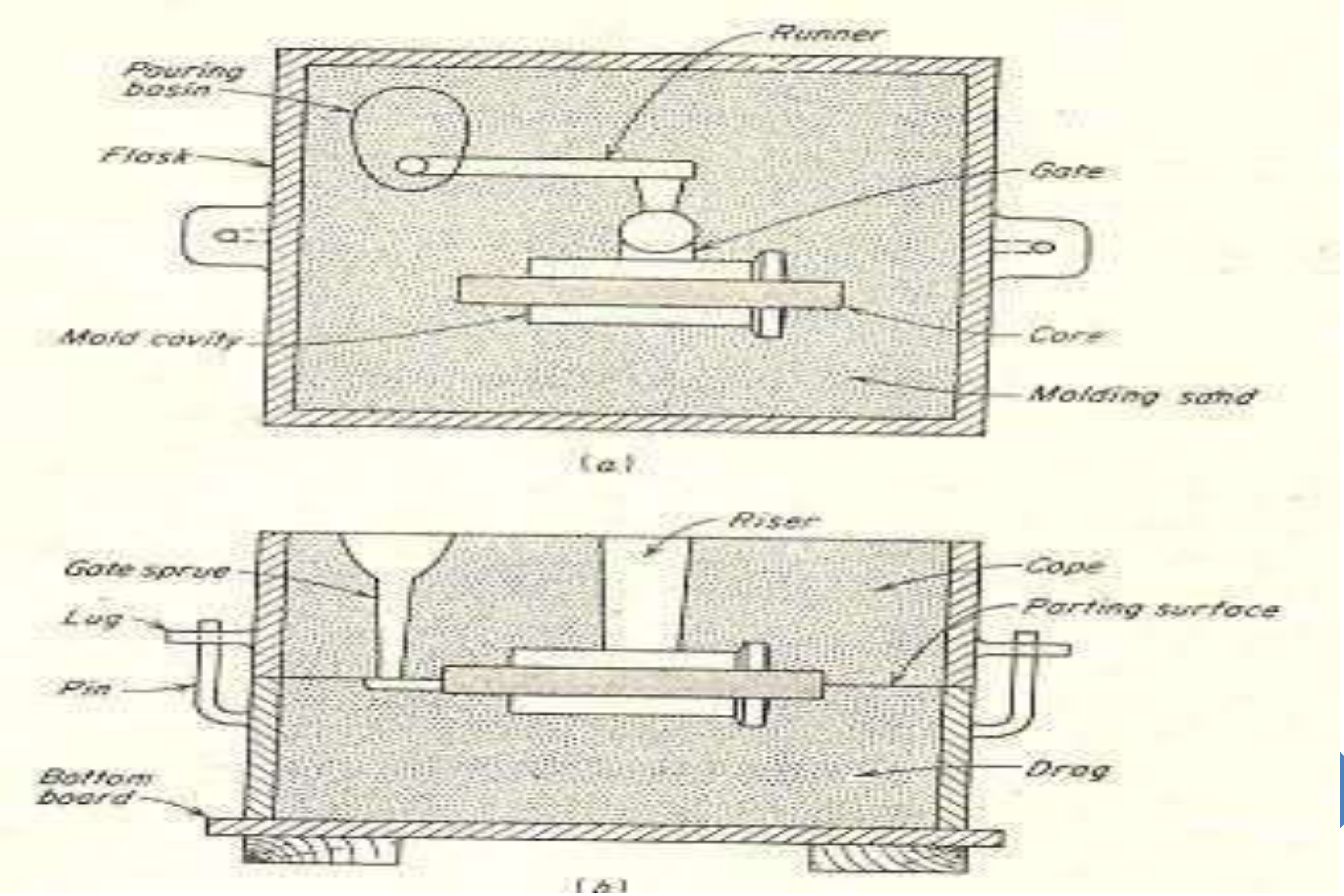
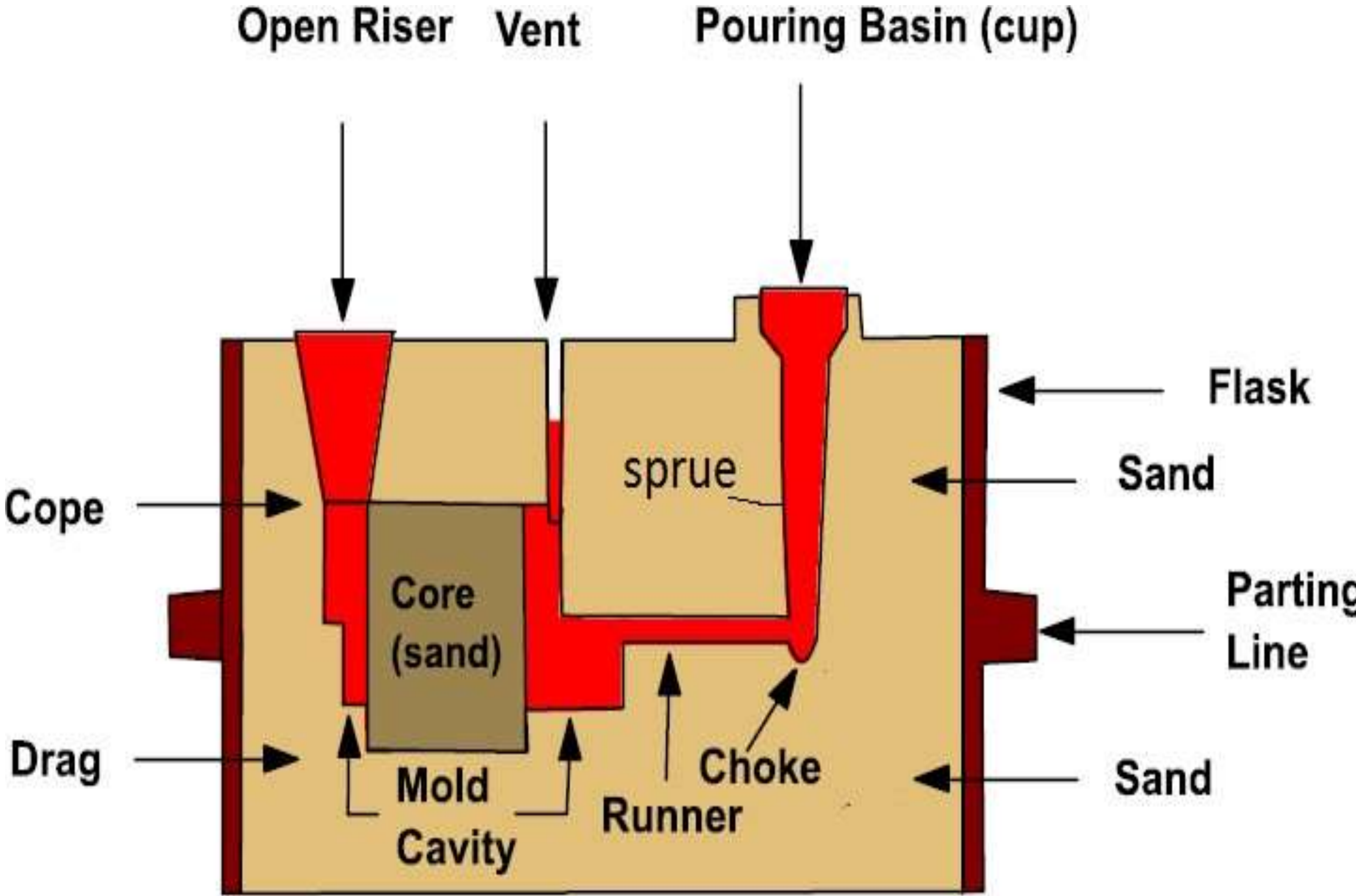
Syllabus

- **Production techniques:**
- Manufacture of sand castings, mould production, moulding techniques, cores & core making, melting & casting, finishing operation. Shell, investment and die casting process, centrifugal casting, other special techniques.

IMPORTANT CASTING TERMS




Open Riser
Vent
Pouring Basin (cup)
Flask
sprue
Sand
Cope
Core
(sand)
Parting
Line
Drag
Mold
Cavity
Runner
Choke
Sand

- **Flask:** Ametal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as drag – lower moulding flask, cope – upper moulding flask, cheek – intermediate moulding flask used in three piece moulding.
- **Pattern:** It is the replica of the final object to be made. The mould cavity is made with the help of pattern. Parting line: This is the dividing line between the two moulding flasks that makes up the mould.

- **Moulding sand**: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.

- **Facing sand:** The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings.

❖ *Making a simple sand mould :*

1)The drag flask is placed on the board

2)Dry facing sand is sprinkled over the board

3) Drag half of the pattern is located on the mould board. Dry facing sand will provide a non-sticky layer.

4) Molding sand is then poured in to cover the pattern with the fingers and then the drag is filled completely

5) Sand is then tightly packed in the drag by means of hand rammers. Peen hammers (used first close to drag pattern) and butt hammers (used for surface ramming) are used.

6) The ramming must be proper i.e. it must neither be too hard or soft. Too soft ramming will generate weak mould and imprint of the pattern will not be good. Too hard ramming will not allow gases/air to escape and hence bubbles are created in casting resulting in defects called ‘blows’. Moreover, the making of runners and gates will be difficult.

7) After the ramming is finished, the excess sand is leveled/removed with a straight bar known as strike rod.

8) Vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification. Done by vent rod.

9) The finished drag flask is now made upside down exposing the pattern.

10) Cope half of the pattern is then placed on the drag pattern using locating pins. The cope flask is also located with the help of pins. The dry parting sand is sprinkled all over the drag surface and on the pattern.

11) A sprue pin for making the sprue passage is located at some distance from the pattern edge. Riser pin is placed at an appropriate place.

12) Filling, ramming and venting of the cope is done in the same manner.

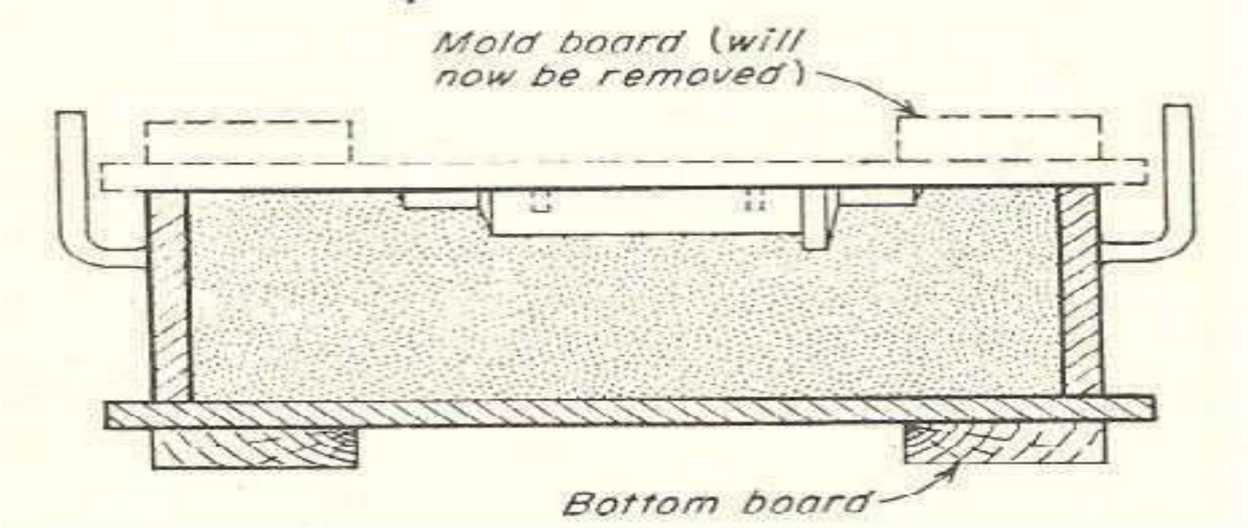
13) The sprue and riser are removed and a pouring basin is made at the top to pour the liquid metal.

