Foundry Technology Unit 3

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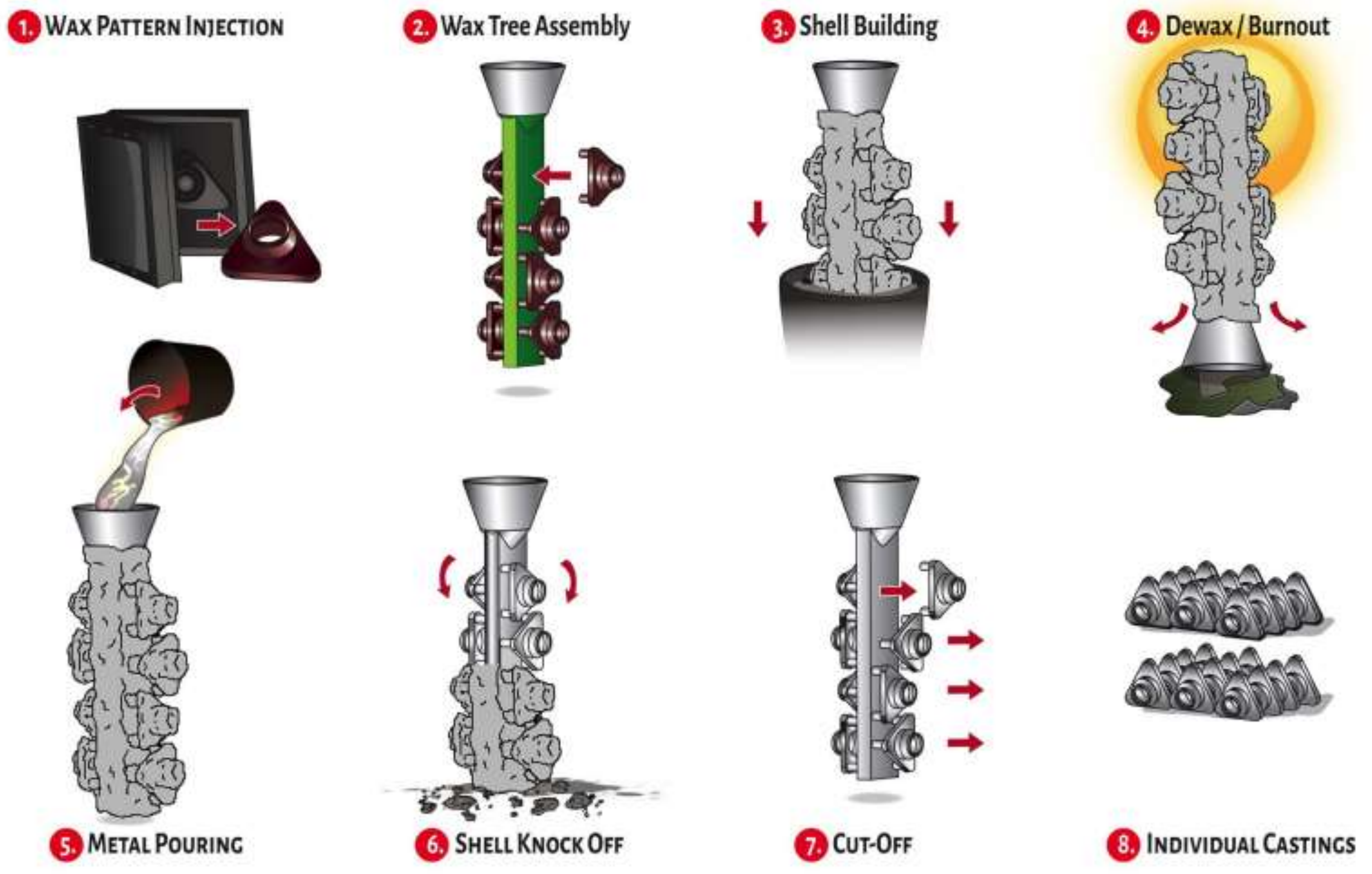
-Monil Salot

Syllabus Unit 3

- **Casting Processes:**
  - Shell molding and casting process,
  - Investment casting process,
  - Permanent molding process.
  - Gravity and Pressure Die-casting.
  - Centrifugal casting process.
  - Low Pressure Die-casting (LDPC) process.

- **Melting:**
  - Melting of cast iron,
  - Constructional features of Cupola, Principles and operation of Cupola furnace. Advances in cupola melting operation,
  - Melting of aluminum and Copper-based alloys.
  - Furnaces used, Melt-treatments such as degassing, Grain refining and modification.

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

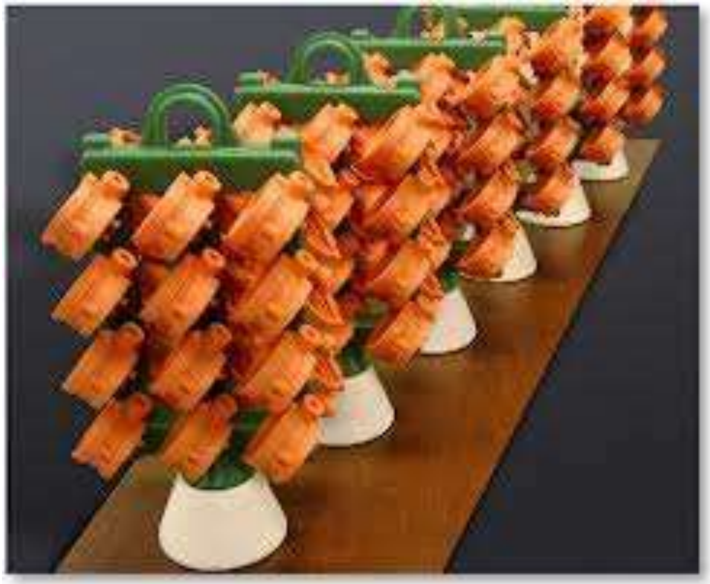
- Lost Foam Casting (LFC) is modern form of investment casting.

- 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

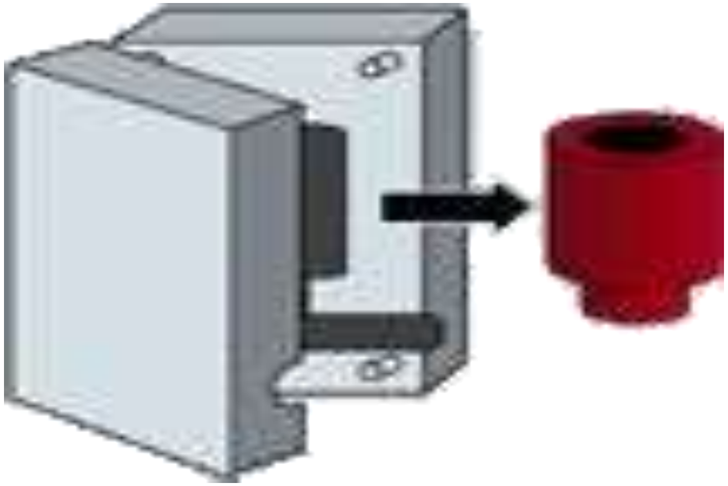


Fig. 1 Wax Injection

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

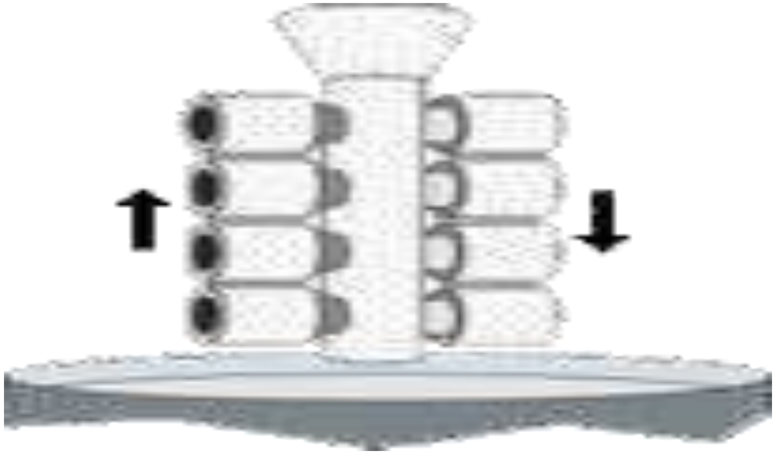


Fig. 3. Shell Building

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)
- Toeliminate any left over wax, contaminants and drive water out
- Metal Casting poured while mold still hot

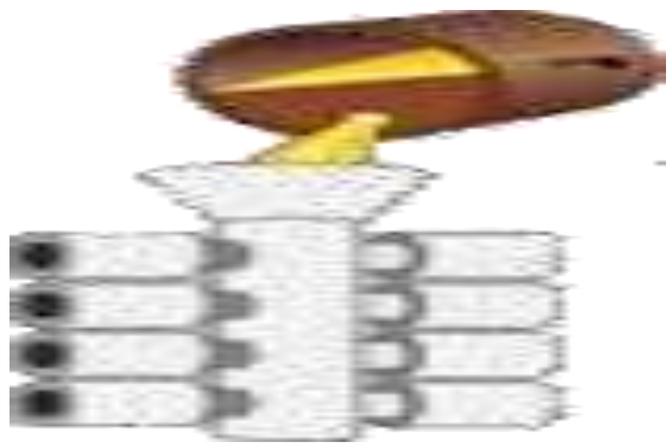


Fig. 5. Metal Casting Pouring

6. Knockout and CutOff

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

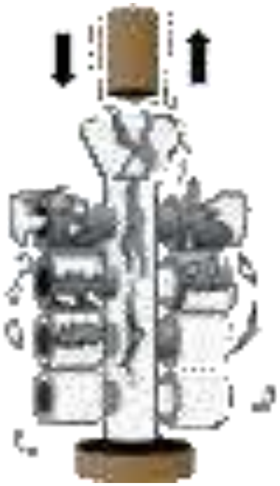


Fig. 6. Knockout

Fig. 7. Cut Off

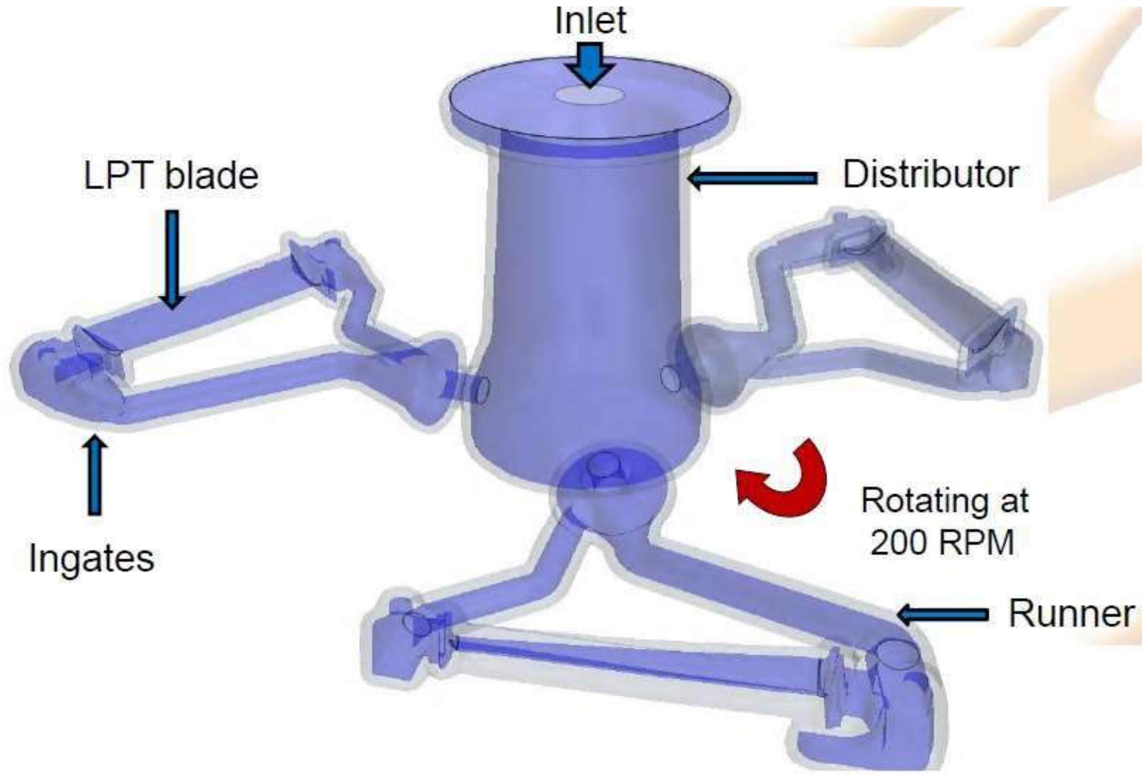
Techniques

SUMMARY

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

CENTRIFUGAL INVESTMENT CASTING

Centrifugal forces distributes the molten material in the mould

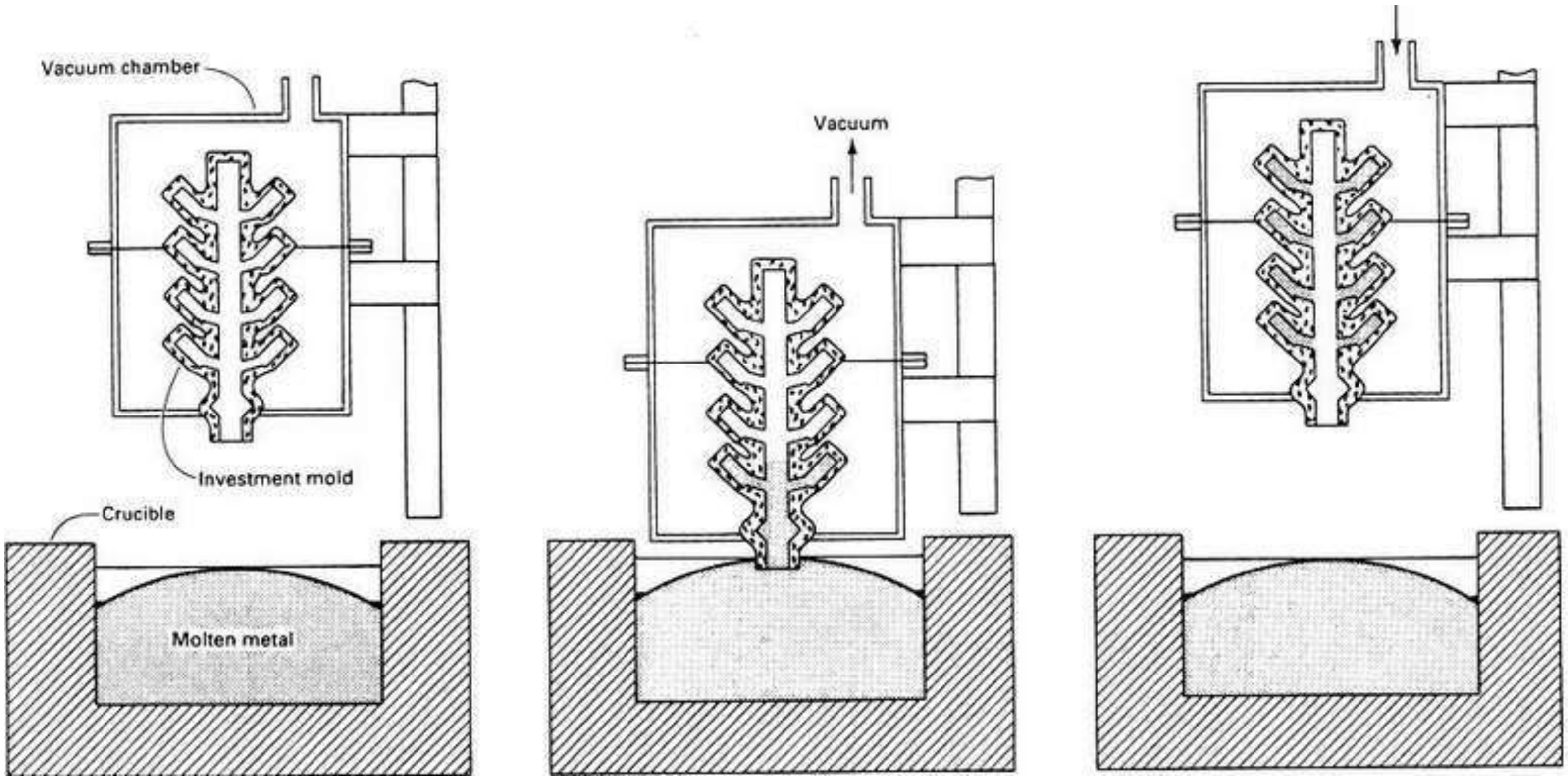


- Crystal growth aligns in the direction of centrifugal forces.
- Solid Liquid Transition

COUNTER GRAVITY CASTING

1. The mold is placed in a vacuum chamber with a fill pipe
2. The chamber is sealed and lowered a precise distance into the melt
3. Vacuum is created
4. Metal moves up into the sprue

cavity, filling every section completely


Vacuum chamber
Investment mold
Crucible
Molten metal
Vacuum

SOLID INVESTMENT PROCESS

- Wax Pattern is placed in a bottom sealed container

- This Assembly is then placed in a vaccum chamber

- Gypsum based refractory mixed with water is then filled into it.
- It is ***fired*** firing melts the wax and also sinters the mold.