14) Pattern from the cope and drag is removed.

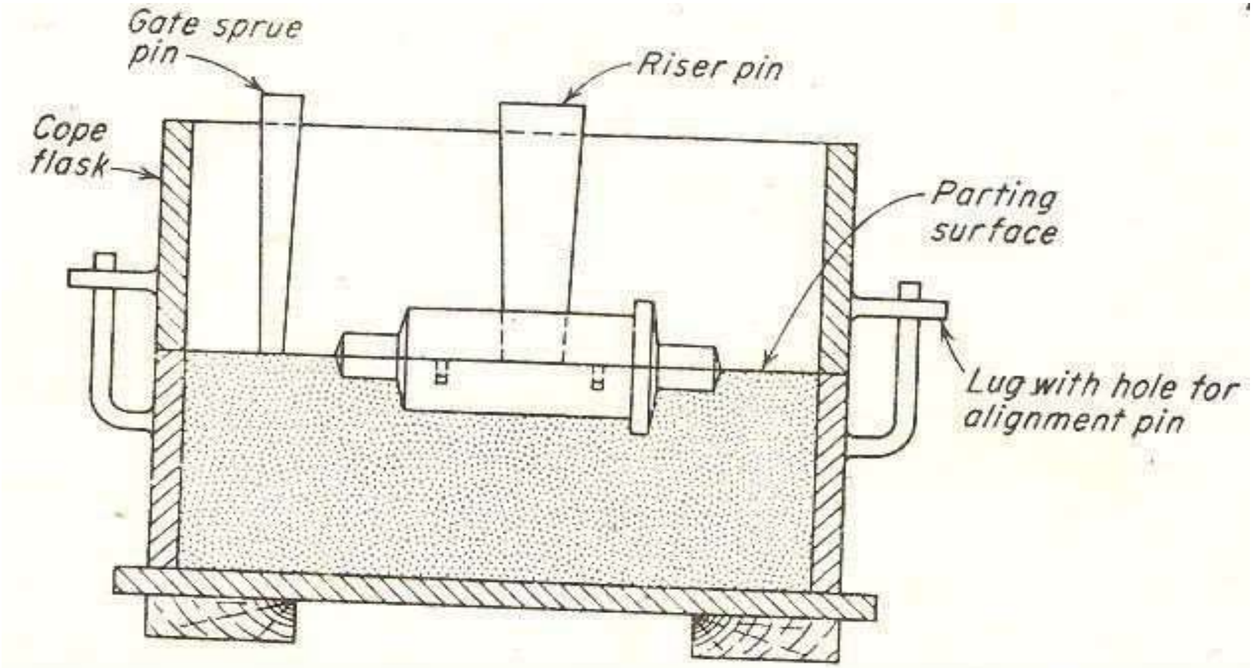
15) Runners and gates are made by cutting the parting surface with a gate cutter. A gate cutter is a piece of sheet metal bent to the desired radius.

16) The core for making a central hole is now placed into the mould cavity in the drag. Rests in core prints.

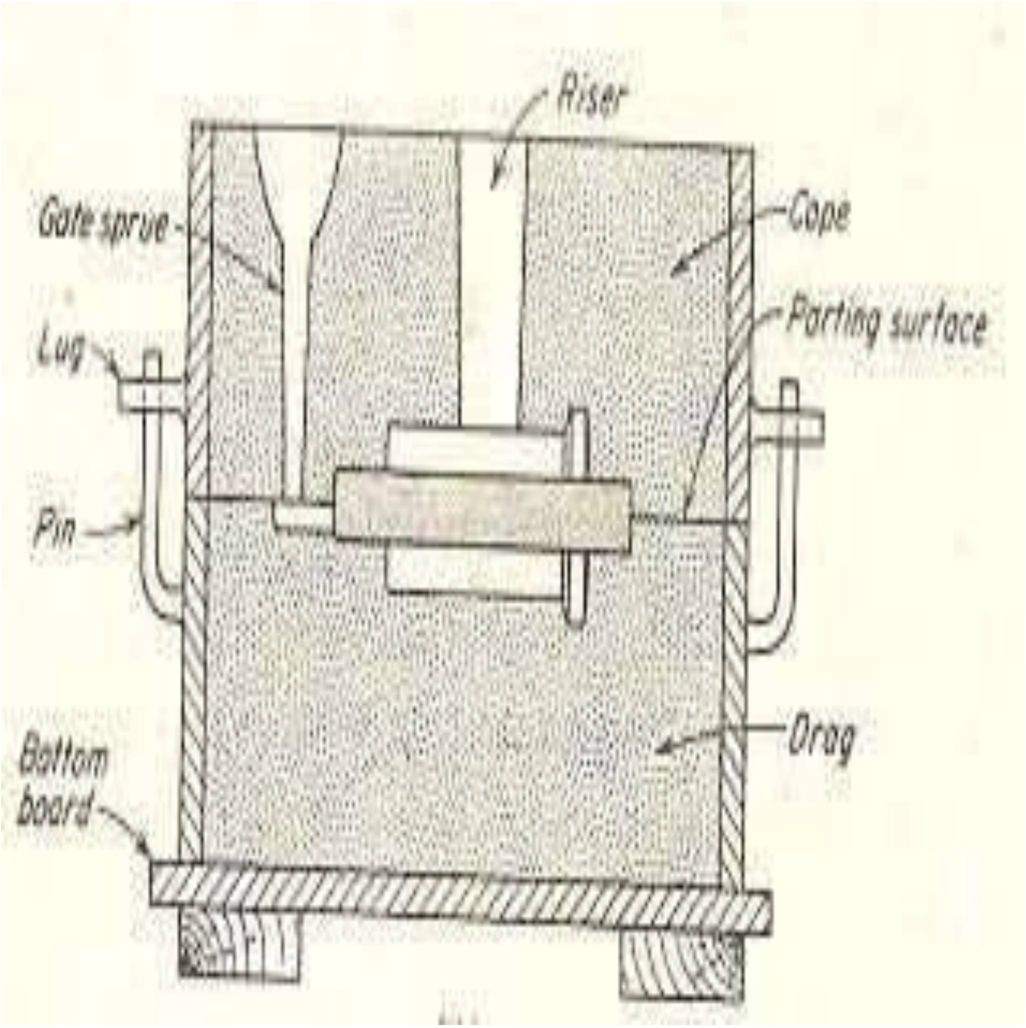
17) Mould is now assembled and ready for pouring.



Mold board (will now be removed)
Bottom board



Gate sprue pin
Riser pin
Cope flask
Parting surface
Lug with hole for alignment pin



Riser
Gate sprue
Cope
Parting surface
Lug
Pin
Drag
Bottom board

Moulding processes

(A) According to the method used :

1) Floor moulding
2) Bench moulding
3) Pit moulding
4) Machine moulding

1) Floor moulding :

- This method of moulding is commonly used for preparing the mould

  of heavy and large size of jobs.

- In floor moulding , the floor itself acts as a drag.
- It is preferred for such rough type of casting where

  the upper surface finish has no importance.

2) Bench moulding :

- Bench moulding is done on a work bench of a height convenient to the moulder.
- It is best suited to the mould of small and light items which are to be casted by non- ferrous metals.

3) Pit moulding :

- Large sizes of jobs which cannot be accommodated in moulding

  boxes are frequently moulded in pits.
- Here, the pit acts as a drag. Generally, one box, i.e.

  cope is sufficient to complete the mould.
- Runner and riser , gates and pouring basin are cut in it.

4) Machine moulding :

- Machine moulding method is preferred for mass production of identical casting as most of the moulding operations such as ramming of sand, rolling over the mould, and gate cutting etc. are performed by moulding machine.
- Therefore, this method of moulding is more efficient and economical in comparison to hand moulding.

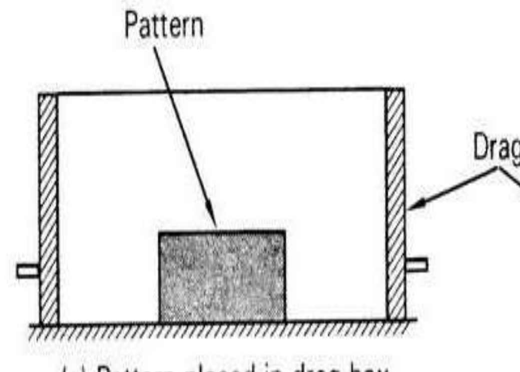
(B) According to the mould materials

1) Green sand moulding
2) Dry sand moulding
3) Loam sand moulding
4) Core sand moulding

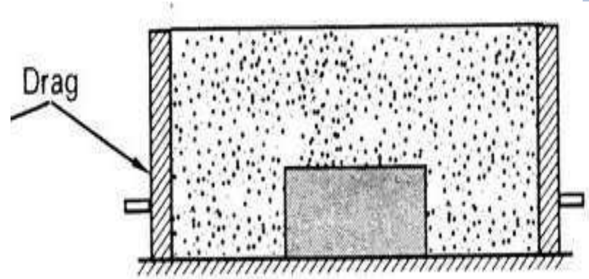
1) Green sand moulding

- Procedure involved in making green sand moulds

1. Suitable proportions of silica sand (85 - 92 %), bentonite binder (6-12 %), water (3-5 %) and additives are mixed together to prepare the green sand mixture.
2. The pattern is placed on a flat surface with the drag box enclosing it as shown in figure (a). Parting sand is sprinkled on the pattern surface to avoid green sand mixture sticking to the pattern.
3. The drag box is filled with green sand mixture and rammed manually till its top surface. Refer figure (b).