Advantages/Disadvantages

Why Prefer Investment Casting?

- Many Intricate forms with undercuts can be cast.
- A very smooth surface is obtained with no parting line.
- Dimensional accuracy is good.
- Certain unmachinable parts can be cast to preplanned shape.
- It may be used to replace die-casting where short runs are involved.
- The lost wax method out performs any other casting process when it comes to superior surface finishes especially when compared to sand casted, forged or welded fabrications.

Impact of Advantages

- Reliability

The investment casting process provides reliable process controls and repeatability that are maintained from casting to casting

- Tolerances

Investment Casting routinely holds to tolerances of ± .005”. This is not always possible with other types of casting processes.

- Amortization Lowers Tooling Cost

The initial wax injection mold to produce the patterns, averaged over the entire production quantity, is often lower than other casting tooling costs. Quality tooling produces a quality part and will be more cost efficient in the long run.

Impact of Advantages

- Better for the Environment

An investment casting is produced from wax patterns which in most cases can be reclaimed and used again. The wax pattern is a great way to see your part before it is cast, thus eliminating expensive revisions and reducing metal scrap. More importantly, the investment casting process produces parts to net or near net shapes which significantly reduces or eliminates the amount of secondary machining. Most scrap from secondary services like machining can be reused as well.

- Design & Casting Versatility

Investment Casting works with over 100 different ferrous and non-ferrous casting alloys. This allows investment casting process to be used in a variety of industries as it produces a wide range of cast and casting based assemblies. Lost wax castings provide the maximum design flexibility for manufacturing complex, **multi part products** in many cases.

Impact of Advantages

- Intricate Design

When using investment castings, design engineers can easily incorporate features such as logos, product ID's/numbers, and letters into their component. Through holes, slots, blind holes, external and internal splines, gears, and thread profiles can often be cast to reduce secondary machining time and total part cost.

Disadvantages & Limitations

- This process is expensive(labour costs), is usually limited to small casting, and presents some difficulties where cores are involved.
- Holes cannot be smaller than 1/16 in. (1.6mm) and should be no deeper than about 1.5 times the diameter.
- Investment castings require very long production-cycle times versus other casting processes.
- This process is practically infeasible for high-volume manufacturing, due to its high cost and long cycle times.
- Many of the advantages of the investment casting process can be achieved through other casting techniques if principles of thermal design and control are applied appropriately to existing processes that do not involve the shortcomings of investment castings

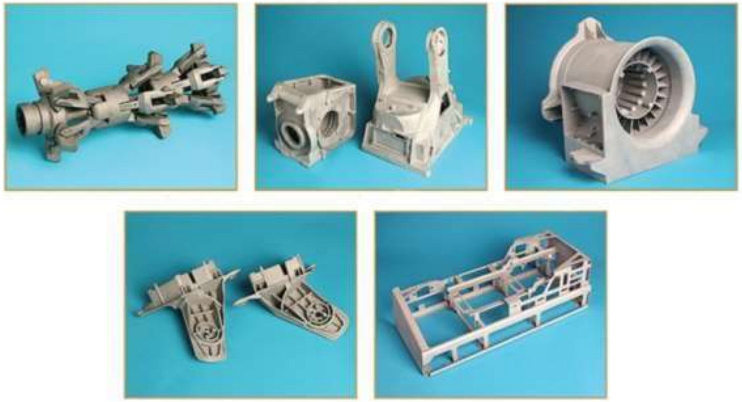
Disadvantages

- Some of the reasons for the high cost include specialized equipment, costly refractories and binders, many operations to make a mold, a lot of labor is needed and occasional minute defects.

Applications

Applications

- When **design complexity**, **tolerance control** and **repeatability** are the name of the game, **Investment Casting** is by far the most **cost-effective** solution compared to other methods of producing metal parts and assemblies



Aerospace Industry

- From Boeing to NASA **Investment castings** are built ready to integrate, providing significant cost savings over other manufacturing methods
- **Quality** has always been top priority, especially for aerospace components

AEROSPACE INDUSTRY

- Turbine airfoils
- Aircraft engine
- Industrial gas turbine industries

Boeing 777-APU duct- Ti-alloy

Medical Instruments

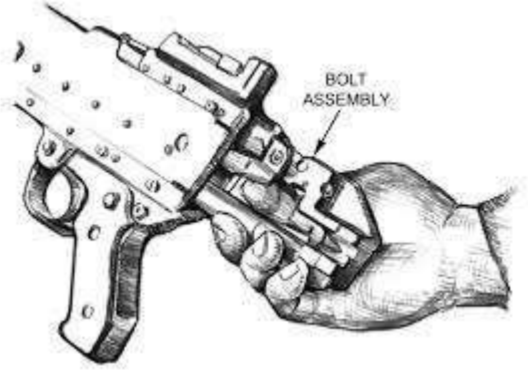
- **Surgical implants**

  e.g. knee & **hip joints**

  Ti_6Al_4V alloys, Co-Cr-Mo alloys

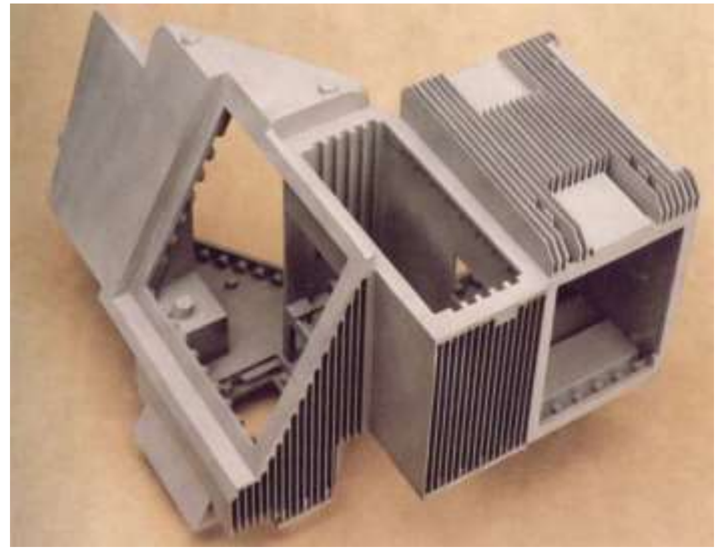
MILITARY EQUIPMENT

- Military equipment need to meet very **tight tolerances** and **high quality standards**
- Joysticks for drone planes/UAVs
- Gun triggers, hammers & sights
- Trigger guards
- Bolt catches
- Bolt carriers



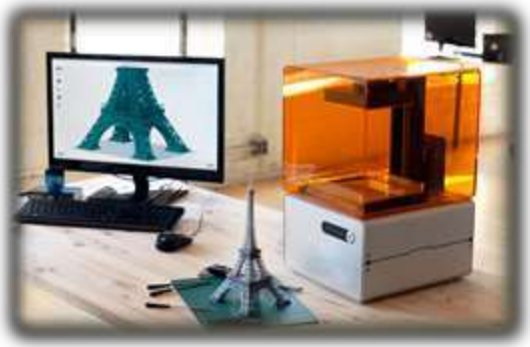
MILITARY EQUIPMENT

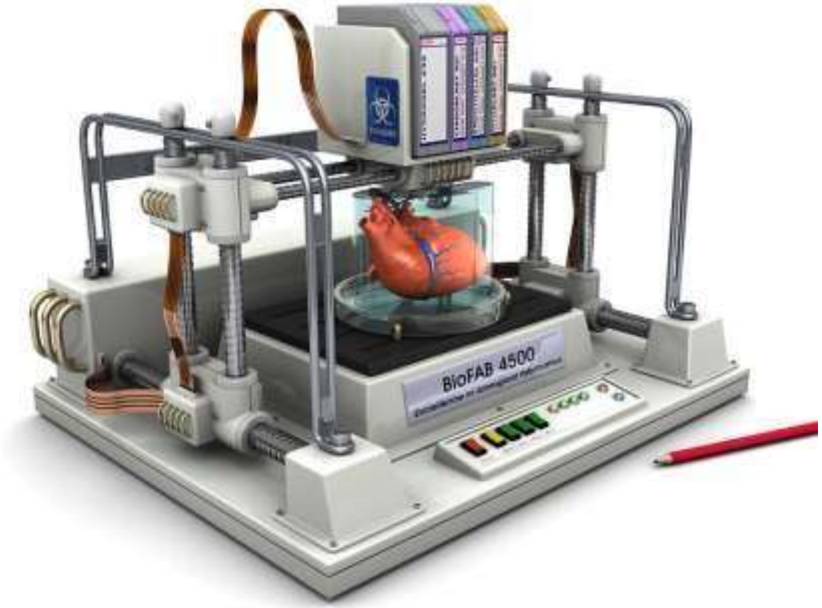
- Selector levers
- Pistol grips
- Tank Control System
- Spare parts and more..



3D PRINTING

- Paving way for **new opportunities**..
- Process of making a **three-dimensional solid object** of **virtually** any **shape** from a **digital model**





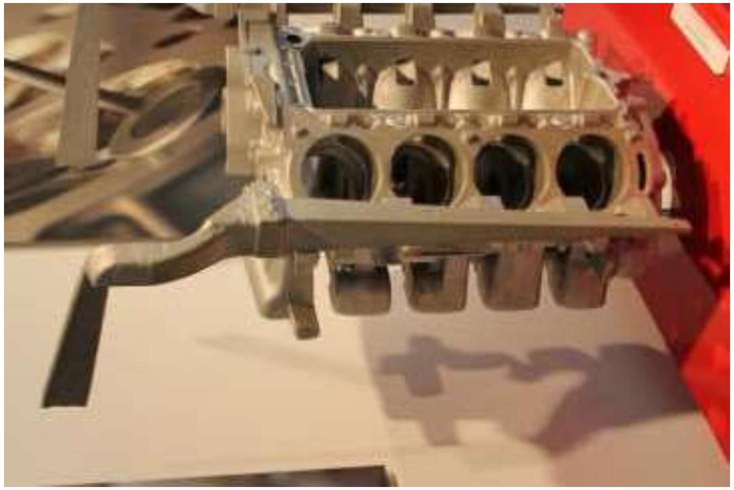
3D Printing

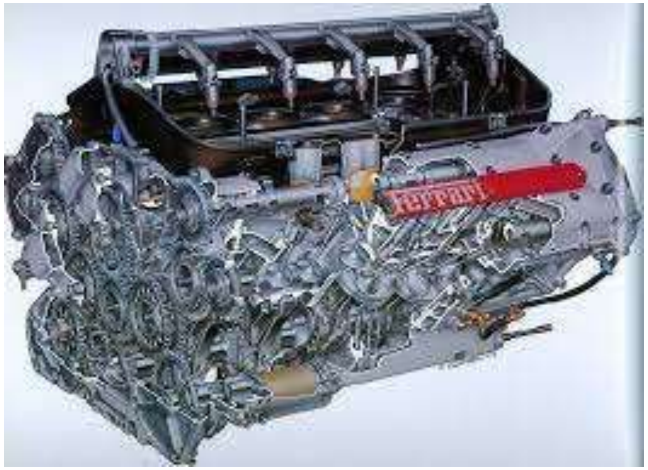
- Used for **prototyping** and distributed manufacturing, with **applications** in **architecture**, **automotive**, **military**, **fashion**, **education** and many others

AUTOMOTIVE INDUSTRY

- Automotive castings offer the **next generation** of **weight reduction**, **highly complex designs**, and **surface finishing** for major automotive manufacturers worldwide
- Pre-combustion chamber for tractors, matadors
- Gear shifter for 4 wheelers vehicles
- Water pump body
- Engines

Automotive Industry
Ferrari Engine

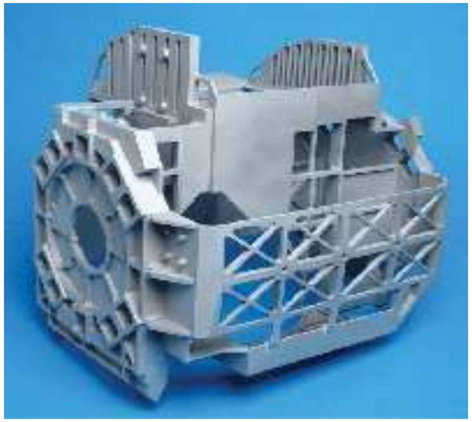




Further Applications

- Investment cast components provides **near net shape** that can solve **cost-performance challenges** for manufacturers of:
- Agricultural, industrial and other heavy equipment
- Firearms
- Marine vehicles
- Construction tools & equipment
- Household & office fixtures
- Door hardware and more…

Continue..



Permenant moulding Methods

Various types Of Permenant Moulding Process.

1)Gravity Process
2)Slush Process
3)Low Pressure process
4)Vacuum Process

What is permanent Moulding?

- Permanent mold casting is metal casting process that employs reusable molds ("permanent molds"), usually made from metal.
- The most common process uses gravity to fill the mold, however gas pressure or a vacuum are also used.
- A variation on the typical gravity casting process, called slush casting, produces hollow castings. Common casting metals are aluminum, magnesium, and copper alloys. Other materials include tin, zinc, and lead alloys and iron and steel are also cast in graphite molds.




Gravity process.

- The gravity process begins by preheating the mold to 150-200 °C (300-400 °F) to ease the flow and reduce thermal damage to the casting.
- The mold cavity is then coated with a refractory material or a mold wash, which prevents the casting from sticking to the mold and prolongs the mold life.
- Any sand or metal coresare then installed and the mold is clamped shut.
- Molten metal is then poured into the mold. Soon after solidification the mold is opened and the casting removed to reduce chances of hot tears.
- The process is then started all over again, but preheating is not required because the heat from the previous casting is adequate and the refractory coating should last several castings. Because this process is usually carried out on large production run workpieces automated equipment is used to coat the mold, pour the metal, and remove the casting.

- **The metal is poured at the lowest practical temperature in order to minimize cracks and porosity.**

- **The pouring temperature can range greatly depending on the casting material; for instance zinc alloys are poured at approximately 700 °F (371 °C), while gray iron is poured at approximately 2,500 °F (1,370 °C).**

Slush Casting

- ***Slush casting*** **is a variant of permanent molding casting to create a hollow casting or hollow cast.**

- **In the process the material is poured into the mold and allowed to cool until a shell of material forms in the mold.**

- **The remaining liquid is then poured out to leave a hollow shell. The resulting casting has good surface detail but the wall thickness can vary.**

- **The process is usually used to castornamental products, such as candlesticks, lamp bases, and statuary, from low-melting-point materials.**

- **A similar technique is used to make hollow chocolate figures for Easter and Christmas.**

- The method was developed by William Britain in 1893 for the production of lead toy soldiers.
- It uses less material than solid casting, and results in a lighter and less expensive product.
- Hollow cast figures generally have a small hole where the excess liquid was poured out.

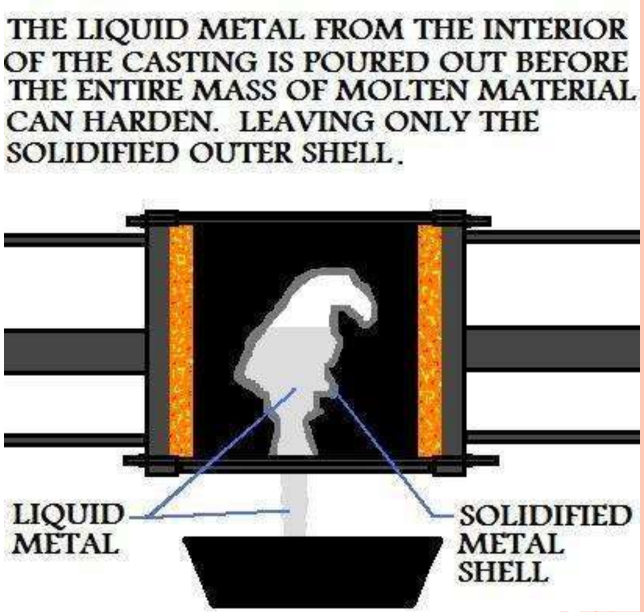


Fig. (a) Slush Casting

Low Pressure Process

- Low-pressure permanent mold (***LPPM***) casting uses a gas at low pressure, usually between 20 to 100 kpa to push the molten metal into the mold cavity.