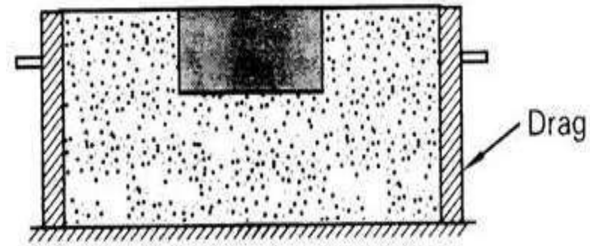
(a) Pattern placed in drag box



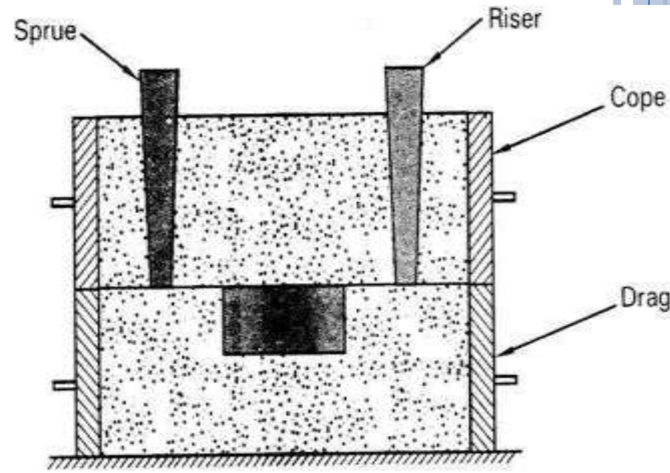
(b) Drag is filled with sand

4. The drag box is now inverted so that the pattern faces the top as shown in figure (c). Parting sand is sprinkled over the mould surface of the drag box.

5. The cope box is placed on top of the drag box and the sprue and riser pin are placed in suitable locations. The green sand mixture is rammed to the level of cope box as shown in figure (d).



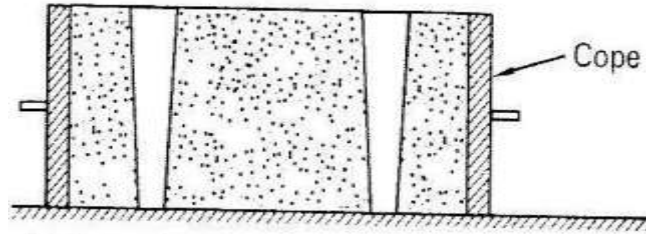
(c) Drag box inverted so that pattern faces the top



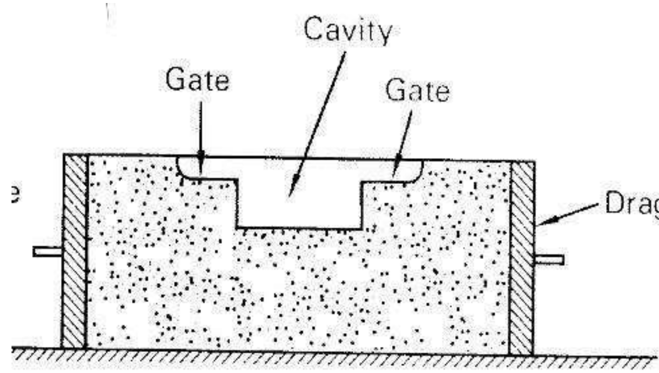
(d) Cope is placed on drag. Sprue & riser placed in position & sand rammed in cope box

6. The sprue and the riser are removed from the mould. The cope box is lifted and placed aside, and the pattern in the drag box is withdrawn by knocking it carefully so as to avoid damage to the mould.

7. Gates are cut using hand tools to provide passage for the flow of molten metal. Refer figure (e) and (f).



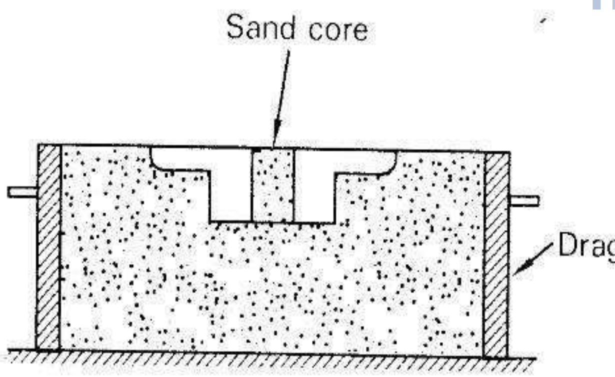
(e) Sprue & riser are removed. Cope box is placed aside of drag



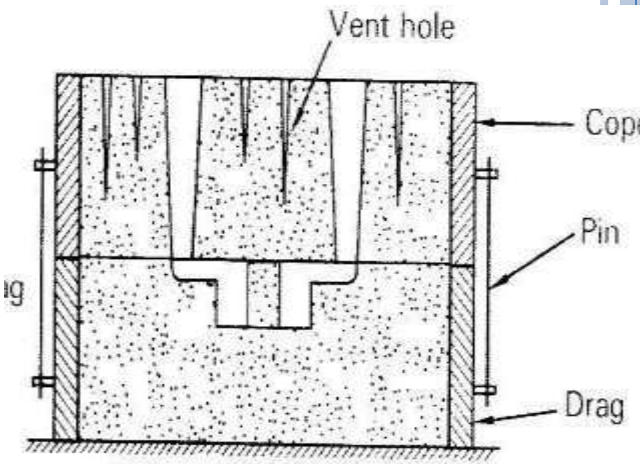
(f) Pattern is removed to leave a cavity in the mould. Gates are cut.

8. The mould cavity is cleaned and finished. Cores, if any, are placed in the mould to obtain a hollow cavity in the casting. Refer figure (g).

9. The cope is now placed on the drag box and both are aligned with the help of pins. Vent holes are made to allow the free escape of gases from the mould during pouring. The mould is made ready for pouring. Refer figure (h).



(g) Core is placed in mould cavity



h) Cope placed on drag & vent holes are made. Mould is ready for pouring

- **Advantages**
  - Green sand molding is adaptable to machine molding.
  - No mold baking or drying is required.
  - There is less mold distortion than in dry sand molding.
  - Time and cost associated with mold baking or drying is eliminated.
  - Green sand molding provides good dimensional accuracy across the parting line.
- **Disadvantages**
  - Green sand molds possess lower strengths.
  - They are less permeable.
  - There are more chances of defects (like blow holes etc.) occurring in castings made by green sand molding.
  - Surface finish deteriorates as the weight of the casting increases.
  - Dimensional accuracy of the castings decreases as their weight increases.

2) Dry sand moulding

- Here, in the preparation of the mixture for dry sand moulding, special binding material such as resin, molasses, flour, or clay are mixed to give strong bond to the sand.
- All parts of mould are completely dried before casting.
- Dry sand moulding is widely used for large size of work such as parts of engine, large size of fly wheel and rolls for rolling mill.
- This process is costlier than green sand moulding but much superior in quality.

3) Loam sand moulding

- Loam sand moulding are prepared with coarse grained silica sand, clay, coke, horse manure and water.
- This process of moulding is performed in different way.
- First, a rough structure of desired shape is made by hand by using bricks and loam sand.
- The surface of structure are blackened and dried before being casted.

4) Core sand moulding

- For core sand moulding, mixture is prepared with silica sand, olivine, carbon and chamotte sands.
- Sand that contains more than 5% clay may not be used as core sand.
- For core making by hand, the core sand is filled and rammed in the core box

  properly.
- The Whole operation takes a short time after the core box is withdrawn and the

(C) Other moulding processes:

1) Shell moulding
2) Permanent mould casting
3) Carbon dioxide moulding

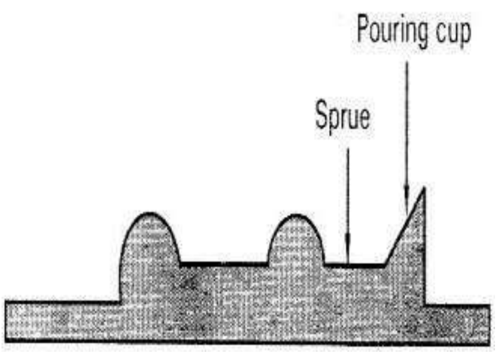
1) Shell moulding

- Shell moulding is an efficient and economical method for producing steel castings.
- The process was developed by Herr Croning in Germany during World war-II and is sometimes referred to as the Croning shell process.

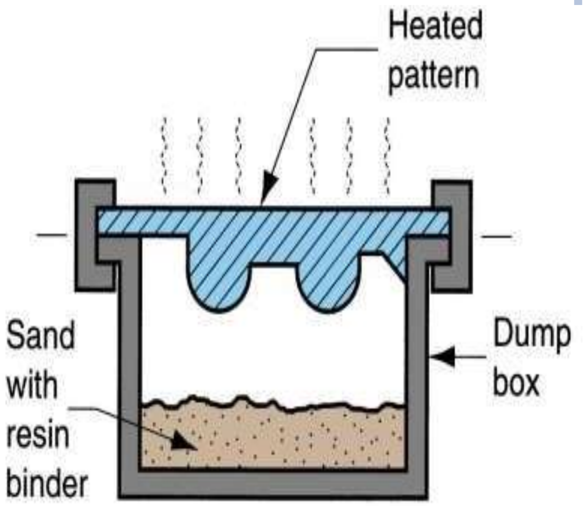
Procedure involved in making shell mould

a. A metallic pattern having the shape of the desired casting is made in one half from carbon steel material. Pouring element is provided in the pattern itself. Refer figure (a).

1. The pattern is inverted and is placed over a box as shown in figure (1). The box contains a mixture of dry silica sand or zircon sand and a resin binder (5% based on sand weight).

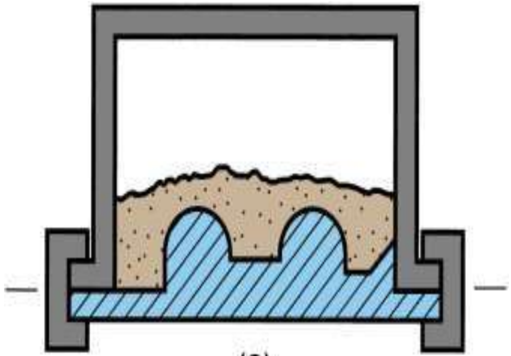


(a) One half of a pattern to produce dumble shaped casting



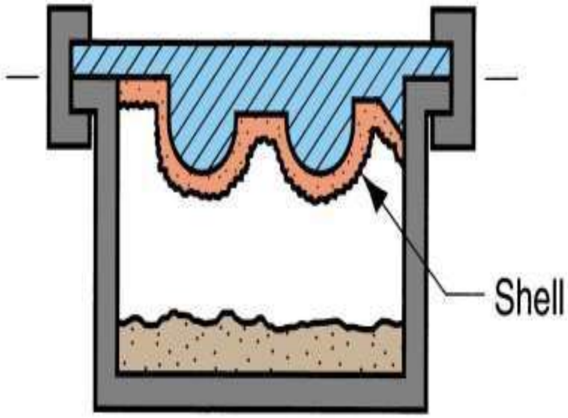
(1)

2. The box is now inverted so that the resin-sand mixture falls on the heated face of the metallic pattern. The resin-sand mixture gets heated up, softens and sticks to the surface of the pattern. Refer figure (2).



(2)

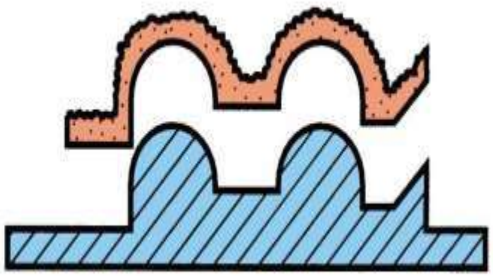
3. After a few seconds, the box is again inverted to its initial position so that the lose resin-sand mixture falls down leaving behind a thin layer of shell on the pattern face. Refer figure (3).