- The pressure is applied to the top of the pool of liquid, which forces the molten metal up a refractory pouring tube and finally into the bottom of the mold.

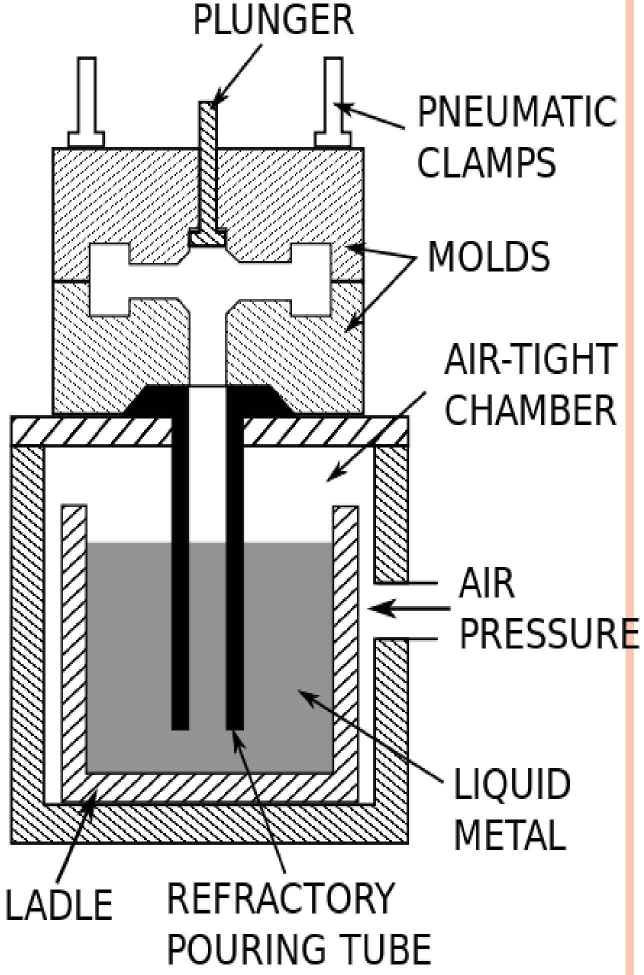
- The pouring tube extends to the bottom of the ladle so that the material being pushed into the mold is exceptionally clean.

- ✓ No risers are required because the applied pressure forces molten metal in to compensate for shrinkage.
- ✓ Yields are usually greater than 85% because there is no riser and any metal in the pouring tube just falls back into the ladle for reuse.

- ✓ **The vast majority of LPPM casting are from aluminum and magnesium, but some are copper alloys. Advantages include very little turbulence when filling the mold because of the constant pressure, which minimizes gas porosity and dross formation.**

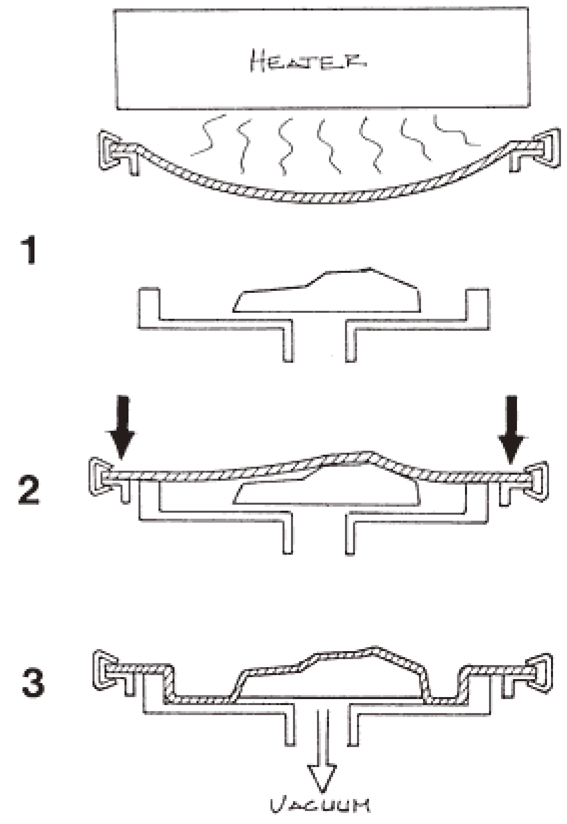
- ✓ **Mechanical properties are about 5% better than gravity permanent mold castings.**

- ✓ **The disadvantage is that cycles times are longer than gravity permanent mold castings**.



Vacuum process

- Vacuum permanent mold casting retains all of the advantages of LPPM casting, plus the dissolved gases in the molten metal are minimized and molten metal cleanliness is even better.
- The process can handle thin-walled profiles and gives an excellent surface finish.
- Mechanical properties are usually 10 to 15% better than gravity permanent mold castings. The process is limited in weight to 0.2 to 5 kg (0.44 to 11 lb).



How the vacuum Forming machine Work?

- **Vacuum forming is a good technique of creating a seamless plastic form.**

- **A mold of an object is taken and placed inside the vacuum forming machine.**

- **A sheet of plastic is then draped over the top of the mold covering all the edges and angles.**

- **Then the vacuum former is closed and the machine turned on, causing the interior to heat up to a predetermined temperature.**

- **The plastic sheeting softens until it becomes flexible. The plastic is pulled down around the mold forming a vacuum.**

- **On completion, the machine is switched off and allowed to cool. Later, the plastic unit is removed from the machine**.

ADVANTAGES

- **The main advantages are the reusable mold, good surface finish, and good dimensional accuracy.**

- **Typical tolerances are 0.4 mm for the first 25 mm (0.015 in for the first inch) and 0.02 mm for each additional centimeter (0.002 in per in); if the dimension crosses the parting line add an additional 0.25 mm (0.0098 in).**

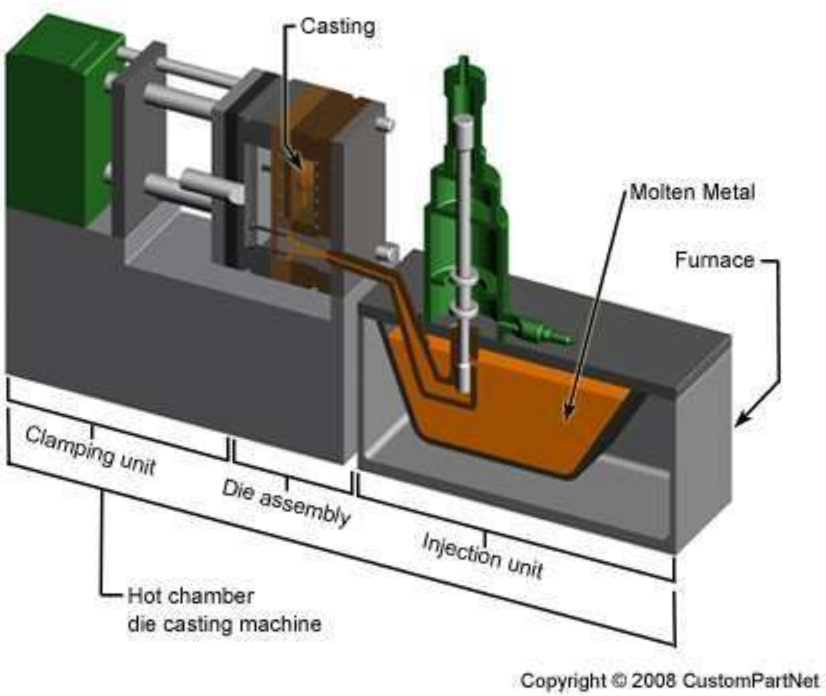
- **the ease of inducing directional solidification by changing the mold wall thickness or by heating or cooling portions of the mold.**

Disadvantages

- **There are three main disadvantages: high tooling cost, limited to low-melting-point metals, and short mold life.**
- **The high tooling costs make this process uneconomical for small production runs.**
- **When the process is used to cast steel or iron the mold life is extremely short.**
- **For lower melting point metals the mold life is longer but thermal fatigue and erosion usually limit the life to 10,000 to 120,000 cycles.**

DIE CASTING

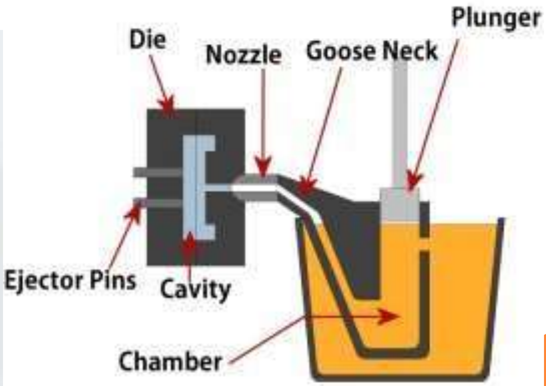
DIE CASTING : CLASSIFICATION OF DIES



- WHAT IS A **DIE**?
- A die is a **specialized tool** used in manufacturing industries **to cut or shape material** mostly using a press tool , mould & die casting. Like molds, dies are generally customized to the item they are used to create. Products made with dies range from simple paper clips to complex pieces used in advanced technology

PRESS TOOL MOULD **DIE CASTING**





DEFINETION OF DIE CASTING

- Die casting is a **metal casting process** that is characterized by **forcing molten metal under high pressure into a mold cavity.** The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process.
- Most die castings are made from non-ferrous metals, specifically

1.) zinc

2.) copper

3.) aluminium

4.) magnesium

5.) lead

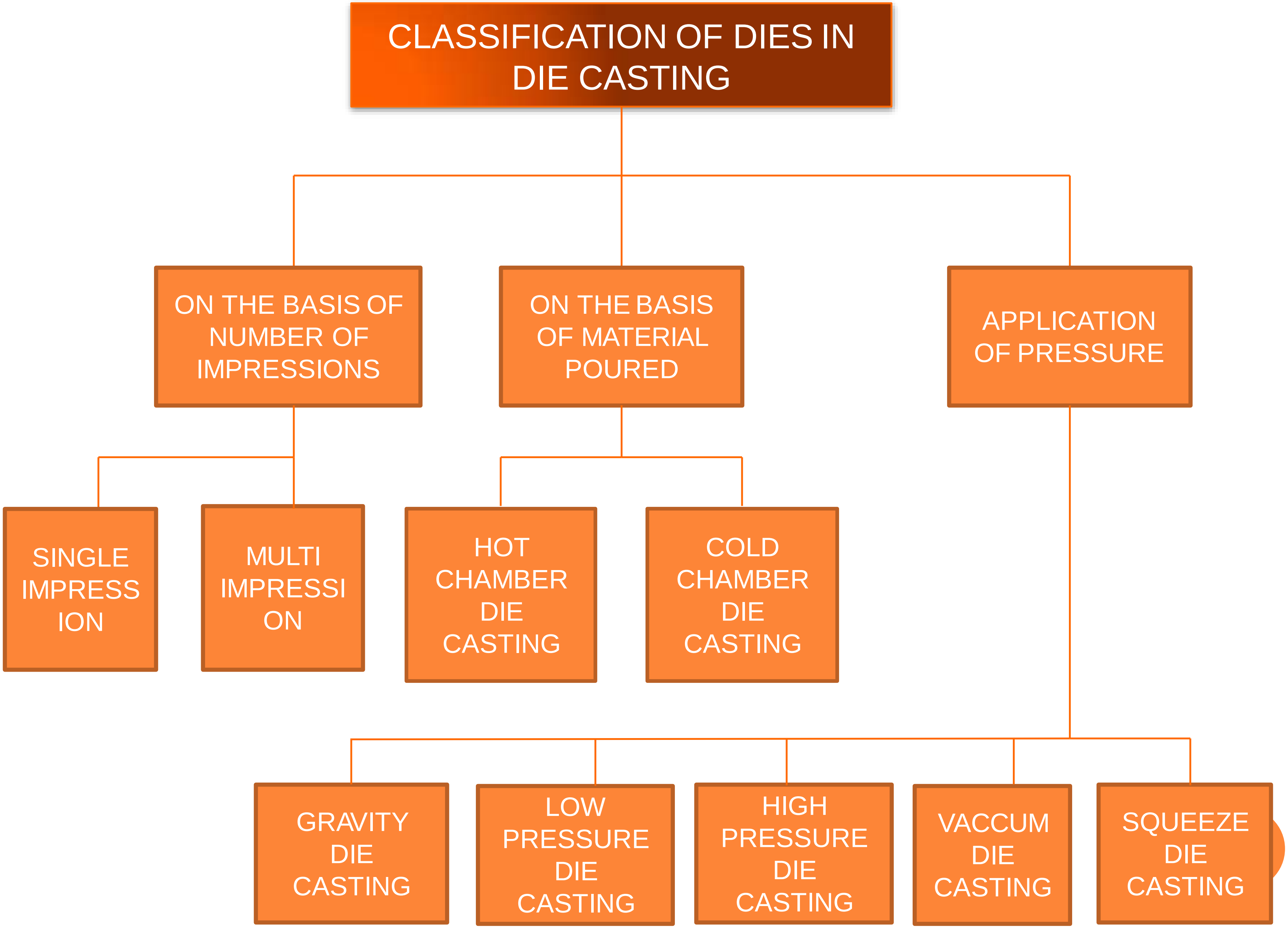
6.) pewter : 85–99% tin along with copper , antimony , bismuth.

7.) tin based alloys

- Depending on the type of metal being cast, a hot- or cold-chamber machine is used.

- Maximum weight limits for aluminium, brass, magnesium, and zinc castings are approximately 70 pounds (32 kg), 10 lb (4.5 kg), 44 lb (20 kg), and 75 lb (34 kg), respectively.[8]
- The material used defines the minimum section thickness and minimum draft required for a casting as outlined in the table below. The thickest section should be less than 13 mm (0.5 in), but can be greater.[9]

Metal	Minimum section	Minimum draft
Aluminium alloys	0.89 mm (0.035 in)	1:100 (0.6°)
Brass and bronze	1.27 mm (0.050 in)	1:80 (0.7°)
Magnesium alloys	1.27 mm (0.050 in)	1:100 (0.6°)
Zinc alloys	0.63 mm (0.025 in)	1:200 (0.3°)


CLASSIFICATION OF DIES IN DIE CASTING
ON THE BASIS OF NUMBER OF IMPRESSIONS
ON THE BASIS OF MATERIAL POURED
APPLICATION OF PRESSURE
SINGLE IMPRESSION
MULTI IMPRESSION
HOT CHAMBER DIE CASTING
COLD CHAMBER DIE CASTING
GRAVITY DIE CASTING
LOW PRESSURE DIE CASTING
HIGH PRESSURE DIE CASTING
VACCUM DIE CASTING
SQUEEZE DIE CASTING

Single cavity dies

- As the name indicates, here the No. cavities is only one. This means the die produces only one component per shot. The single are used when,
- With the available Die casting machine, only single cavity die can be accommodated, w.r.t. the locking force, shot weight and die size.
- Required production is less, which does not necessitate a multiple cavity die.
- Component may require center gating.
- Complexity of component is such that it requires side cores in many directions, which may not permit more than one cavity.

- **Advantages**
  - Die cost is low
  - Design and manufacturing is easy.
  - Die is smaller in size, which makes it possible for use of smaller capacity machine.

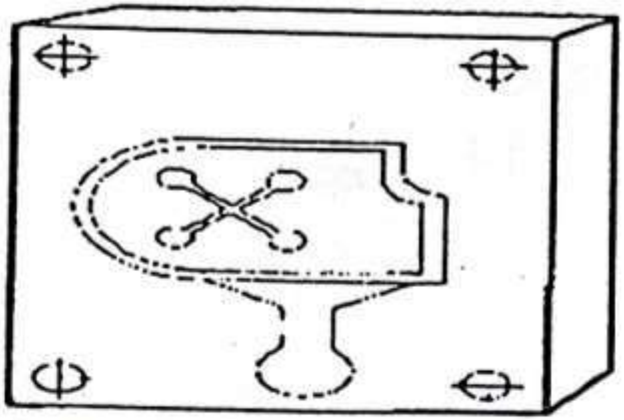
- **Disadvantages**
  - Unit cost per casting is more.
  - Production capacity is less.
  - Edged gated component in hot chamber die casting machine will cause imbalance as they are placed on one side of the injection centre line.