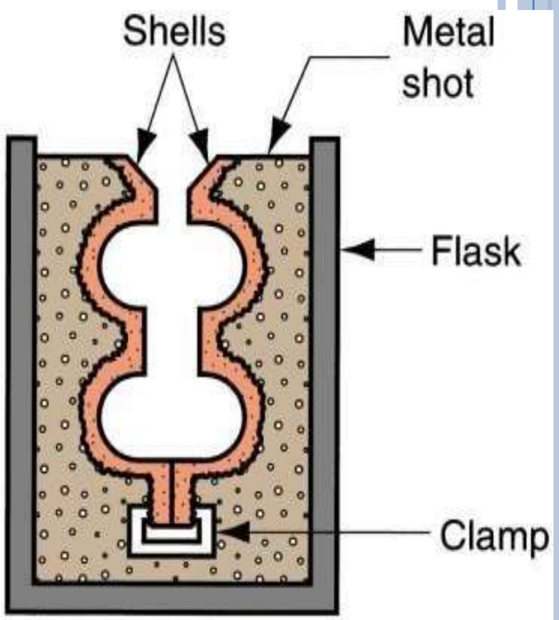
(3)

4. The pattern along with the shell is removed from the box and placed in an oven for a few minutes which further hardens the shell and makes it rigid. The shell is then stripped from the pattern with the help of ejector pins that are provided on the pattern. Refer figure (5).

5. Another shell half is prepared in the similar manner and both the shells are assembled, together with the help of bolts, clips or glues to form a mould. The assembled part is then placed in a box with suitable backing sand to receive the molten metal. Refer figure (6).

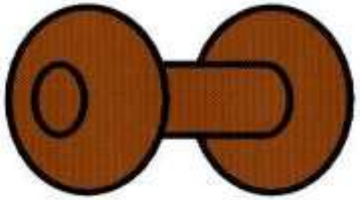


(5)



(6)

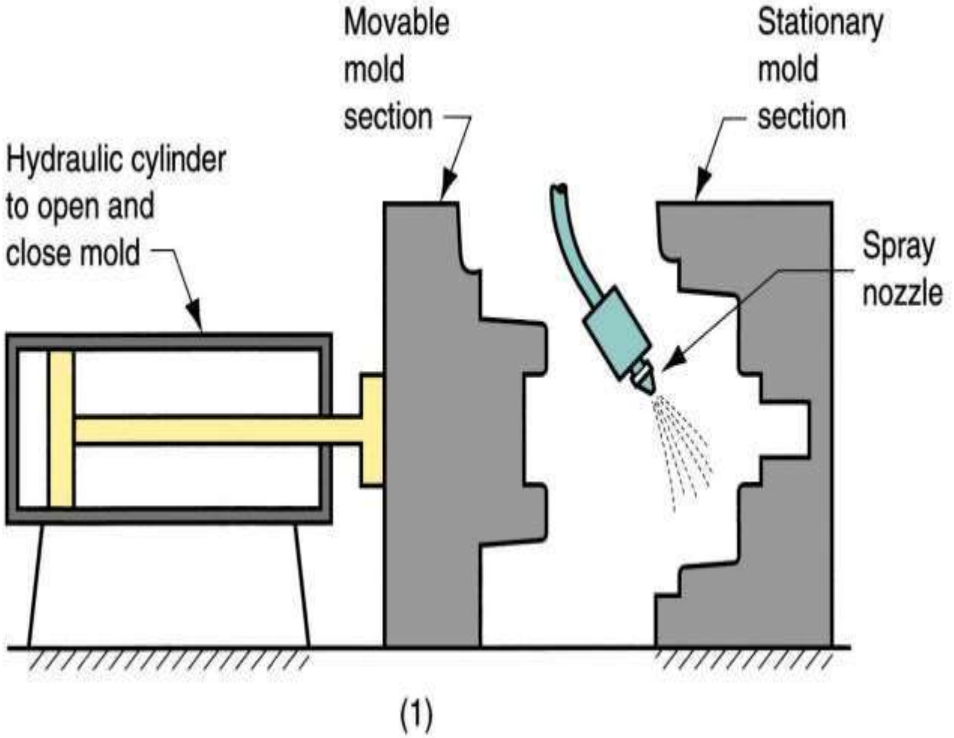
6. AFTER THE CASTING SOLIDIFIES, IT IS REMOVED FROM THE MOULD, CLEANED AND FINISHED TO OBTAIN THE DESIRED SHAPE AS SHOWN IN FIGURE (7).



(7)

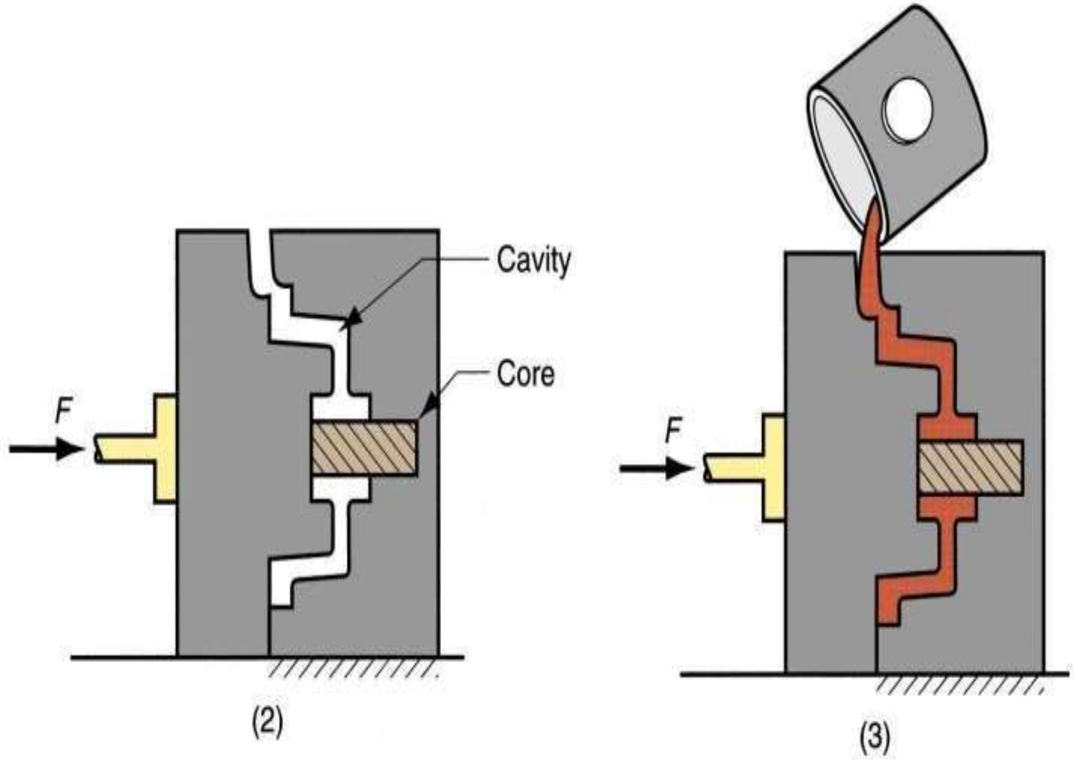
- Advantages
  - ✓ Better surface finish and dimensional tolerances.
  - ✓ Reduced machining.
  - ✓ Requires less foundry space.
  - ✓ Semi-skilled operators can handle the process easily.
  - ✓ Shells can be stored for extended periods of time.
- Disadvantages
  - ✓ Initially the metallic pattern has to be cast to the desired shape, size and finish.
  - ✓ Size and weight range of castings is limited.
  - ✓ Process generates noxious fumes.

2) Permanent Mold Casting



Steps in permanent mold casting: (1) mold is preheated and coated

Permanent Mold Casting



Steps in permanent mold casting: (2) cores (if used) are inserted and mold is closed, (3) molten metal is poured into the mold, where it solidifies.

3) CARBON DIOXIDE (CO_2) MOLDING

- Carbon dioxide moulding also known as sodium silicate process is one of the widely used process for preparing moulds and cores.
- 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 carbon dioxide gas. For this reason, the process is commonly known as $C0_2$ process.

❖ Steps involved in making carbon dioxide mould

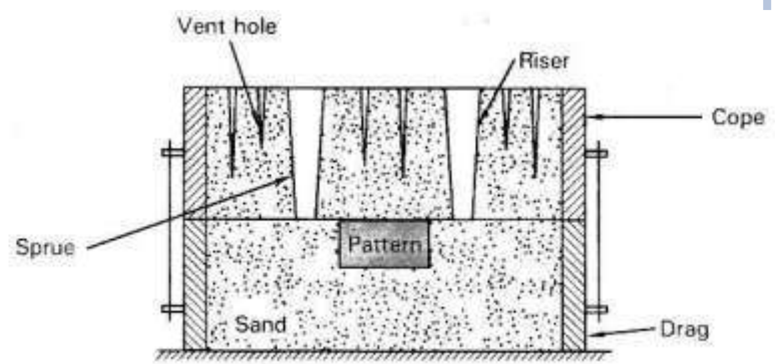
- Suitable proportions of silica sand and sodium silicate binder (3-5% based on sand weight) are mixed together to prepare the sand mixture.
- Additives like aluminum oxide, molasses etc., are added to impart favorable properties and to improve collapsibility of the sand.
- The pattern is placed on a 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 the operations like placing sprue and riser pin and ramming the cope box are similar to that of green sand moulding process.

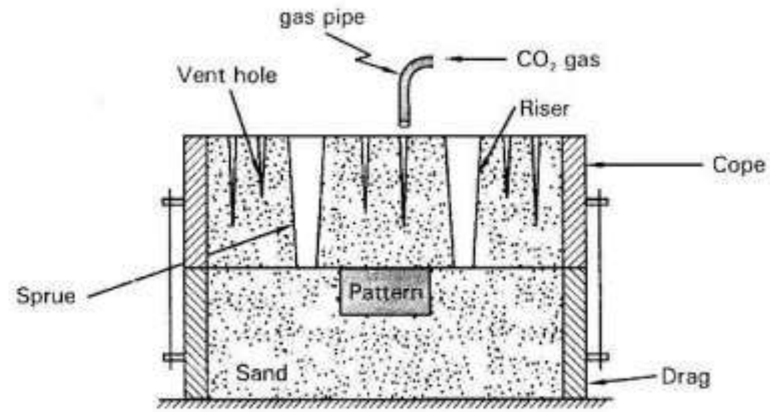
- Figure (a) shows the assembled cope and drag box with vent holes. At this stage, the carbon dioxide gas is passed through the vent holes for a few seconds. Refer figure (b).
- Sodium silicate reacts with carbon dioxide gas to form silica gel that binds the sand particles together. The chemical reaction is given by:

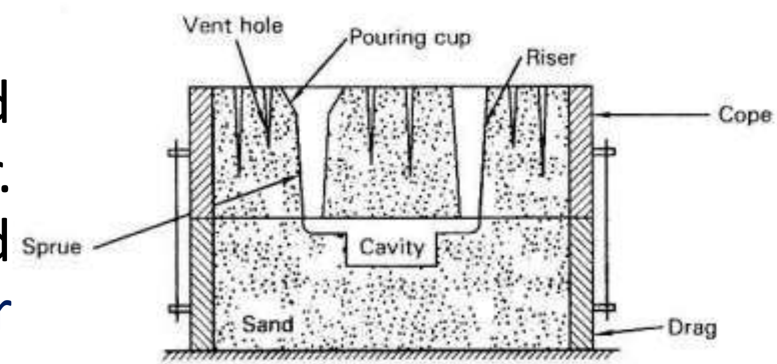
$$Na_2Si03 + C0_2 \rightarrow Na_2C0_3 + Si0_2$$

(Sodium Silicate) (silica gel)

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







Advantages

- Instantaneous strength development. The development of strength takes place immediately after carbon dioxide gassing is completed.
- Since the process uses relatively safe carbon dioxide gas, it does not present sand disposal problems or any odour while mixing and pouring. Hence, the process is safe to human operators.
- Very little gas evolution during pouring of molten metal.

Disadvantages

- Poor collapsibility of moulds is a major disadvantage of this process.
- There is a significant loss in the strength and hardness of moulds which have been stored for extended periods of time.
- Over gassing and under gassing adversely affects the properties of cured sand.

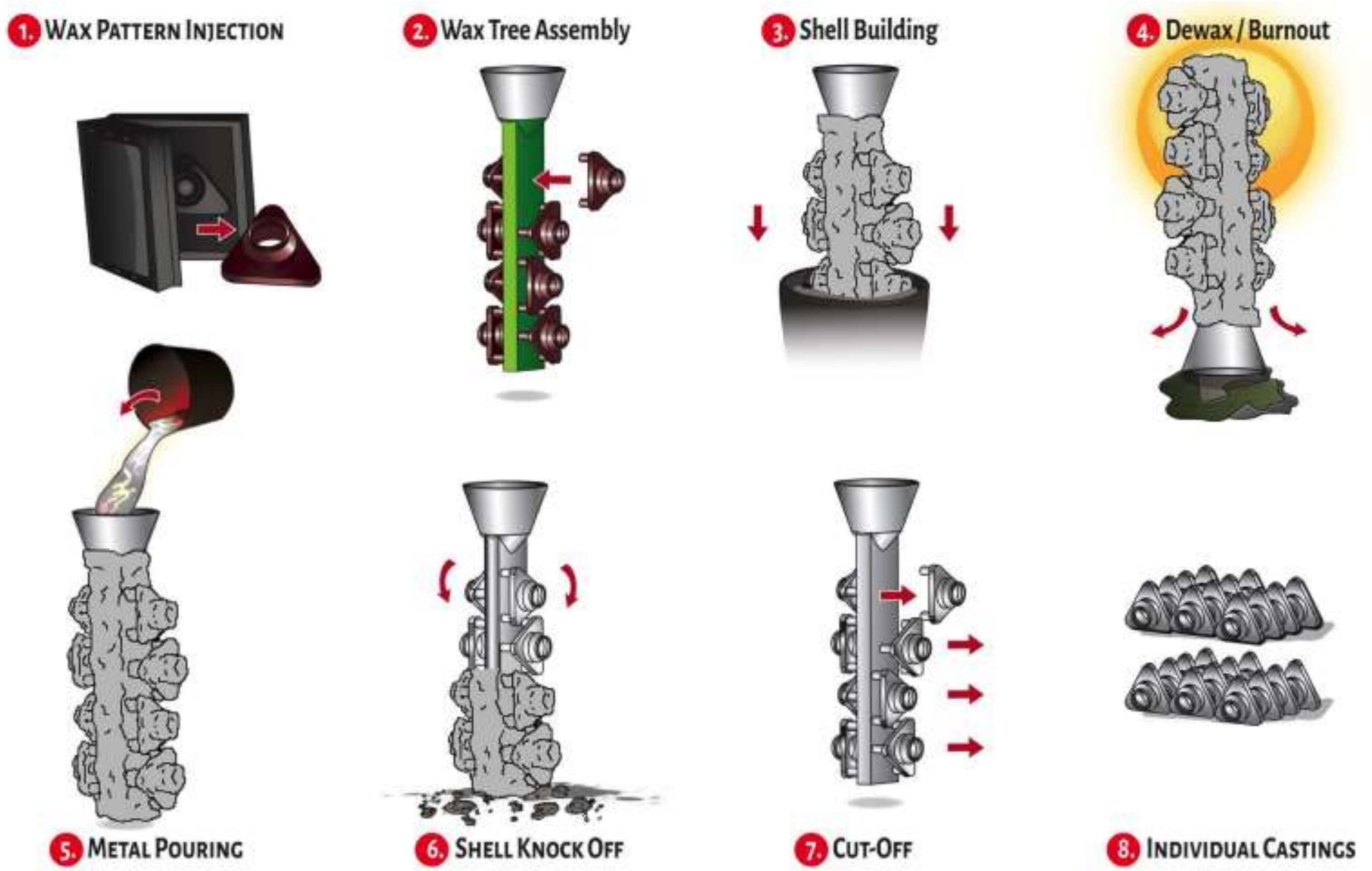
No Bake Moulding Process

- **Nobake is a casting process that involves the use of chemical binders to bond the molding sand.**
- **Sand is conveyed to the mold fill station in preparation for filling of the mold. A mixer is used to blend the sand with the chemical binder and catalyst.**
- **As the sand exits the mixer, the binder begins the chemical process of hardening. This method of mold filling can be used for each half of the mold (cope and drag).**
- **Each mold half is then compacted to form a strong and dense mold.**

- A rollover is then used to remove the mold half from the pattern box. After the sand has set, a mold wash may be applied.
- Cores, if required, are set into the drag and the cope is closed over the cores to complete the mold.
- A series of mold handling cars and conveyors move the mold into position for pouring. Once poured, the mold is allowed to cool before shake-out.

- The shake-out process involves breaking the molded sand away from the casting. The casting then proceeds to a casting finishing area for riser removal, casting finishing and finalization.
- The broken pieces of molded sand are further broken down until the sand is returned to grain size. The sand can now be either reclaimed for reuse in the casting process or removed for disposal.
- Thermal reclamation is the most efficient, complete method of Nobake sand reclamation.

Investment Casting



CONTENTS

- Overview
- Introduction
- Procedure
- Techniques
- Advantages/DisAdvantages
- Applications

Overview/History

- This technique is both one of the oldest & most advanced of the metallurgical art.
- The root of this technology, the “lost wax” method dates back to at least fourth millennium B.C and was originated in China.
- From 5,000 years ago, when beeswax formed the pattern, today high-technology waxes are used in molding.
- In today's world Investment Casting touches all of our lives. When we fly on an airplane, drive an automobile, play golf, we are using investment casting.

INTRODUCTION

- Commonly referred to as “Lost wax Casting”.
- The Pattern is made up of wax or plastic Such as Polystyrene because of low melting temperature.
- The molten metal is poured into the ceramic mold and mold is formed using wax pattern.(The wax assembly is dipped into high-grade ceramic slurry)
- Investment casting is often referred to as "lost-wax casting" because the wax pattern is melted out of the mold after it has been formed.

Introduction

- Investment casting can make use of most metals, most commonly using Al alloys, bronze alloys, Mg alloys, cast iron, stainless steel, and tool steel.

- This process is beneficial for casting metals with high melting temperatures that can not be molded in plaster or metal.

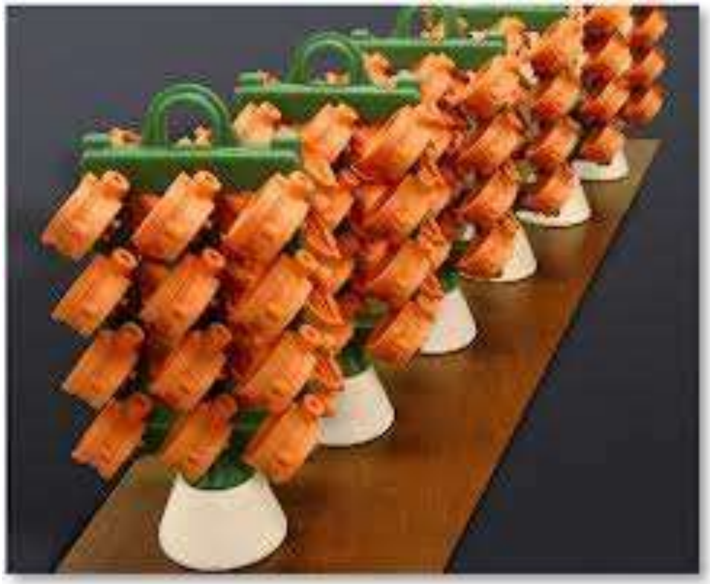
- Parts that are typically made by investment casting include those with complex geometry such as turbine blades or firearm components.

INTRODUCTION

- Lost Foam Casting (LFC) is modern form of investment casting.
- LFC is a type of **evaporative-pattern casting** process that is similar to investment casting except foam is used for the pattern instead of wax.
- Most Commonly used foam is polystyrene foam.

Pattern made up of foam

Pattern made up of Wax



Patterns Comparison For Lost Wax Casting & Lost Foam Casting

Procedure

PROCESS OF INVESTMENTCASTING

1. Pattern Making:

- Manufacture Wax Pattern
- Master Die desired
- Allowances(Wax ,Ceramic Coating and Metal shrikange) added into Master Die

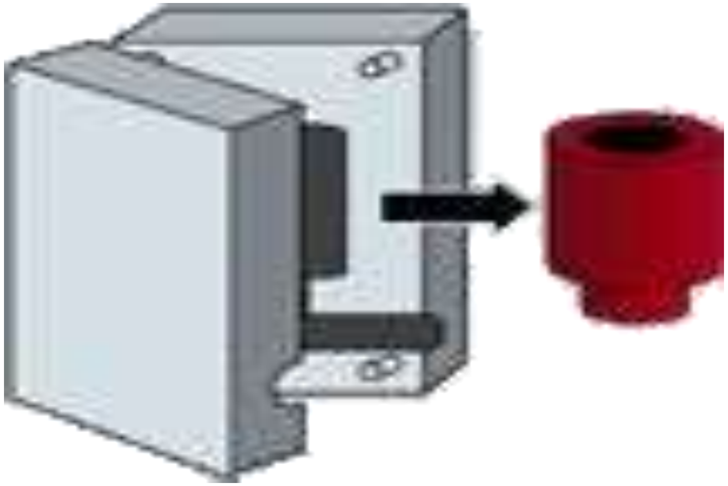


Fig. 1 Wax Injection

2. Assembly

- Several Wax Pattern Combine for a Single Casting
- Wax Bar(Central Sprue)
- Pouring Cup
- Wax pattern Tree

Fig. 2. Assembly

3. Shell Buliding

- Dip Assembly in a Refractory Slurry
- Refractory Slurry(Fine Grained Silica,Water and Binders)
- Achieve Required Ceramic Coating