Multiple Cavity Dies

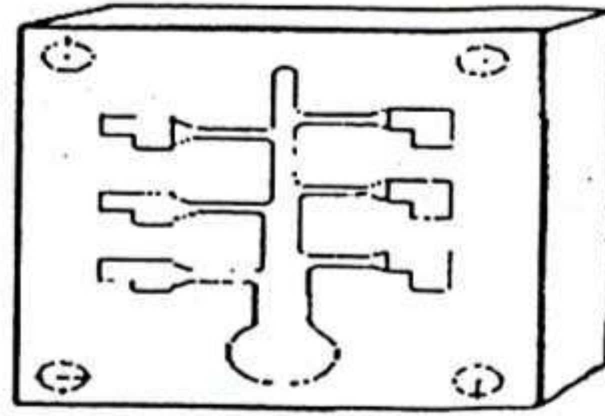
- The Multiple cavity dies have more than one or several cavities and all cavities are similar or identical, such that identical components are produced. Multiple cavities dies are used when,
  - The required production volume is large.
  - The available die casting machine can accommodate more than one cavity die
  - It becomes economically feasible to go for multiple die wrt the investments unit cost price.

- **Advantages**
  - Production rate is high.
  - Unit cost per component is less.
  - Edged gated components can also be placed symmetrically around the injection center line

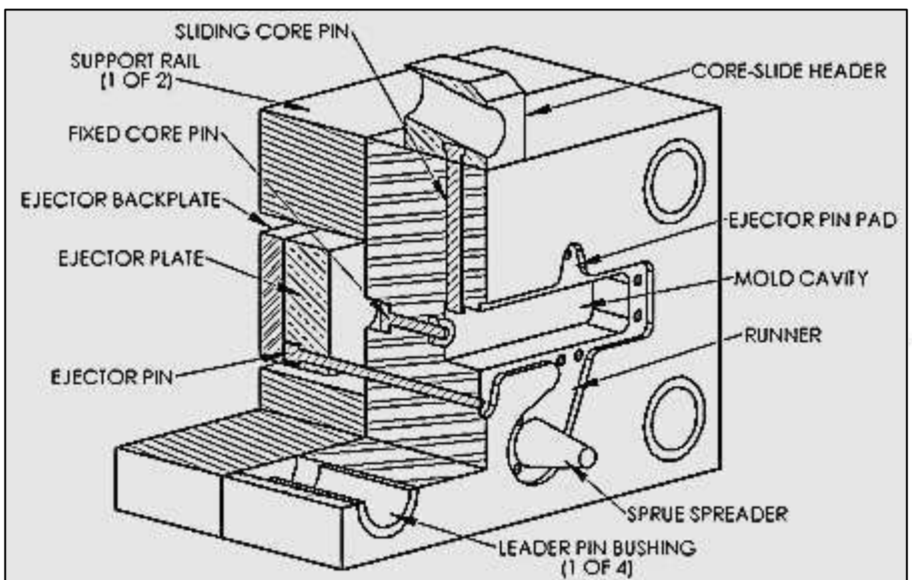
- **Disadvantages.**
  - Initial investment of the is more.
  - With increase in number of cavities, the feed balancing and thermal balancing becomes more complicated.
  - With increase in number of cavities, the design and manufacturing becomes more complex.
  - These require larger capacity machines which reduces the number shots per hour. This is because the operating speed in larger capacity machines is less compared to that of smaller capacity machines.

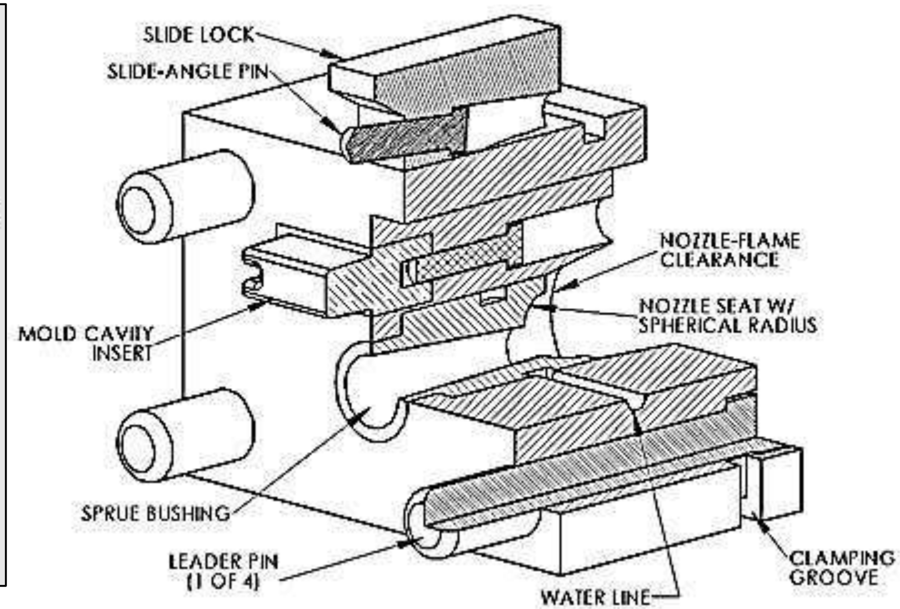


SINGLE CAVITY DIE



MULTIPLE CAVITY DIE

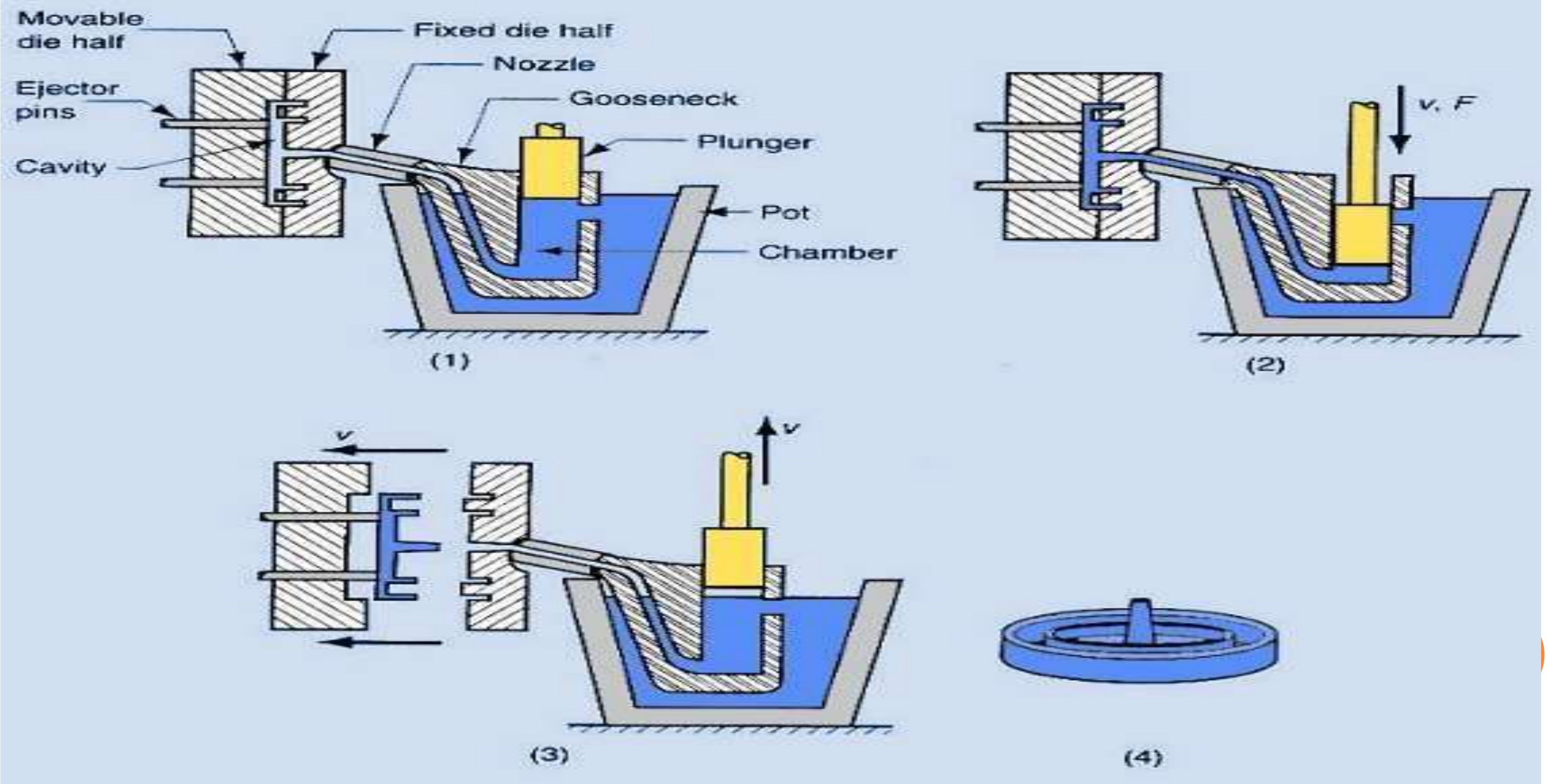




HOT CHAMBER DIE CASTING

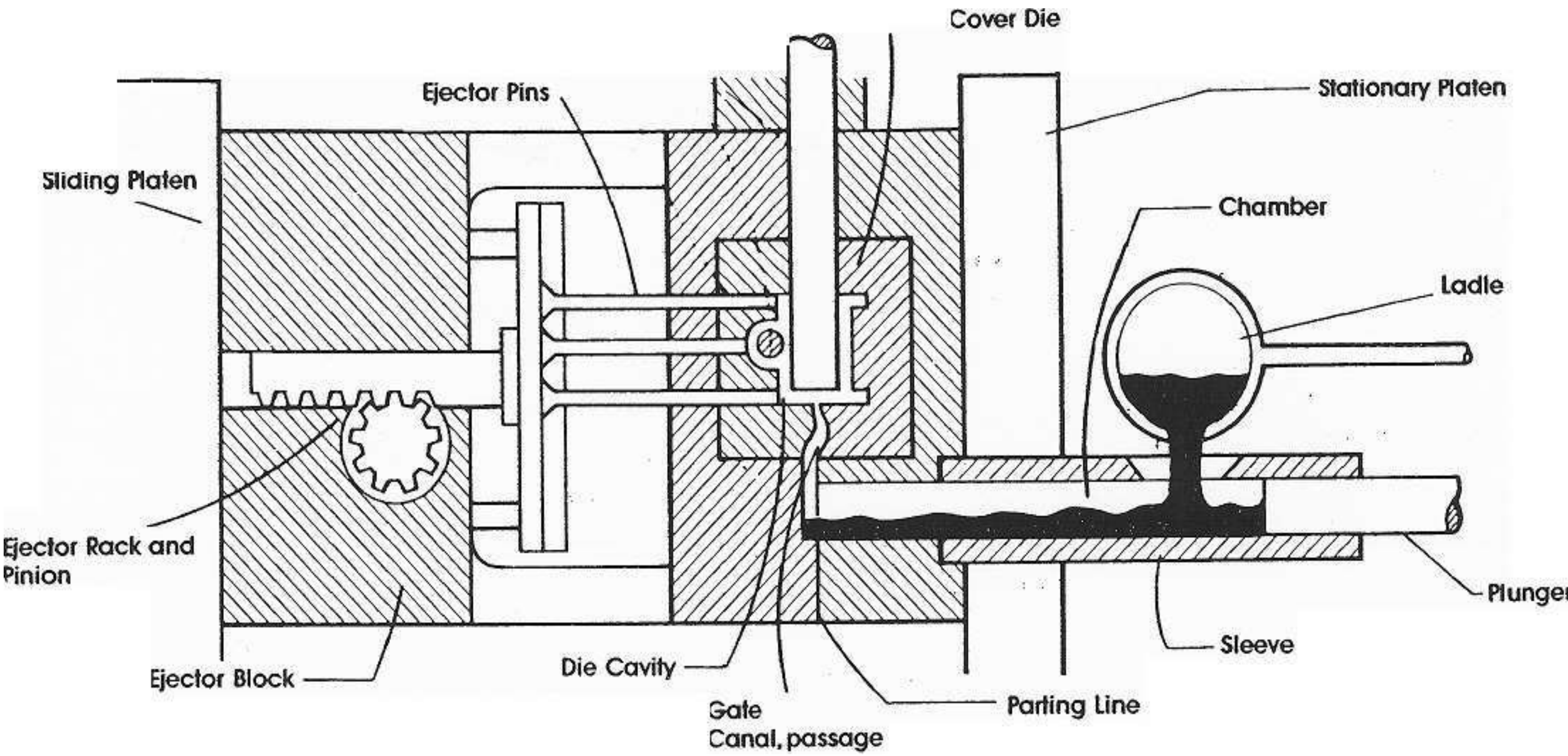
- **In hot chamber die casting manufacture, the supply of molten metal is attached to the die casting machine and is an integral part of the casting apparatus for this manufacturing operation.** The metal for casting is maintained at an appropriate temperature in a holding furnace adjacent to, if not part of, the machine. The injection mechanism is located within the holding furnace and a substantial part of it is therefore in constant contact with the molten metal. Pressure is transmitted to the metal by the injection piston, which forces it through the gooseneck and into the die. On the return stroke metal is drawn into the gooseneck for the next shot. In this process there is minimum contact between air and the metal to be injected, thus minimizing the tendency for turbulent entrainment of air in the metal during injection. Due to the prolonged contact between the metal and parts of the injection system hot chamber is restricted to zinc-base alloys. The Zinc alloys are the most widely used in the die casting process. They have very desirable physical, mechanical and casting properties. They also have the ability to be readily finished with commercial electroplated or organic coatings.

- **Some applications of Zinc Die Castings**:
- Automotive Industry
- Fuel Pumps
- Carburetor Parts
- Valve Covers
- Handles



COLD CHAMBER DIE CASTING

- The essential feature of this process is the independent holding and injection units. In the cold chamber process metal is transferred by ladle, manually or automatically, to the shot sleeve. Actuation of the injection piston forces the metal into the die. This is a single-shot operation. This procedure minimizes the contact time between the hot metal and the injector components, thus extending their operating life. However, the turbulence associated with high-speed injection is likely to entrain air in the metal, which can cause gas porosity in the castings. The cold chamber process is used for the production of aluminum and copper base alloys and has been extended to the production of steel castings. Next to zinc aluminum is the most widely used die-casting alloy. The primary advantage is it light weight and its high resistance to corrosion. Magnesium alloy die-castings are also produced and are used where a high strength–to–weight ratio is desirable.
- The mold has sections, which include the “cover” or hot side and the “movable” or ejector side. The die may also have additional moveable segments called slides or pulls, which are used to create features such as undercuts or holes which are parallel to the parting line. The machines run at required temperatures and pressures to produce a quality part to near net-shape.



- Some application for Aluminum Die Castings:
- Automotive industry
- Home Appliances
- Communication Equipment
- Sports & Leisur

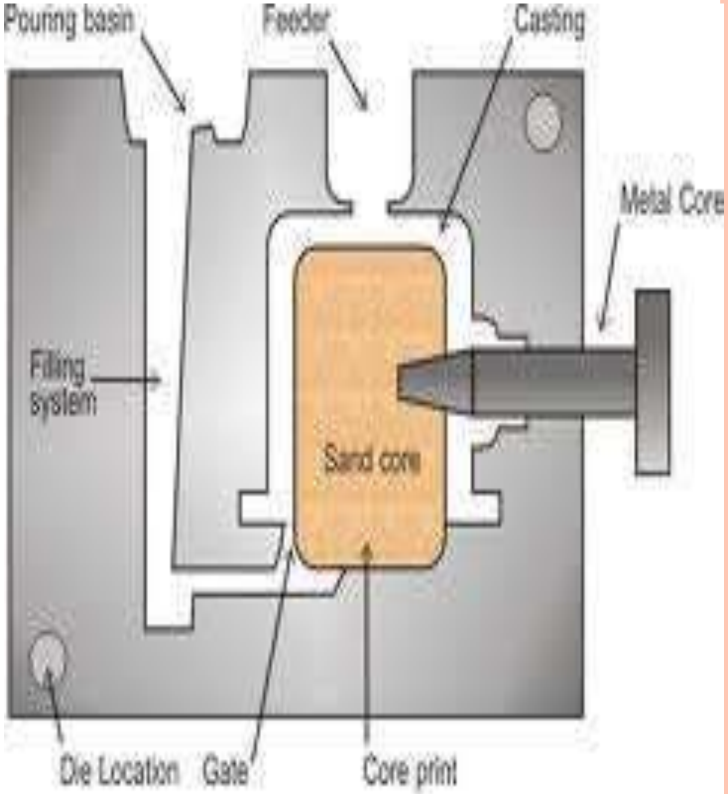
Gravity Die Casting

- Gravity die casting is a simple casting process which utilises reusable metallic moulds. The process is primarily used for simple shapes with some basic coring possible. It is mostly suited to casting light alloys but can also be used for steel and cast irons.