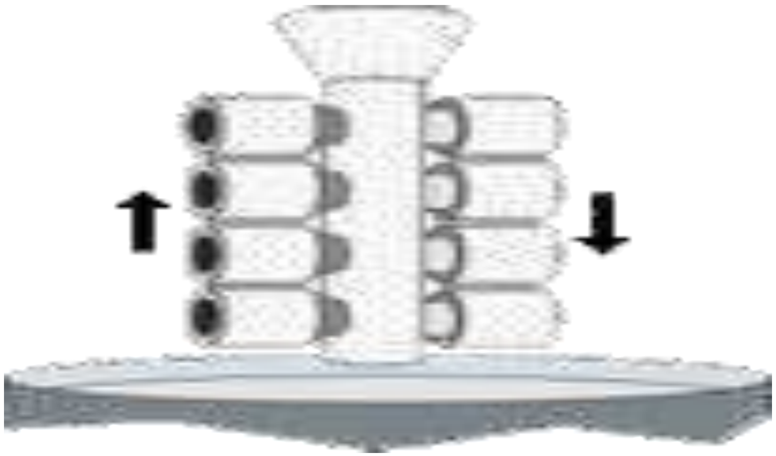


Fig. 3. Shell Building

4. DEWAX

- Allow to Harden in air
- Ceramic Mold is turned upside down and heated(90-175 ‘C)
- Wax flow out of Mold

Fig. 4. Dewax

5. Metal Casting Pouring

- Ceramic mold further heated(550-1100 ‘C)
- To eliminate any left over wax, contaminants and drive water out
- Metal Casting poured while mold still hot

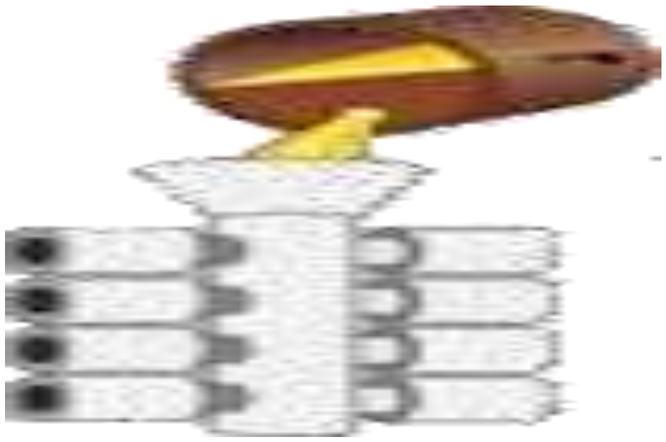


Fig. 5. Metal Casting Pouring

6. Knockout and CutOff

- Once the casting has cooled sufficiently, the mold shell is chipped away from the casting
- Gates and Runners are cut from the casting

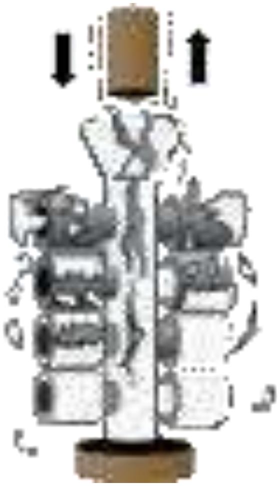
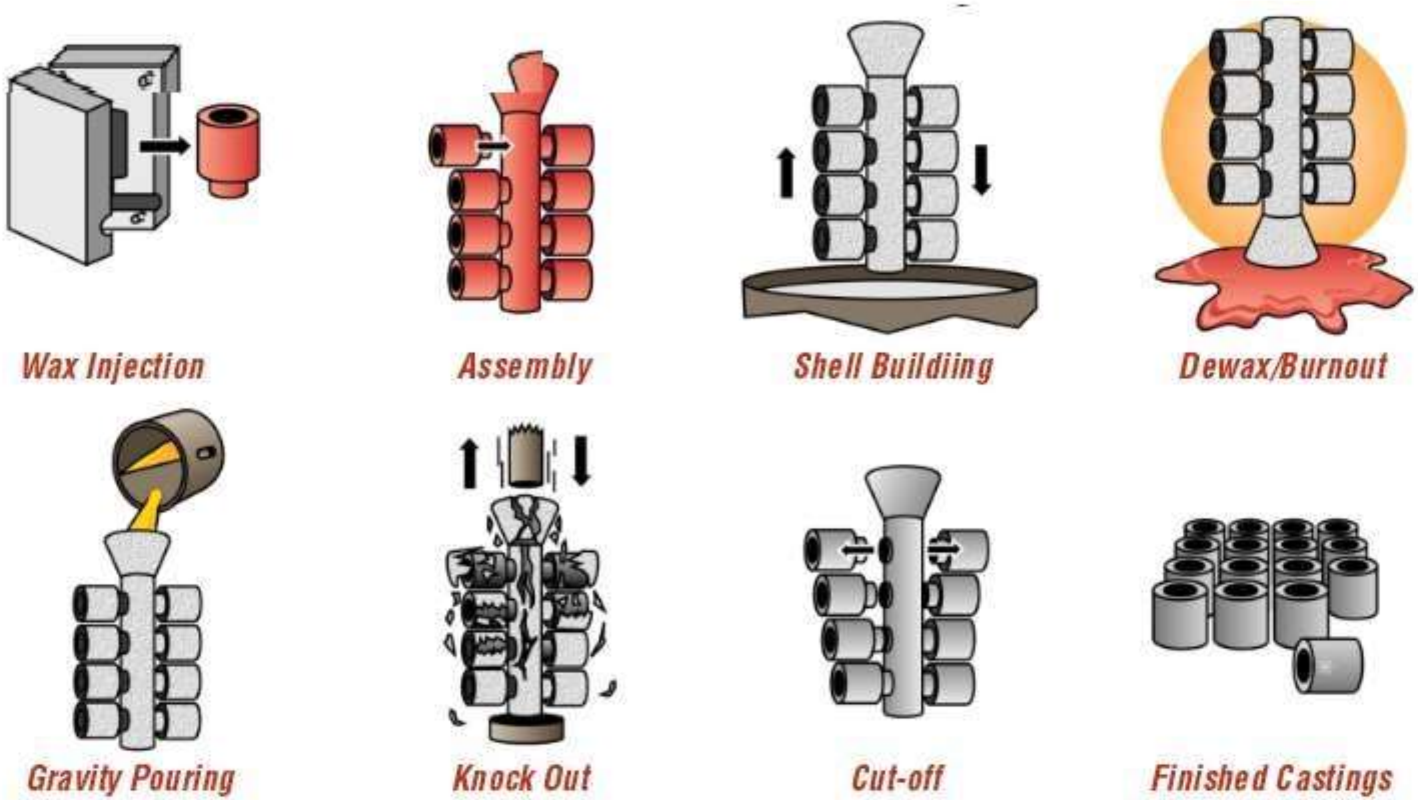


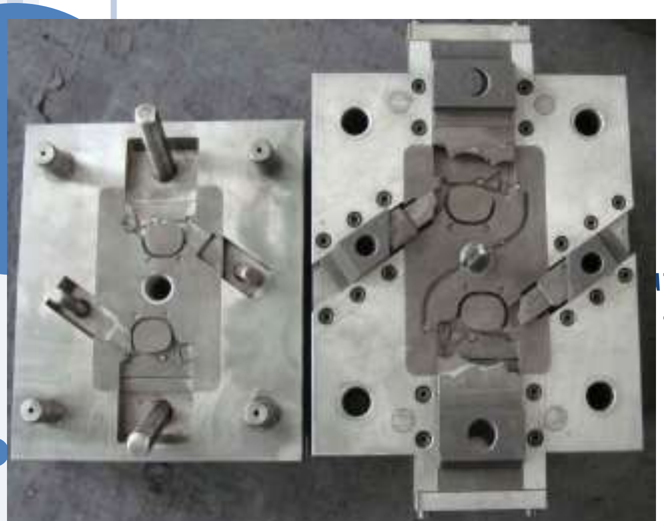
Fig. 6. Knockout

Fig. 7. Cut Off

SUMMARY


Wax Injection
Assembly
Shell Buildiing
Dewax/Burnout
Gravity Pouring
Knock Out
Cut-off
Finished Castings

Die casting is a permanent mold casting procedure, in which the mold is made of metal and large number of castings are produced from it.



TING

Die Casting

Common Metals:

- Alloys of Al, Mg, and Cu are mostly cast.
- Iron and steel can also be cast .
- Alloys of lead, tin and zinc can also be cast by this process.

Die Casting

Mold:

- The mold is made of special die steels.

Die: The mold made of metals is called “die”.

- These steels have very high melting point and must resist very high temperatures

DIE CASTING

- This mold is only preferred when a large no. of castings are to be prepared

Reason: This is a expensive mold.

- The die is in two halves.

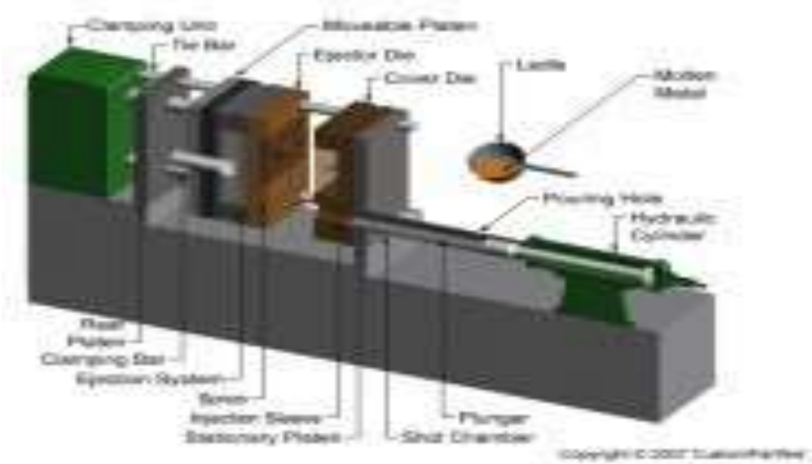
- One half is fixed while other is moveable to allow the casting to be removed.

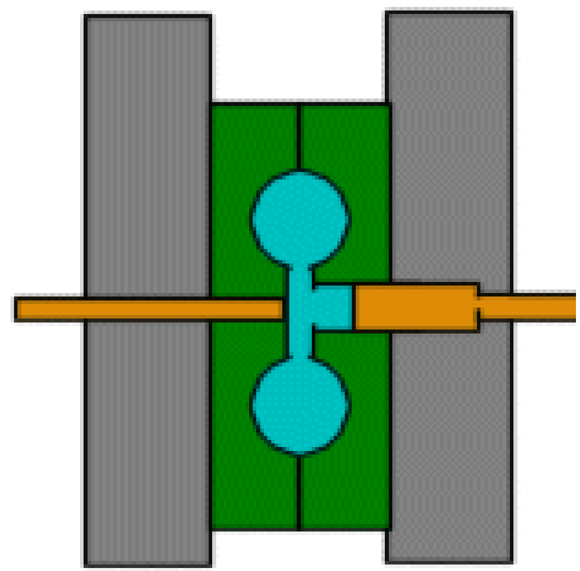
DIE CASTING

Process:

A die-cycle is completed in following steps:

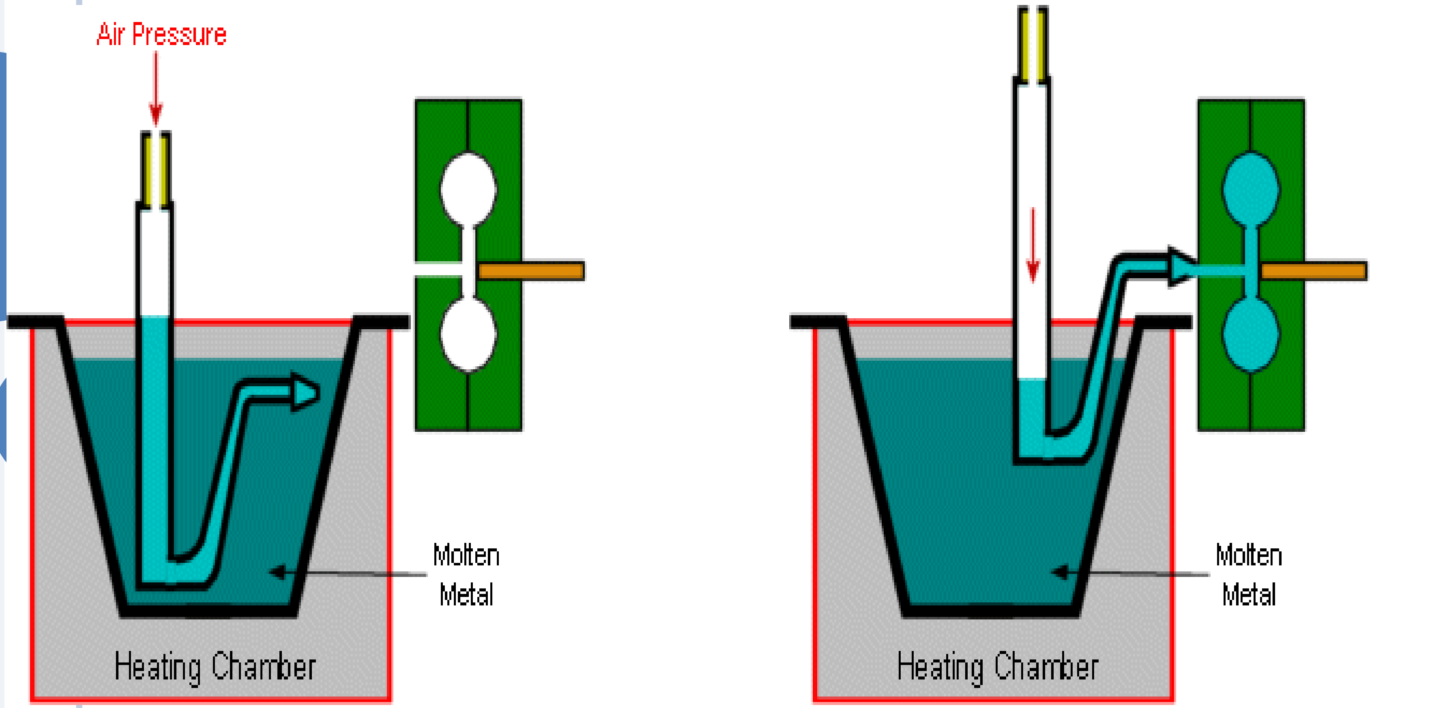
- The ladle brings the molten metal from the furnace and pours it into the shot sleeve.
- Plunger pushes the molten metal into the cavity in the die, with a pressure of nearly 9800 psi.





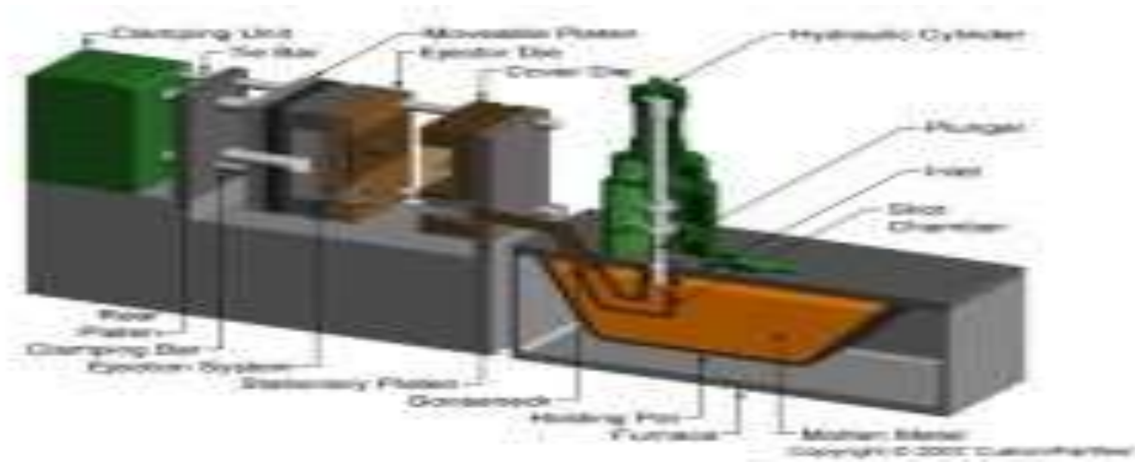
Die Casting

- When metal is filled in the neck; incase of air-operated m/c, it is raised up to the die and locked in contact with the die opening.



Die Casting

- Plunger is pushed down by a pressure of nearly 5000 psi to inject the molten metal into the cavity in the die.
- After the die is filled, metal is left to solidify.
- Pressure is maintained during solidification by a plunger or compressed air.
- After solidification, pressure is removed, the die is opened and knock-out/ejector pins are used to eject the casting out.



Die Casting

Die cycle:

- A cycle is a complete set of events in which one casting is produced.
- It consists of following steps:
  - Closing the die.
  - Shot: Injection of molten metal in die.
  - Solidification of metal under pressure.
  - Opening the die.
  - Ejection of casting from the die.

Die Casting

Types/methods:

Die casting is done by two methods:

1. Gravity Die Casting/Permanent die casting

    i- Slush casting

    ii- Low pressure die casting

1. Pressure Die Casting

    i- Hot chamber die casting

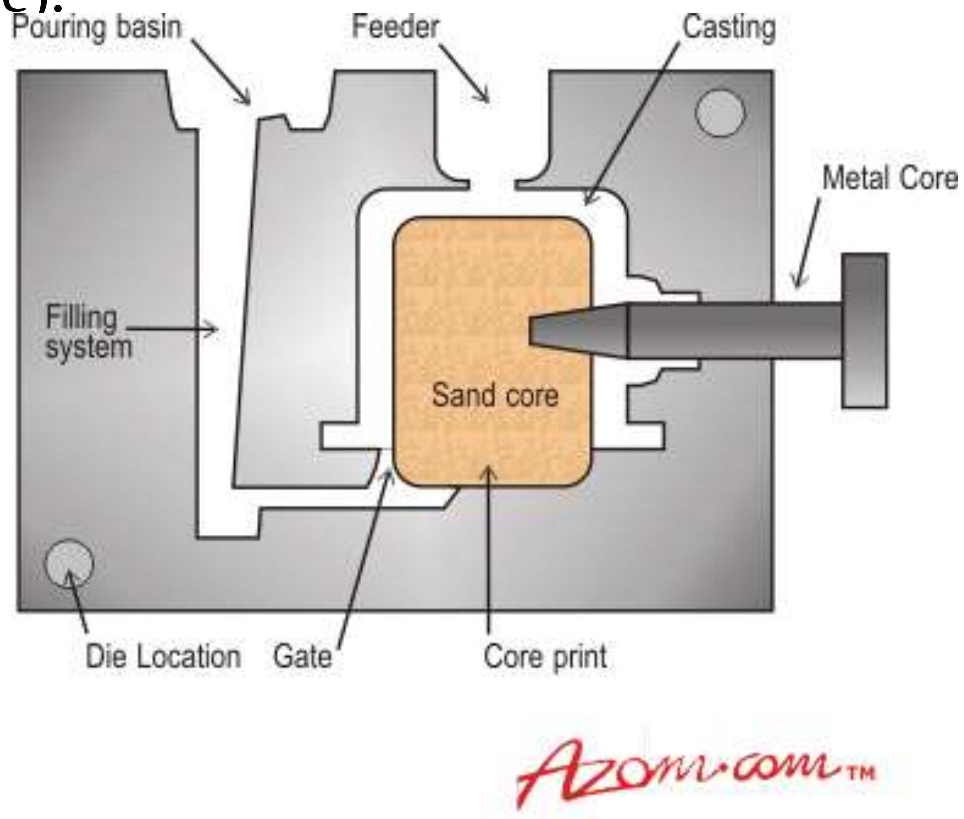
    ii- Cold chamber die casting

    iii- Centrifugal casting

Die Casting

Gravity Die Casting/Permanent die casting:

- Molten metal is poured under gravity (i.e. without pressure).



DIE CASTING

Pressure Die Casting:

- Molten metal is poured under pressure.

- There are two types of pressure die casting.

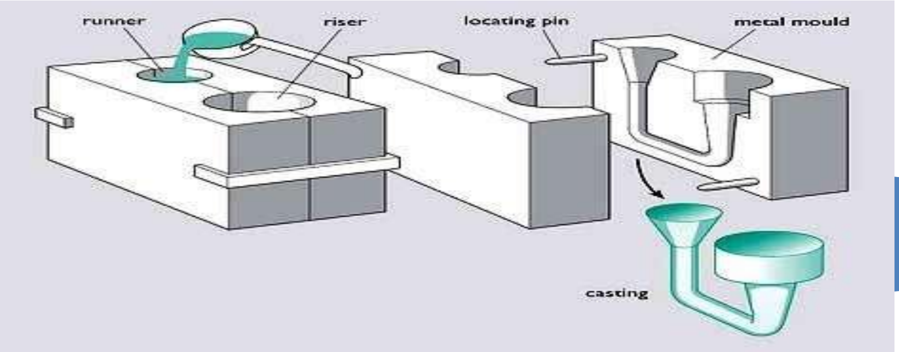
  - Hot-Chamber die casting

  - Cold-chamber die casting

DIE CASTING

Gravity Die Casting:

- In gravity die casting or Permanent Mold Casting, fluid metal is poured by hand into metal molds.
- Both ferrous and non-ferrous metals can be casted.
- Production rate is slow.
- The casting is not so smooth or dimensionally accurate.



Die Casting

Cold-Chamber Die Casting:

- In this pressure die casting process, the basin of molten metal is not a part of the m/c.
- Molten metal is poured from an external melting container and a piston is used to inject the metal under high pressure into the die cavity.
- Injection pressure used in this machine typically 14 to 140 Mpa.
- High melting alloys of brass, aluminum, and magnesium are casted in cold-chamber m/c.

Hot-Chamber Die Casting:

- In this pressure die casting process, the basin of molten metal is a part of the m/c.

- Low melting (less than 700°C) alloys of zinc, tin, and lead are casted in hot-chamber m/c.

- It is mainly used for small castings (0.03kg to 40kg).
- The injection pressure are 7 to 35 MPa.