- The two halves of the mould are sprayed with a coating (usually silicate based) and then put together using locating pins to align the two halves and clamped. The mould is heated using gas burners prior to pouring the molten metal. The mould will typically have a runner for pouring and a riser to allow the molten metal to run through, the filling process is normally aided by spraying the mould with lubricants just prior to pouring.

- **Pros**

- Good surface texture
- Equipment costs are relatively low
- No need for applied pressure,
  so mould designs tend to be quite simple
- Scrap metal can be recycled
- Quick set up times



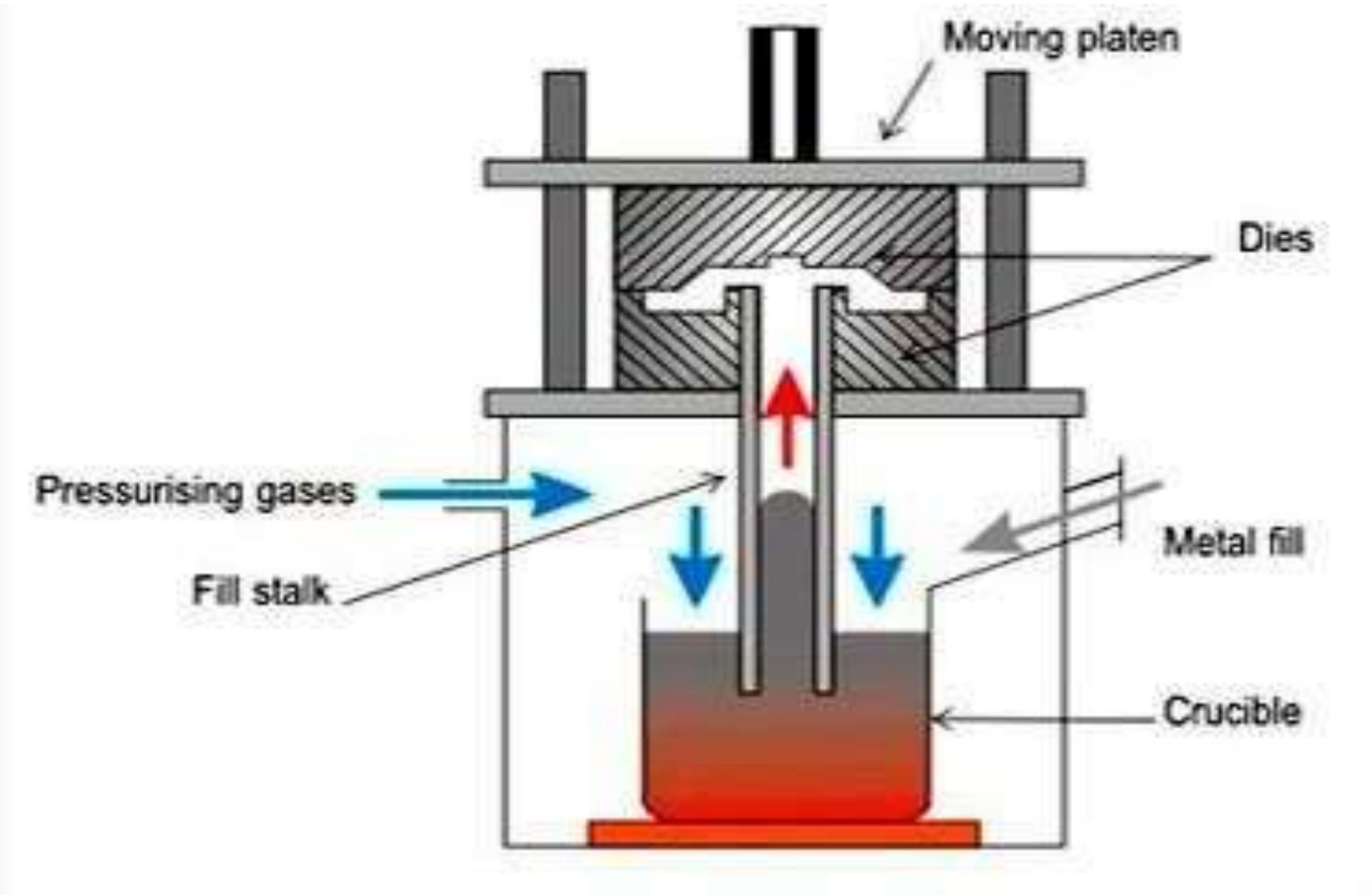
- **Cons**

- High percentage of scrap metal
- High occurrence of porosity, but this can be minimized by slower pouring
- Only good for simple 3D shapes, cannot be used for complex shapes
- There are new coatings becoming available for gravity die casting that are much longer lasting than the silicate based coatings and that prevent the need for constant retouching up and extend the useful life of the moulds.

LOW PRESSURE DIE CASTING

- The process works like this, first a metal die is positioned above a sealed furnace containing molten metal. Arefractory-lined riser extends from the bottom of the die into the molten metal. Low pressure air (15 - 100 kPa, 2- 15 psi) is then introduced into the furnace. This makes the molten metal rise up the tube and enter the die cavity with low turbulence. After the metal has solidified, the air pressure is released . This makes the metal still in the molten state in the riser tube to fall back into the furnace. After subsequent cooling, the die is opened and the casting extracted.

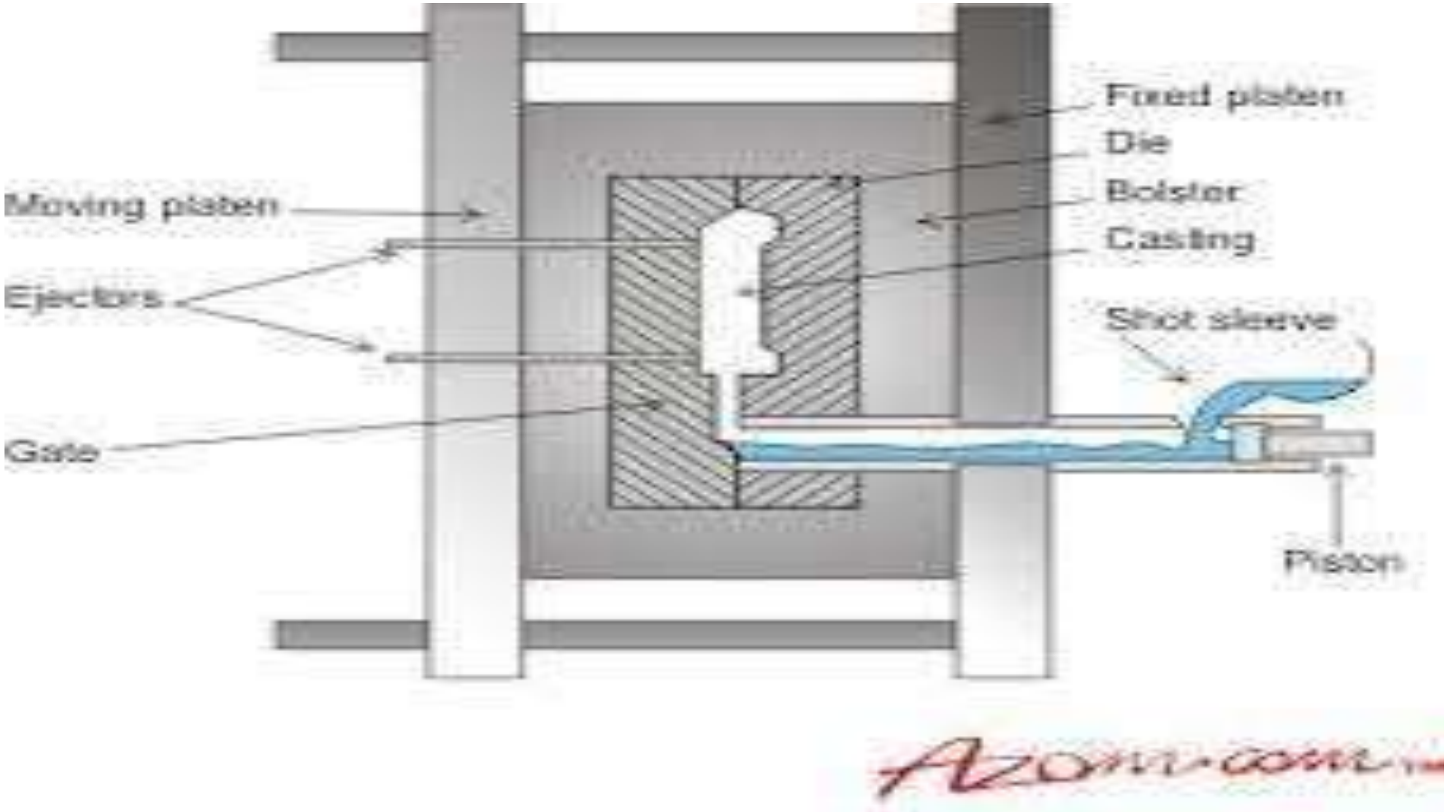
- With correct die design it is possible to eliminate the need of the riser also. This is because of the directional freezing of the casting. After the sequence has been established, the process can be controlled automatically using temperature and pressure controllers to oversee the operation of more than one diecasting machine.



- **Application of Pressure Die Casting**
- Automotive parts like wheels, blocks, cylinder heads, manifolds etc.
- Aerospace castings. Electric motor housings.
- Kitchen ware such as pressure cooker.
- Cabinets for the electronics industry.

HIGH PRESSURE DIE CASTING

- In the high pressure die casting process the metal is forced into a high grade steel tool at high speed and -pressure. The casting temperature is roughly 700°C during casting.
- This equipment consists of two vertical platens on which bolsters are located which hold the die halves. One platen is fixed and the other can move so that the die can be opened and closed. A measured amount of metal is poured into the shot sleeve and then introduced into the mould cavity using a hydraulically-driven piston. Once the metal has solidified, the die is opened and the casting removed.
- In this process, special precautions must be taken to avoid too many gas inclusions which cause blistering during subsequent heat-treatment or welding of the casting product.
- Both the machine and its dies are very expensive, and for this reason pressure die casting is economical only for high-volume production.



- High pressure die casting is a competitive casting method when components have requirements which cannot be achieved by other casting processes such as:

- high volumes and/or
- better tolerances and/or
- smooth surface finish

VACCUM DIE CASTING

- A steel die is enclosed in an airtight bell housing. The housing or receiver has two openings: the sprue, at the bottom, through which molten metal enters the die and the vacuum outlet at the top. The sprue opening is submerged below the surface of the molten metal and the vacuum is drawn within the receiver, creating a pressure differential between the die cavity and the molten metal in the crucible. This pressure differential causes the molten metal to flow up the sprue and into the die cavity, where it solidifies. The die is removed from the receiver, opened, and the casting ejected. The cycle is then repeated with each shot producing from one to several castings, depending on the number of cavities in the die.

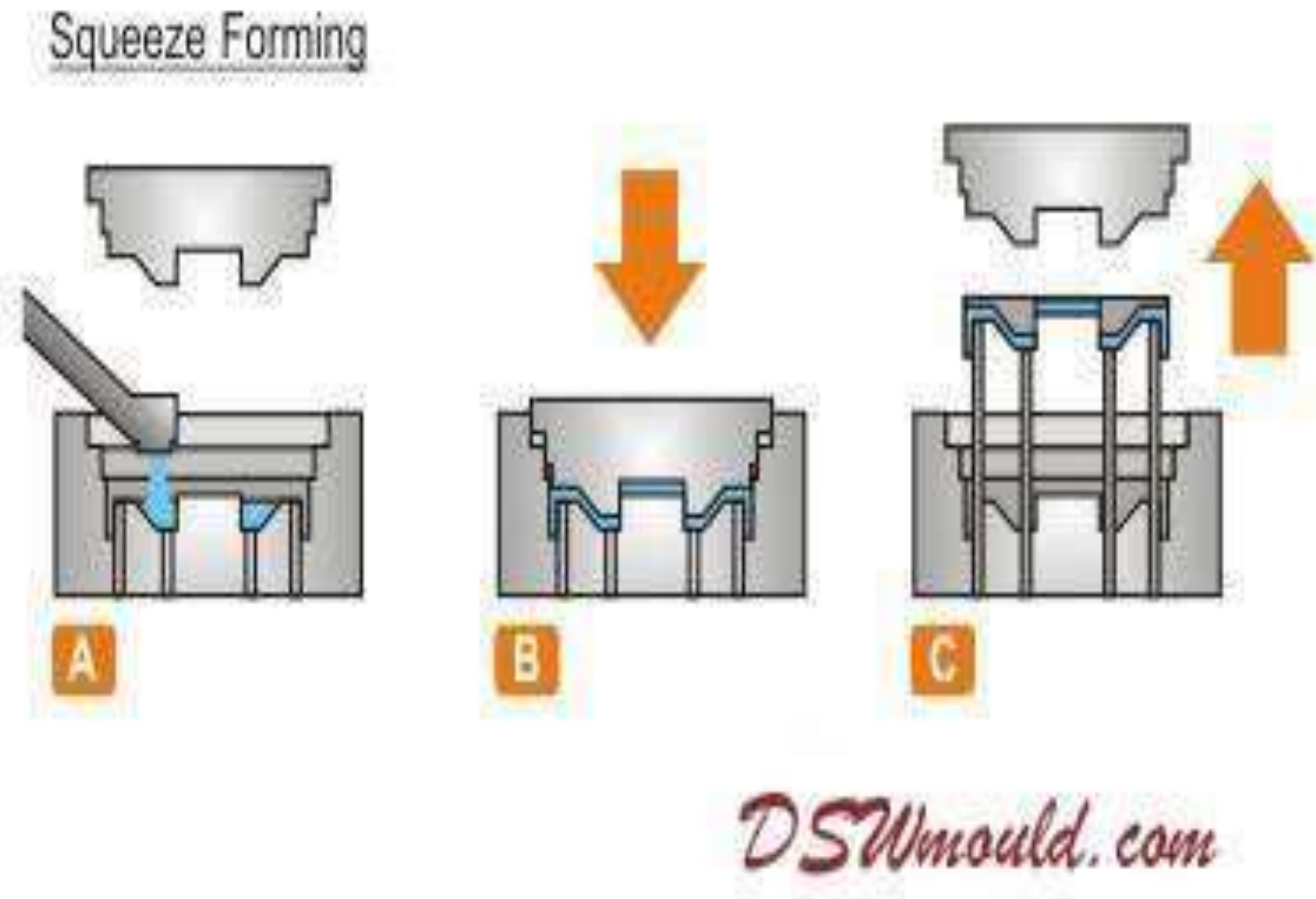
- By controlling the vacuum, the pressure differential between the die cavity and the molten metal can be varied allowing for differential fill rates necessitated by part design and gating requirements. This results in tight control of the fill rate which also directly influences the soundness of the casting. Through proper part design, die design and the use of the vacuum die process, voids, shrinks, and gas pockets can be greatly reduced or eliminated in critical areas.

- Because the sprue opening is submerged beneath the surface of the molten metal, only pure alloy, free from oxides and dross, can enter the die cavity. This helps to produce clean, sound castings with minimal foreign materials that detract from strength, appearance and machinability.

Squeeze Casting

- liquid metal is introduced into an open die, just as in a closed die forging process. The dies are then closed. During the final stages of closure, the liquid is displaced into the further parts of the die. No great fluidity requirements are demanded of the liquid, since the displacements are small. Thus forging alloys, which generally have poor fluidities which normally precludes the casting route, can be cast by this process.