Die Casting

The actual mold life varies:

- **Alloy being cost:** as higher the melting point, shorter the mold life
- **Mold material:** Grey cast iron has the best resistance to thermal fatigue and machines easily.
- **Pouring temperature:** High pouring temperature reduce the mold life, increases shrinkage problems and induce longer cycle time.
- **Mold temperature:** Low temperature produce misruns and high temperature results the mold erosion.
- **Mold configuration:** Difference in section size of mold and casting can produce

Die Casting

Advantages:

- High production rates can be possible
- Good surface finish, smooth cavity produces smooth castings.
- Large number of castings can be produced by metal mold and economical justification for large production.
- The process is fully or semi-automatic, which reduces labor cost.
- Rapid cooling provides small grains size and good strength.

DIE CASTING

- The process is very fast and can produce large number of castings in a small time.
- As casting is done under high pressure so the grains are highly compacted, increasing the strength of the casting.
- High dimensional accuracy.

DIE CASTING

Disadvantages:

- Metal dies are very expensive so high volume production is usually required to justify the expense.
- Die casting machines are expensive too.
- Machining for producing the cavity is expensive.
- Nozzle and piston both require replacements and repairing.
- High melting alloys cannot be prepared in hot chamber m/c.

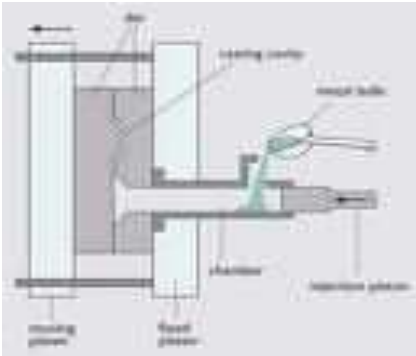
DIE CASTING

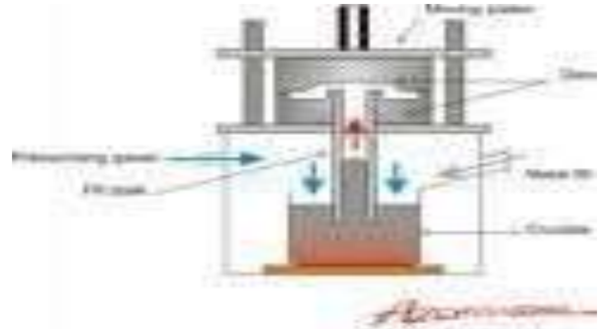
- Expert metallurgical and production control is required for perfect castings.
- Careful gating and vent systems are to be considered.
- Although cold chamber process is applicable to most of alloys but due to ladling operation its production speed is slow.
- The hard and strong metals such as iron and steel cannot be die-cast.

Die Casting

Advantages	Disadvantages	Recommended Application
Good dimensional tolerances are possible	Economical only in very large quantities due to high tool cost	Use when quantity of parts justifies the high tooling cost
Excellent part-part dimensional consistency	Not recommended for hydrostatic pressure applications	Parts are not structural and are subjected to hydrostatic pressure
Parts require a minimal post machining	For Castings where penetrant (die) or radiographic inspection are not required.	
	Difficult to guarantee minimum mechanical properties	

[PRESSURE DIE CASTING TECHNIQUES]





[Pressure-die casting]

[Die cast Part of automobile]

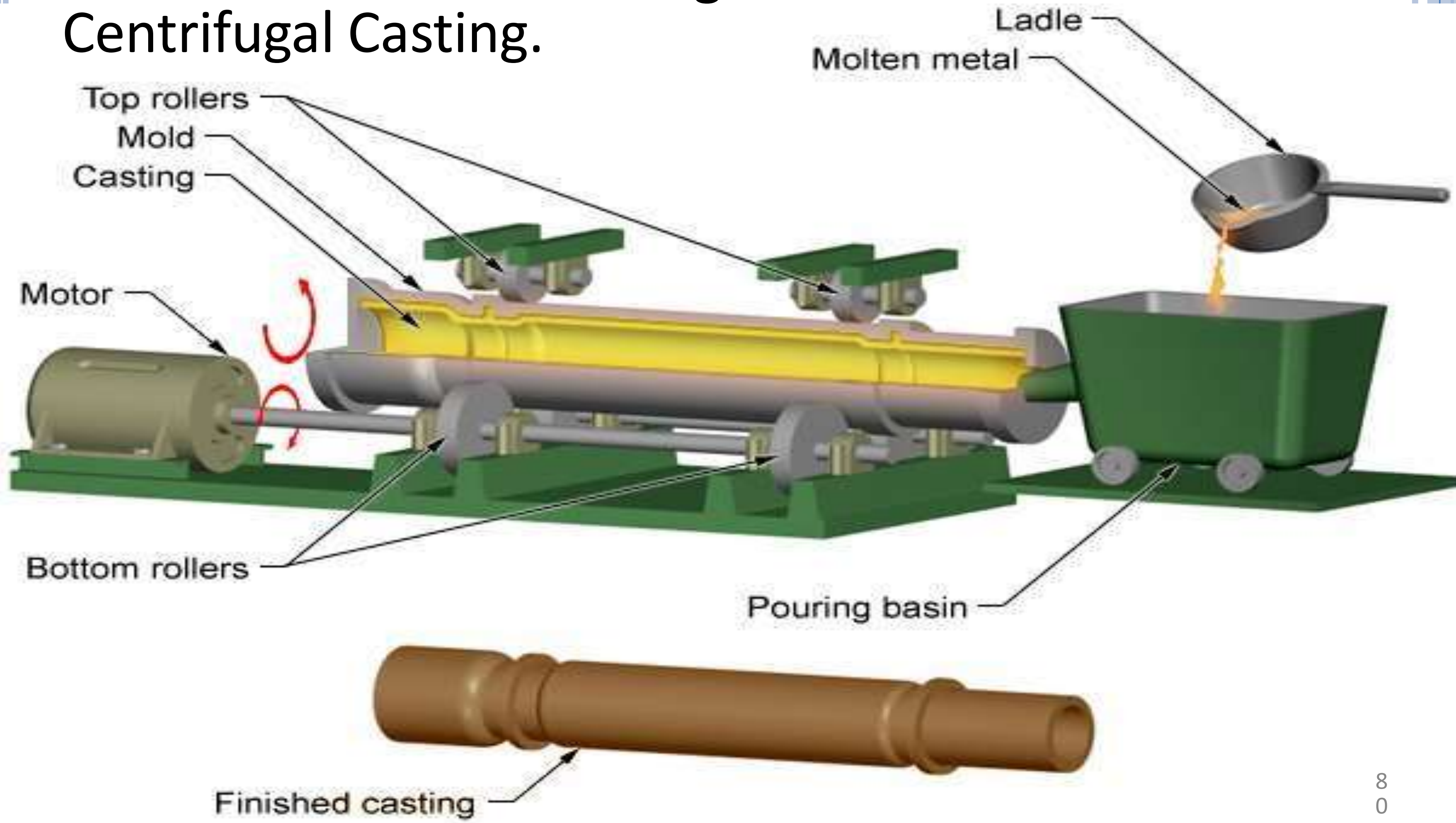
[Die casting Fence fittings]

(Image courtesy: wiki)

Centrifugal Casting

➢ Centrifugal Casting

- Casting that utilizes centrifugal force within a spinning mold to force the metal against the walls is known as Centrifugal Casting.



- Centrifugal casting, sometimes called rotocasting, is a metal casting process that uses centrifugal force to form cylindrical parts.
- This differs from most metal casting processes, which use gravity or pressure to fill the mold.
- In centrifugal casting, a permanent mold made from steel, cast iron, or graphite is typically used. However, the use of expendable sand molds is also possible.
- The casting process is usually performed on a horizontal centrifugal casting machine (vertical machines are also available) and includes the following steps:

Steps Involved in Centrifugal Casting

- **1. Preheat the steel mold and coat the mold interior with the refractory ceramic coating (applied as a spray slurry).**
- **2. Melt the metal in the furnace.**
- **3. Rotate the mold (300-3000 rpm, typically around 1000 rpm), pour the metal, and spin the mold until the casting solidifies.**
- **4. Remove the casting from the mold after solidification.**
- **5. Clean, heat-treat and machine the finished casting**

Centrifugal Casting set up

Characteristics of Centrifugal Casting

1) The casting is relatively free from defects.

2) Non metallic impurities which segregate toward the bore can be machined off.

3) Less loss of metal in tundish compared to that in gating and risering in conventional and sand casting.

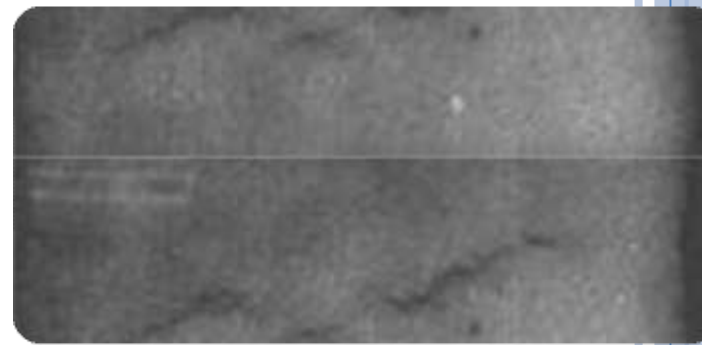
4) Better mechanical properties.

5) Production rate is high.

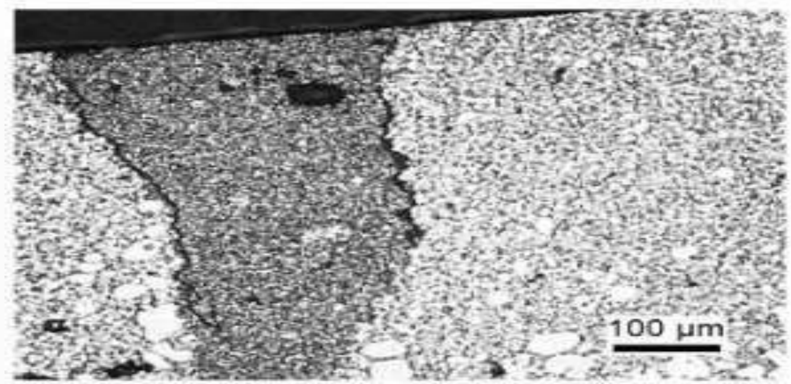
6) Centrifugal casting process can be used for fabricating functionally gradient metal matrix composite material.

DEFECTS:-

- Conventional static casting defects like internal shrinkage, gas porosity and non-metallic inclusions are less likely to occur in centrifugal casting.



- **Hot Tears** – Hot tears are developed in centrifugal castings for which the highest rotation speeds are used. Longitudinal tears occur when contraction of casting combined with the expansion of the mould, generates hoop stresses exceeding the cohesive strength of the metal at temperatures in the solidus region.



- **Segregation** - Centrifugal castings are under various forms of segregation thus pushing less dense constituents at centre.

- **Bending** – Sometimes castings produce zones of segregated low melting point constituents such as eutectic phases and sulphide and oxide inclusions. Various theories explain this, one states vibration is the main cause of banding.