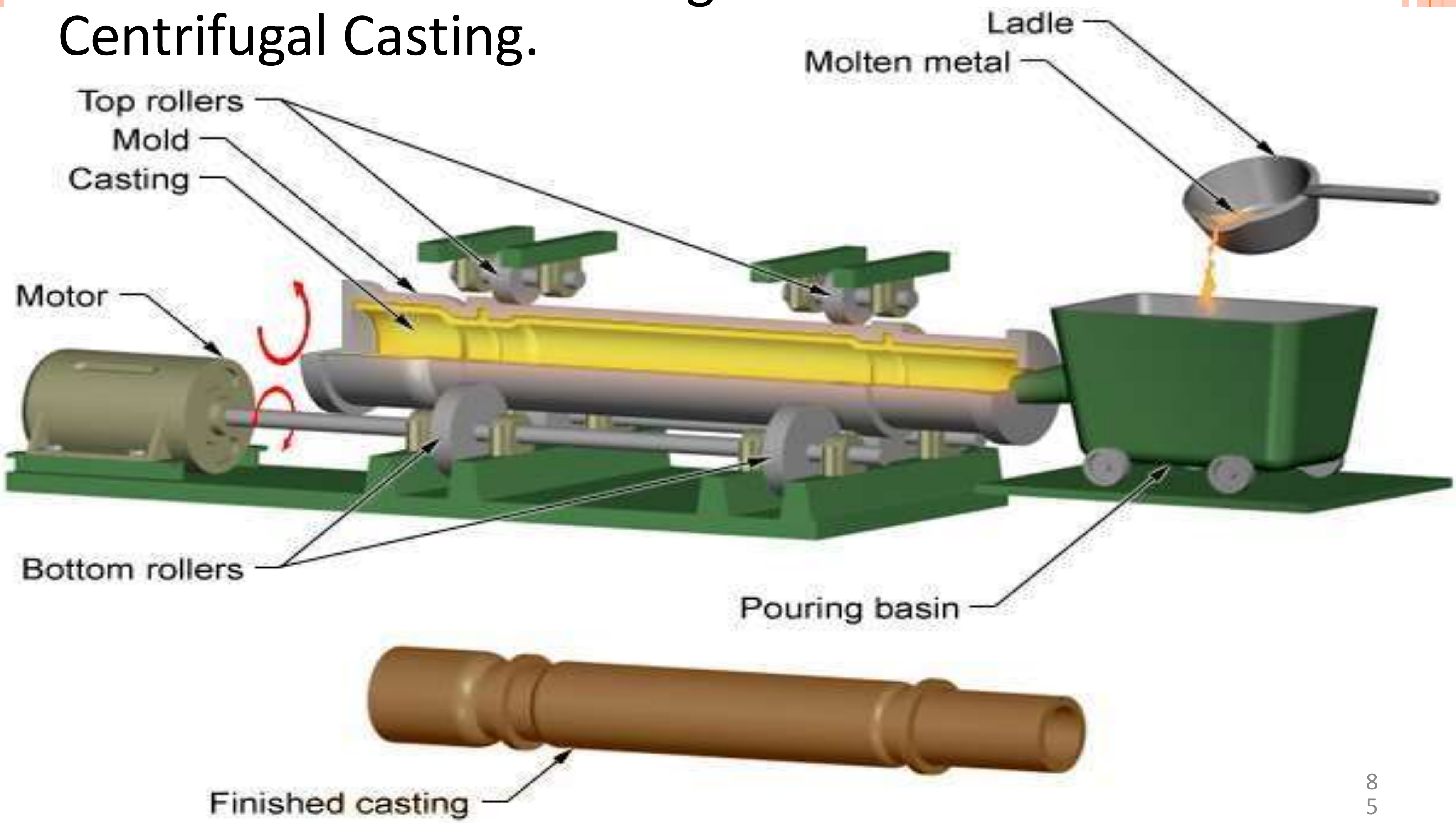
- This technique is especially suited for making fibre-reinforced castings from fibre cake preform. Squeeze casting forces liquid aluminium to infiltrate the preform. In comparison with non-reinforced aluminium alloy, aluminium alloy matrix composites manufactured by this technique can double the fatigue strength at 300°C. Hence, such reinforcements are commonly used at the edges of the piston head of a diesel engine where solicitations are particularly high.


Squeeze Forming
A
B
C
DSWmould.com

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.

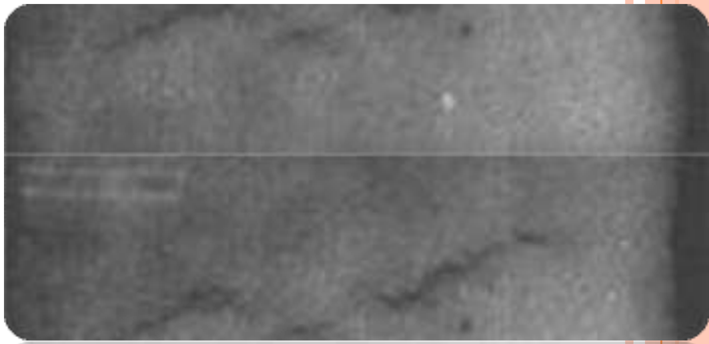
4) Better mechanical properties.

5) Production rate is high.

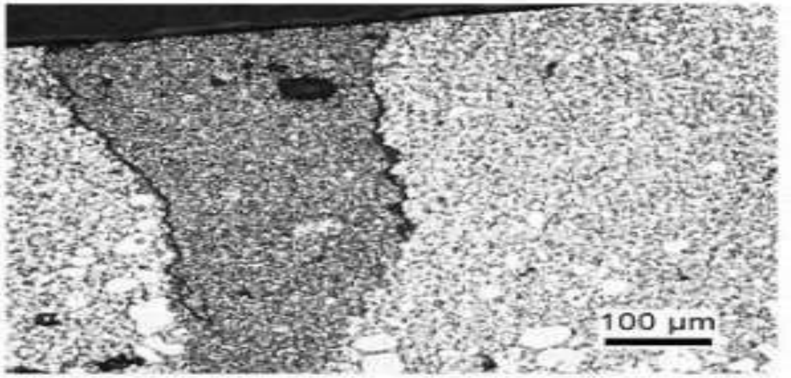
6) Centrifugal casting process can be used for fabricating functionally gradient metal matrix composite material.

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.

- **Banding** – 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.

Applications:-

- Pipes for water gas sewage.
- Bearing Bushes.
- Cylinder Liners.
- Piston rings
- Paper making rollers
- Clutch Plates.
- Pulleys.

Centrifugal Casting

True Centrifugal Casting

Application:-

C.I water supply and sewerage pipes, steel gun barrels, chemical reactor vessels, pressure vessel bodies, reactor tubes and pressure piping for nuclear power plants, paper mill rolls, textile rolls etc.

Semi Centrifugal Casting

Application:-

This process is used for making wheels, rings, rollers, sheaves, pulleys, flywheels, gear blanks, Turbo-Supercharger diaphragm disk, steel railroad wheels, nozzles and similar parts etc.

Centrifuging

Application:-

Products may be irregular or non-symmetrical : valve bodies, plugs, valve bonnets, pillow blocks and yokes etc, jewelery etc.

1.True Centrifugal Casting

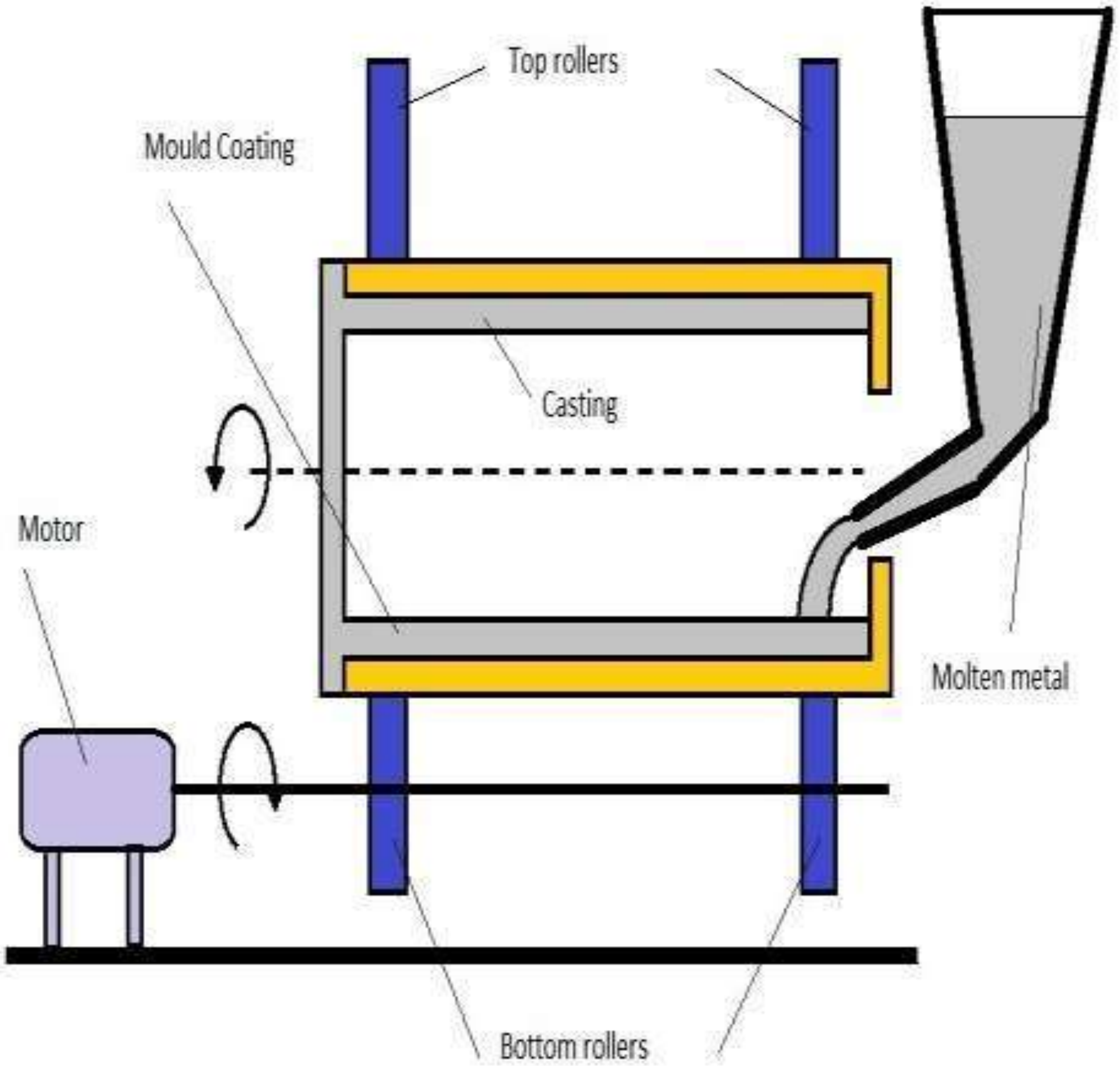
- True centrifugal castings are produced by pouring molten metal into the cavity of a rapidly rotating metal mold to whose walls the metal is thrown centrifugal force and where it solidifies in the form of a hollow casting. True centrifugal casting is the production of hollow casting by the centrifugal force alone and without the aid of a central core.
- Molten metal is poured into the spinning mold cavity and the metal is held against the wall of the mold by centrifugal force. The speed of rotation and metal pouring rate vary with the alloy and size and shape being cast.

1.True Centrifugal Casting

- The centrifugal casting machines used to spin the mould may have either a horizontal or a vertical axis of rotation and for short casting the rotational axis vertical. In the vertical axis machine the central hole will not be completely cylindrical, but will be slightly paraboloidal, which will need machining after the casting is made.

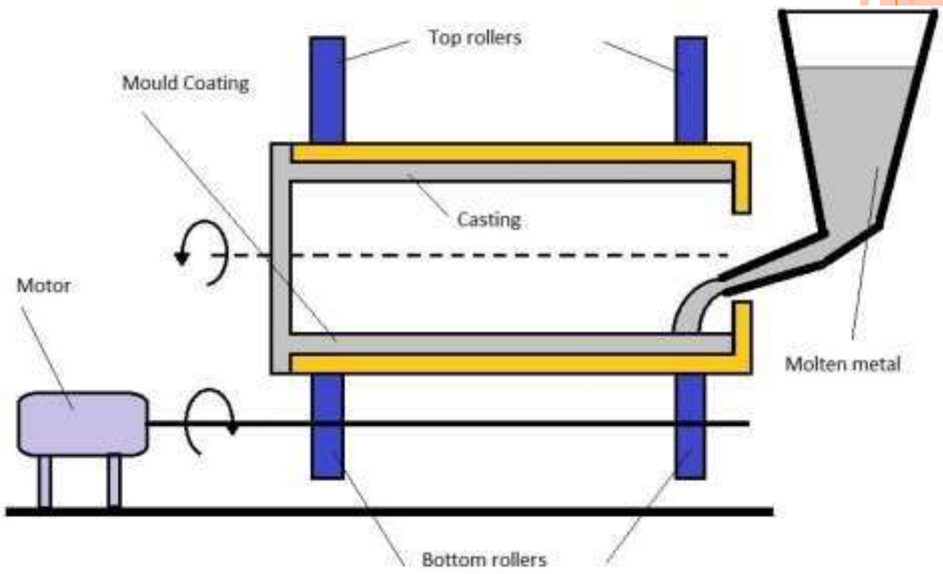
➢ There are two types of horizontal axis centrifugal casting machines which differ in the way the metal is distributed along the length of the mold during pouring :

1. In one , the pouring through (ladle or spout) travels horizontally, while the spinning mold is stationary.
2. In the other type , the ladle is stationary and the mold travels.


Top rollers
Mould Coating
Casting
Motor
Molten metal
Bottom rollers

True Centrifugal Casting

- Molds may be made of cast iron or steel, copper, graphite, ceramic, or dry sand.
- Massive, thick metal molds with a thin refractory coating allow the molten metal to begin solidification faster and for the solidification to proceed from the wall of the mold toward the inside of the cast pipe.
- Another type of horizontal centrifugal casting uses a thick, highly insulating sand interface between the mold and the casting. When the metal introduced, the insulating nature of the sand prevents directional solidification, and hence the metal solidifies from the wall and from the inside pipe face at the same time.



➢ The method of true centrifugal vertical machine which is also known as "The deLavaud Process" is explained below

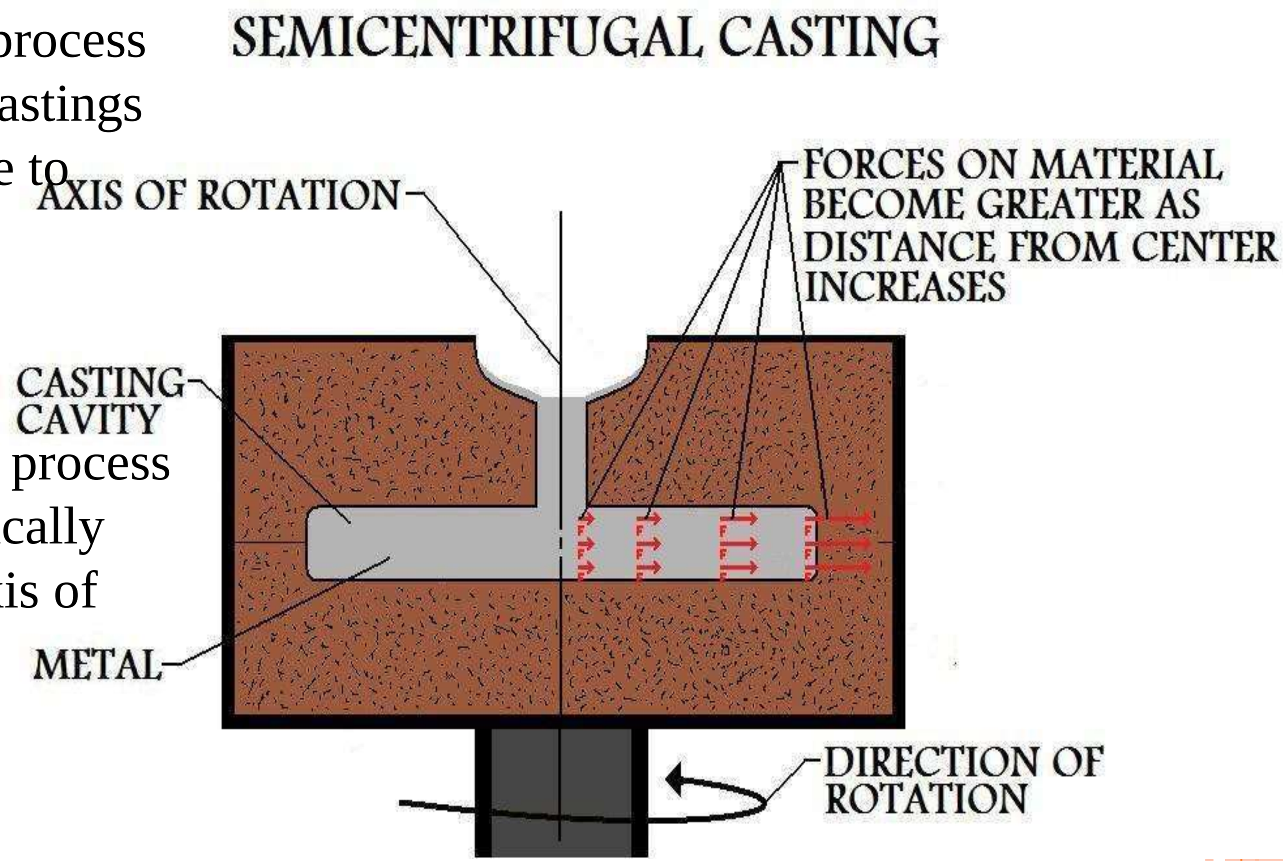
- The machine consists of an accurately machined metal mould surrounded by water. Dry heat-insulating coats are applied to the inner surface f the mould t secure thermal conditions increase its durability and produce iron castings free of chill.
- The metal mould is heated to 150-200^{0}C before pouring; the mould is cooled to by circulating water through the surrounding shell.
- The long pouring spout is inserted t the far extremity of the mould.
- As pouring proceeds, the rotating mould, that is, the machine is moved slowly on the track, leftwards.
- At the end of the process, the machine will be at the lower end of its track, with the mould spinning continuously till the pipe has solidified.
- The cast pipe is then extracted from the mould by inserting a piper puller.

- ***Advantages :-***
- Castings acquire high density and are distinguished for their fine grained structure and high mechanical strength.
- Inclusions and impurities such s oxide, slag, and gas etc, being lighter than the molten metal will segregate toward
- the centre to the inside surface f the casting, where they may be removed by subsequent machining operations.
- Gates and risers are not needed which results in saving in material and increasing the yield.
- High output.
- Formation of hollow interiors without cores.
- The casting are less subject to directional variation than static castings.

- ***Disadvantages:-***
- Contaminations of inner surface of the casting make it necessary to increase finishing allowance for subsequent machining of inner surfaces.
- An inaccurate diameter of the surface of a casting.
- Not all the alloys can be cast by this method.

2.Semi Centrifugal Casting

- Semi centrifugal casting process is used to produce solid castings and hence, requires a core to produce hollow cavities.



- Semi Centrifugal Casting process is used only for symmetrically shaped objects and the axis of rotation of the mould is always vertical.

- Gear blanks, sheaves, wheels and the pulley are the commonly produced parts by Semi Centrifugal Casting process.

WORKING PRINCIPLE OF SEMI CENTRIFUGAL CASTING:-

•In Semi Centrifugal Casting the mould is prepared in the usual manner using cope and drag box.

•The mould cavity is prepared with its central axis being vertical and concentric with the axis of rotation.

•The core is placed in position and the mould is rotated at suitable speeds, usually less than true centrifugal casting process.

•The centrifugal force produced due to the rotation of the mould causes the molten metal to fill the cavity to produce the desired shape.

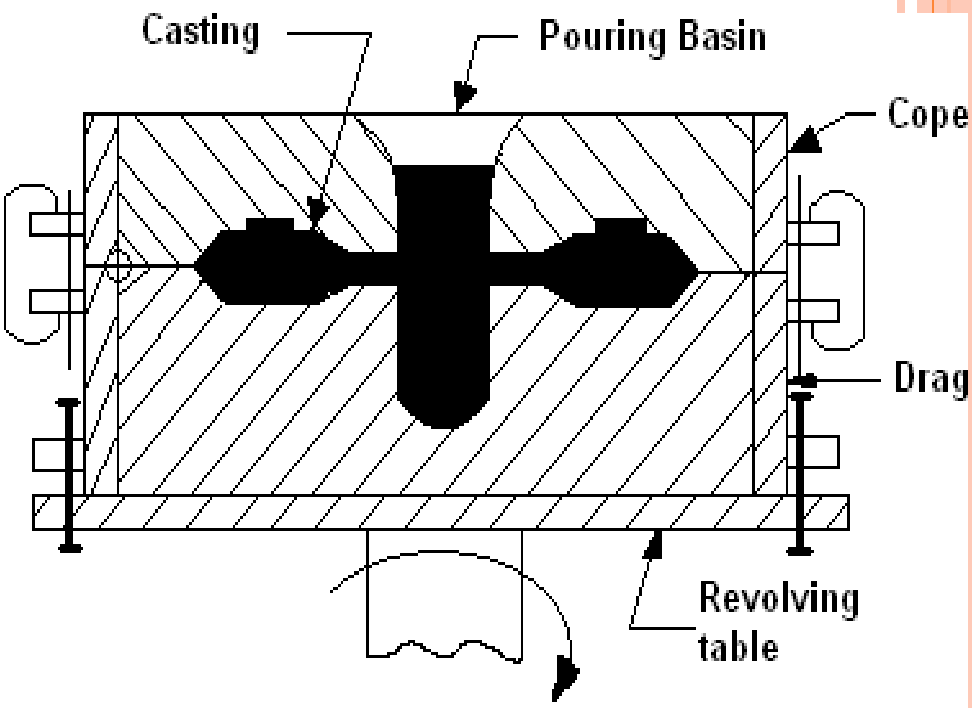


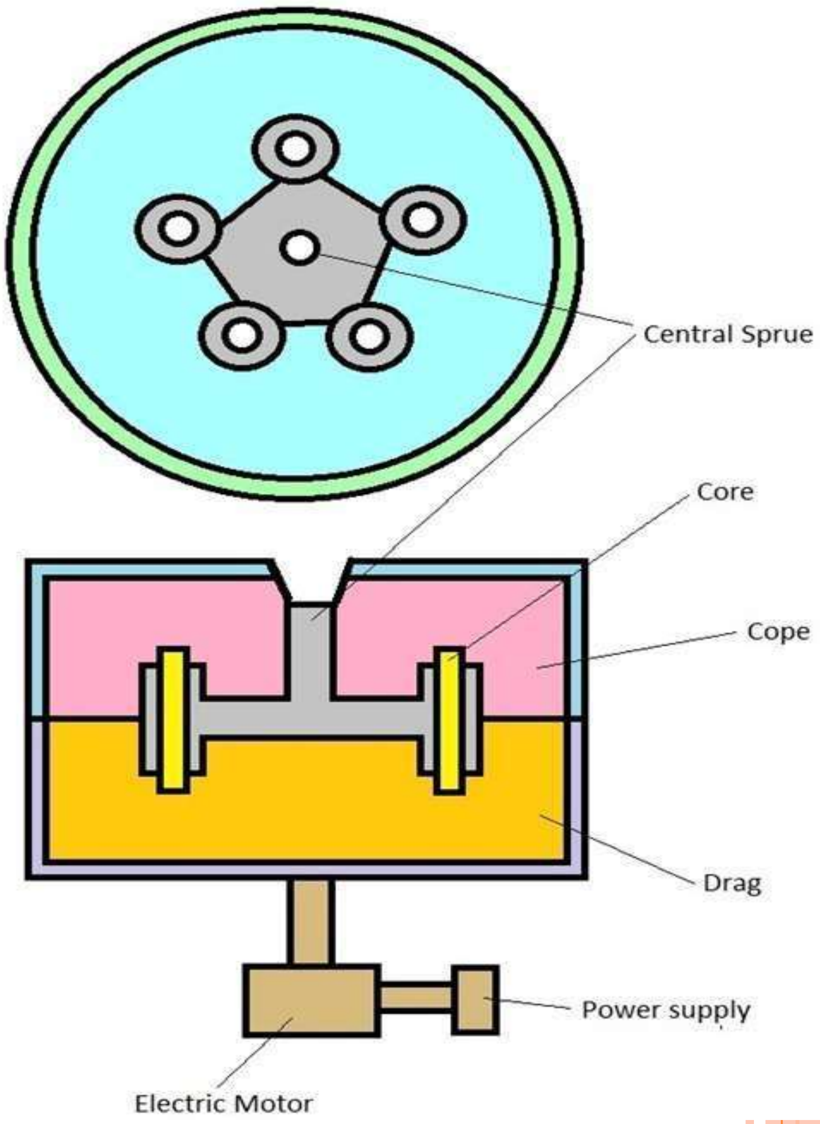
Fig: Semi Centrifugal Casting

3.Centrifuging

- When a group of small molds are arranged in a circle (to balance each other) around the central vertical axis of the flask and the flask is rotated about the vertical axis, the process is called centrifuge casting.

- It is clear that the molds are not symmetrical about the axis of rotation, that is , the axis of casting and the axis of rotation do not coincide with one another.

- Here again the centrifugal force is used to obtain higher pressure on the metal and get more dense castings. The molten metal will flow to all the molds under centrifugal force from a central feeding sprue.



SOME EXAMPLES OF CENTRIFUGAL CASTINGS





Cupola Furnace

What is Furnace???

- Heating media or device.
- Used for heating and melting.
- For providing heat to chemical reactions for processes like cracking.
- The furnace may be heated by fuel as in many furnaces coke is used as a fuel.
- some are operated by electrical energy e.g. electric arc furnace.

Cupola Furnace

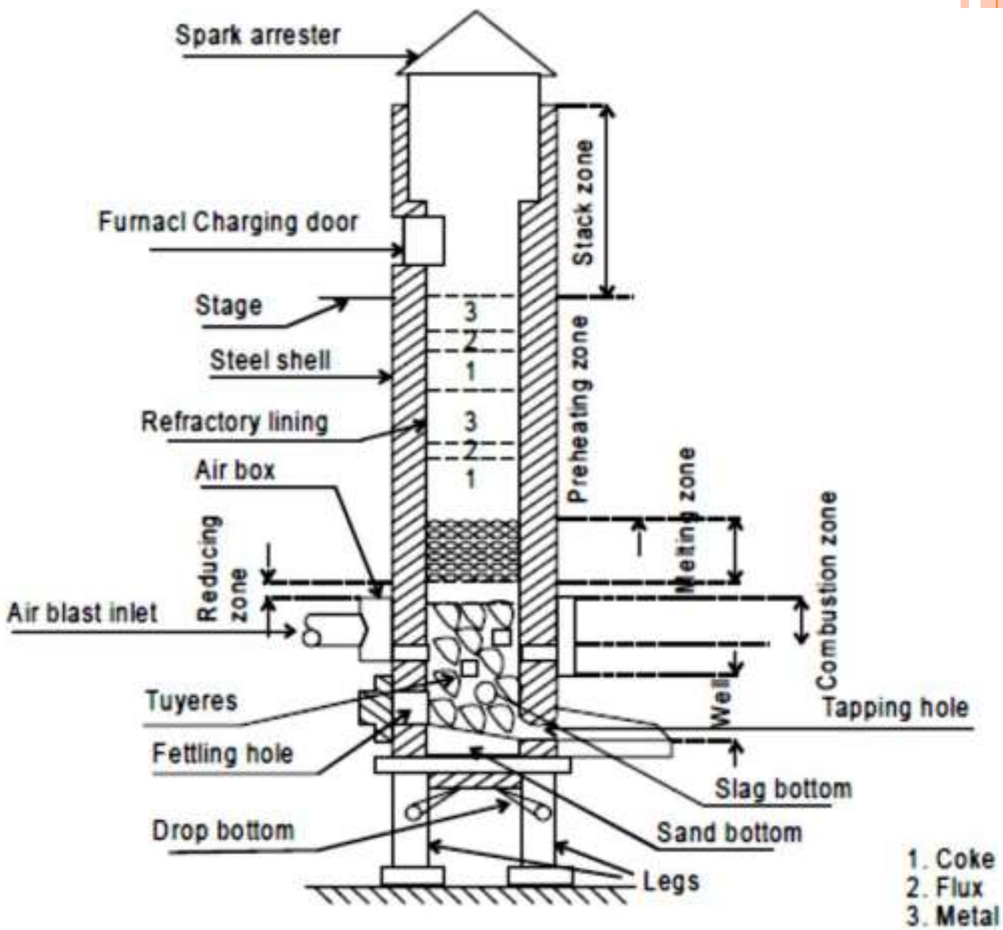
- Cupola was made by Rene-Antoine around 1720.
- Cupola is a melting device.
- Used in foundries for production of cast iron.
- Used for making bronzes.
- Its charge is Coke , Metal , Flux.
- Scrap of blast furnace is re melted in cupola.
- Large cupolas may produce up to 100 tons/hour of hot iron.

Construction

- Cupola is a cylindrical in shape and placed vertical.
- Its shell is made of steel.
- Its size is expressed in diameters and can range from 0.5 to 4.0 m.
- It supported by four legs.
- Internal walls are lined with refectory bricks.
- Its lining is temporary.

Parts of Cupola

- Spark arrester.
- Charging door.
- Air box.
- Tuyeres.
- Tap hole.
- Slag hole.



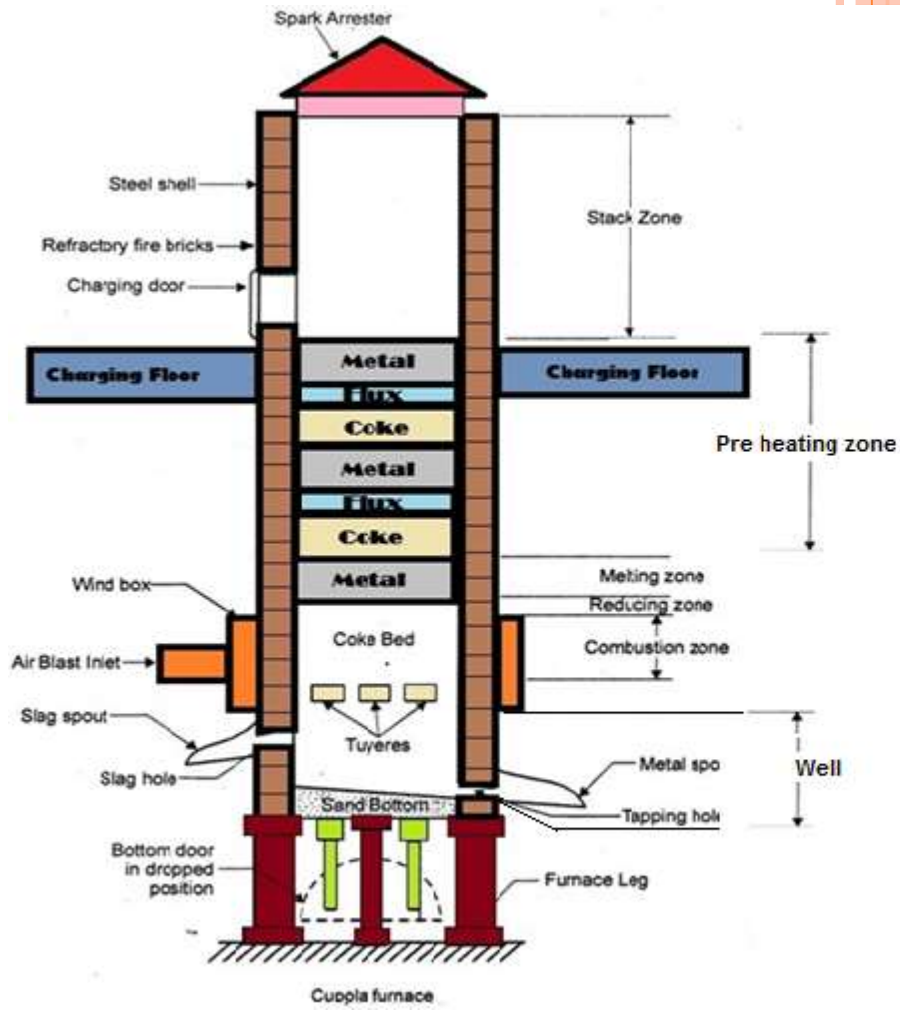
ZONES

Well

- The space between the bottom of the Tuyeres and the sand bed.
- Molten metal collected in this portion.

Combustion zone

- Also known as oxidizing zone .
- Combustion take place in this zone.
- It is located between well and melting zone.
- Height of this zone is normally 15cm to 30cm.

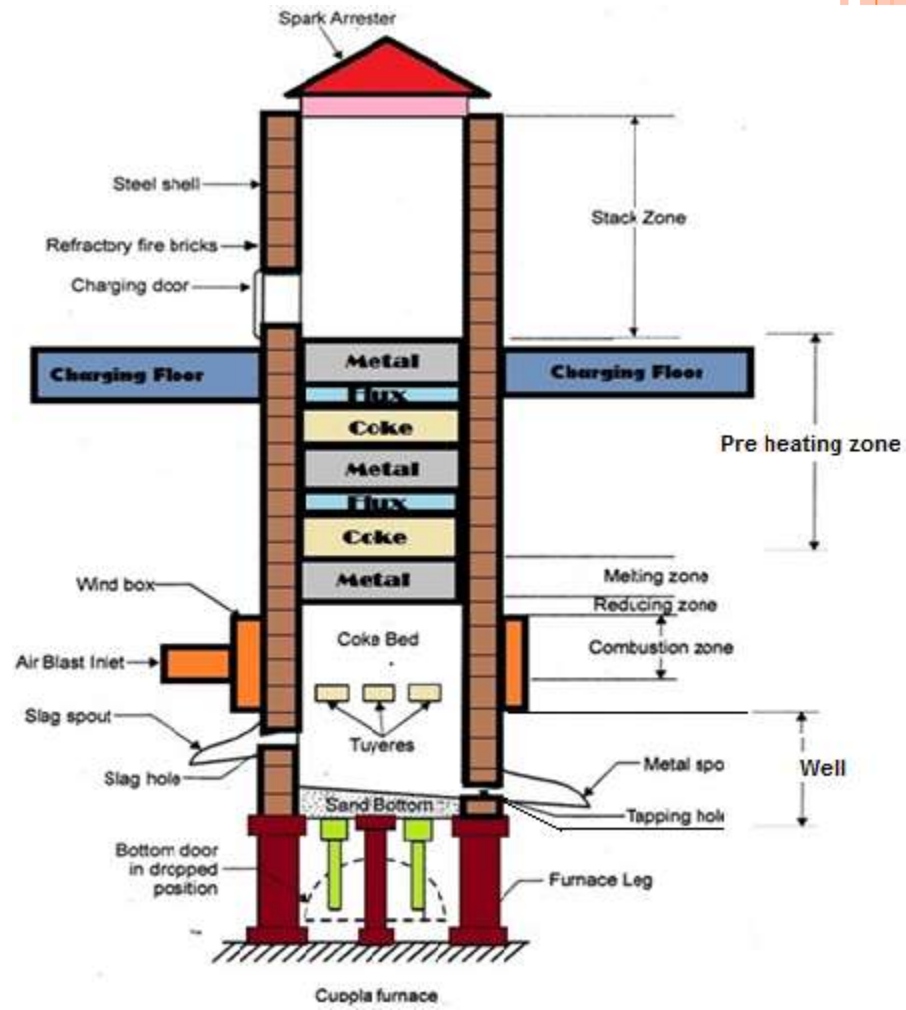


ZONES

- In this zone the temperature is 1540°C to 1870°C.
- The exothermic reactions takes place in this zone these are following .
- $C + O2 \rightarrow CO2 + Heat$
- $Si + O2 \rightarrow SiO2 + Heat$
- $2Mn + O2 \rightarrow 2MnO + Heat$

Reducing zone

- Locate between upper level of combustion zone and upper level of coke bed.



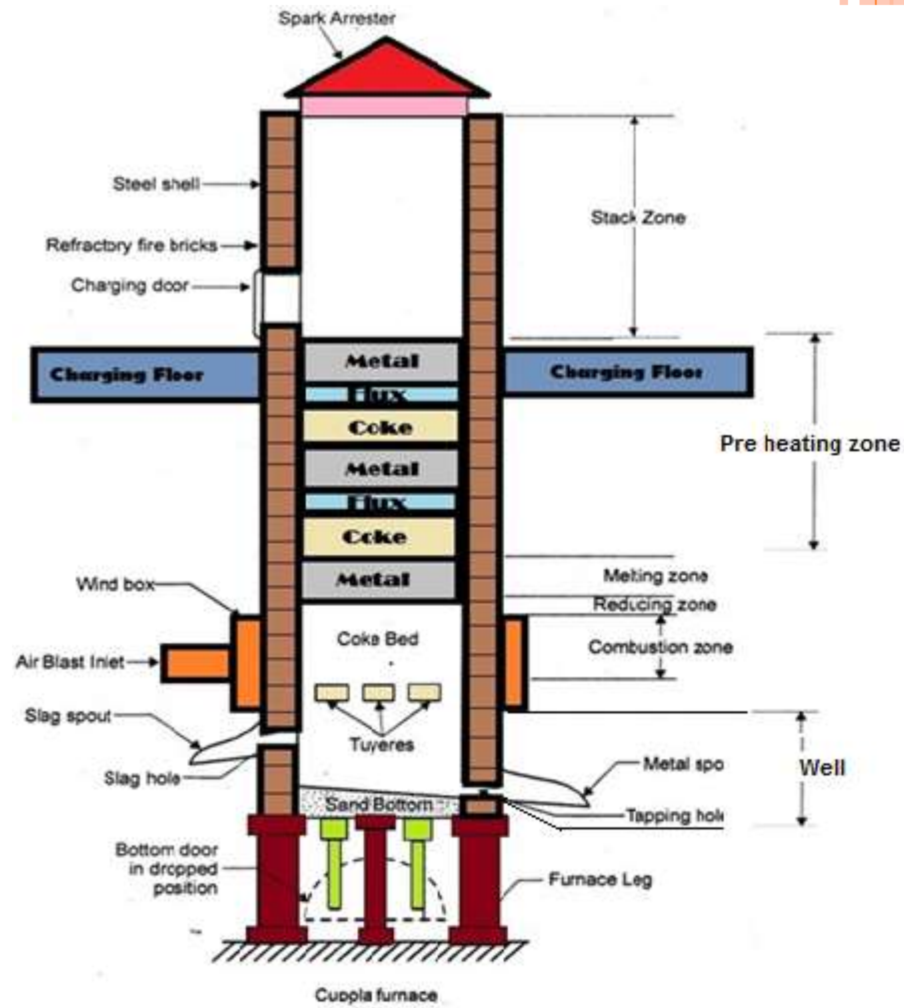
ZONES

- In this zone temperature is about 1200°C.
- In this zone CO_2 change in to CO.

  $CO_2 + C \text{ (coke)} \rightarrow 2CO$

Melting zone

- In this zone the melting is done.
- It is located between preheating zone and combustion zone.
- The following reaction take place in this zone.
- $3Fe + 2CO \rightarrow Fe_3C + CO_2$.



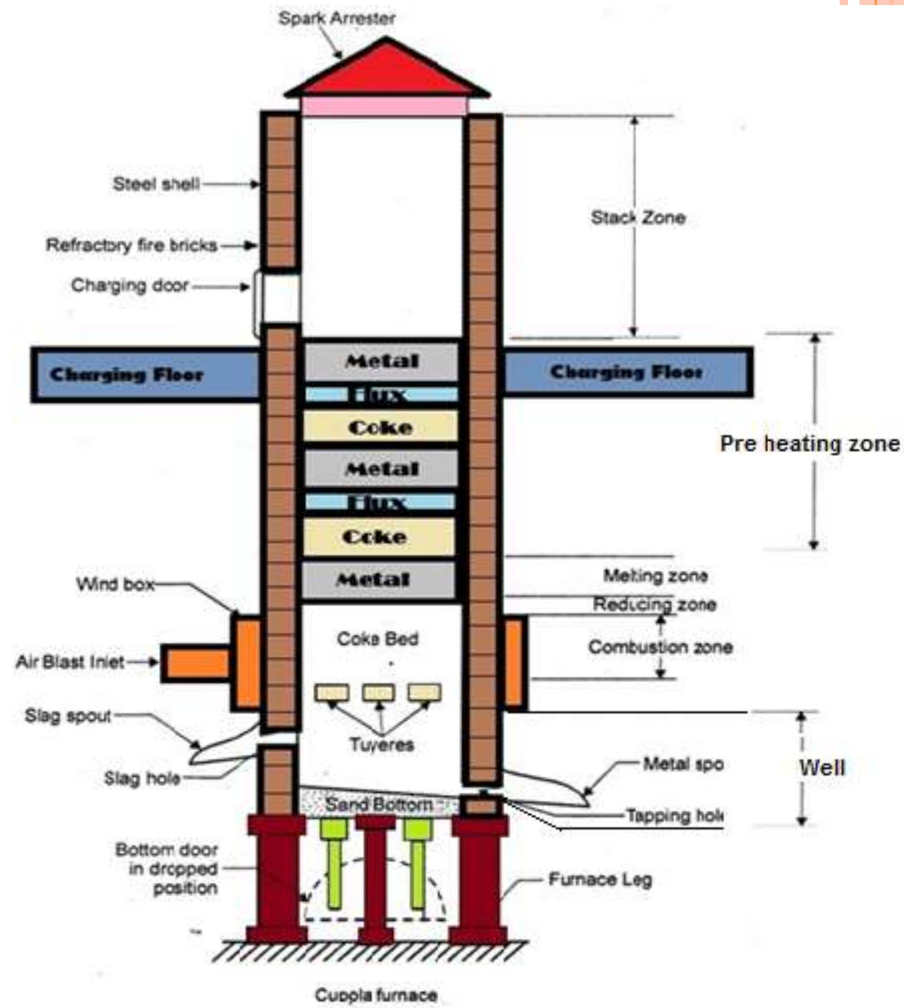
ZONES

Preheating zone

- This zone is starts from the upper end of the melting zone and continues up to the bottom level of the charging door .
- Objective of this zone is preheat the charges from room temperature to about 1090°C before entering the metal charge to the melting zone.

Stack

- The empty portion of cupola above the preheating zone is called as stack. It provides the passage to hot gases to go to atmosphere from the cupola furnace.

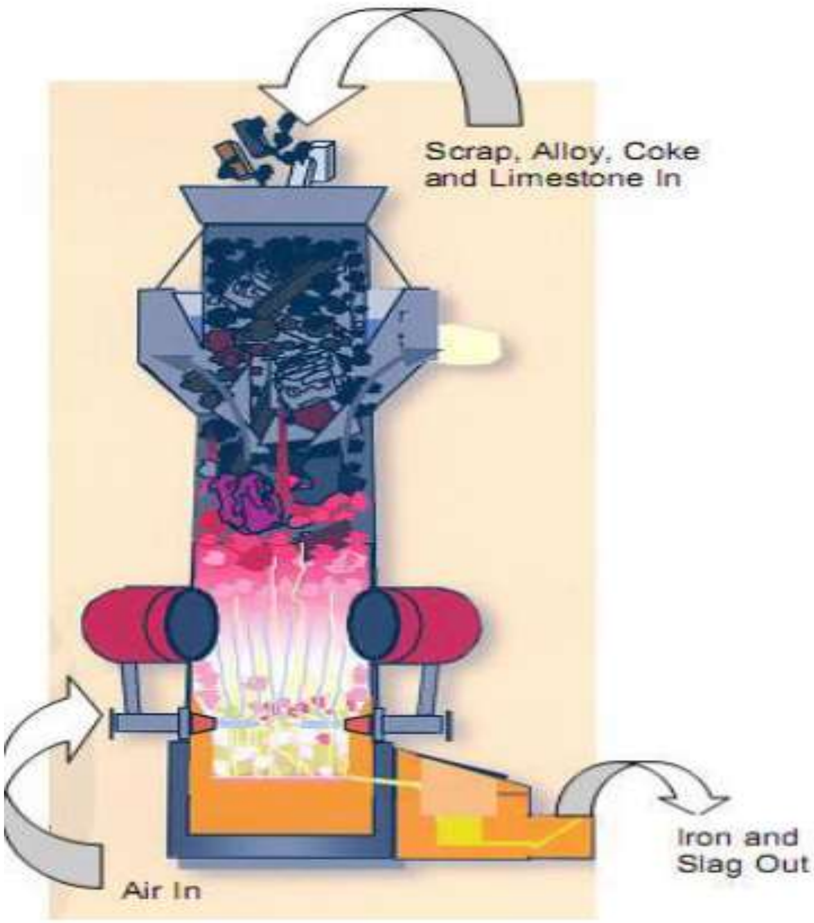


Charging of Cupola Furnace

- Before the blower is started, the furnace is uniformly pre-heated and the metal, flux and coke charges, lying in alternate layers, are sufficiently heated up.
- The cover plates are positioned suitably and the blower is started.
- The height of coke charge in the cupola in each layer varies generally from 10 to 15 cm . The requirement of flux to the metal charge depends upon the quality of the charged metal and scarp, the composition of the coke and the amount of ash content present in the coke.

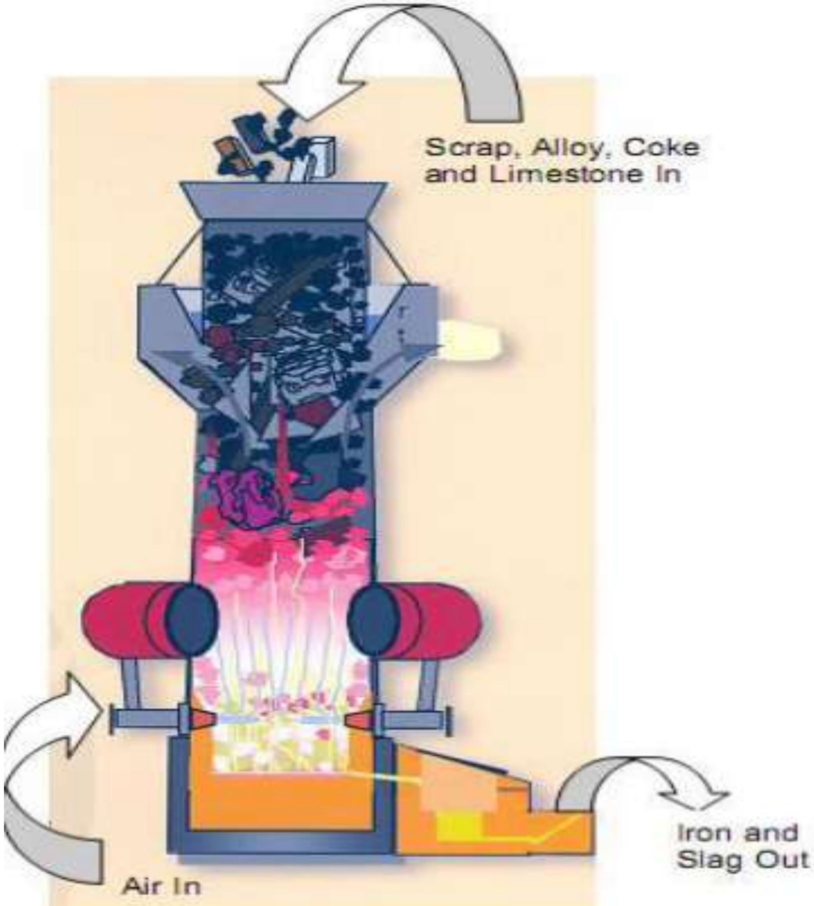
Working of Cupola Furnace

- Its charge consist of scrap, coke and flux.
- The charge is placed layer by layer.
- The first layer is coke, second is flux and third metal.
- Air enter through the bottom tuyeres.
- This increases the energy efficiency of the furnace.
- Coke is consumed.



WORKING OF CUPOLA FURNACE

- The hot exhaust gases rise up through the charge, preheating it.
- The charge is melted.
- As the material is consumed, additional charges can be added to the furnace.
- A continuous flow of iron emerges from the bottom of the furnace.
- The slag is removed from slag hole.
- The molten metal achieved by tap hole.



Operation of Cupola

- Preparation of cupola.
- Firing the cupola.
- Soaking of iron.
- Opening of air blast.
- Pouring the molten metal.
- Closing the cupola.

Preparation of cupola

- Slag and metal adhere to the cupola lining from the previous run is removed and lining of cupola is re made.
- The bottom plates are swung to closing position supported by prob.
- The sand bed is then prepared with molding sand such that its slopes to towards the tap hole.

Firing the Cupola

- The cupola is fired by kindling wood at the bottom.
- This should be done 2.5 to 3 hours before the molten metal is required.
- On the top of the kindling wood a bed of coke is built.
- The height of the coke bed is may be vary from 50cm to 125cm according to the size of cupola.

Soaking of Iron

- When the furnace is charged fully it is maintain for about 45 minutes.
- The charge is slowly heated.
- During the stage the air blast is shut off and iron is soaked.

OPENING OF BLAST AIR

- At the end of the soaking period the air blast is opened.
- The taping hole is closed by a plug when the melting proceeds and molten metal is collect at the bottom.

Pouring of molten metal

- When the sufficient amount of metal has collected in the hearth the slag hole is opened and the slag is removed.
- Then taping hole is opened and molten metal is flows out in the table.
- The same procedure is repeated until the charge is melted and the operation is over.

Closing the cupola

- When the operation is over the air blast is shut off .
- The bottom of furnace is opened by removing the prop.

Advantages

- It is simple and economical to operate .
- Cupolas can refine the metal charge, removing impurities out of the slag.
- High melt rates .
- Ease of operation .
- Adequate temperature control .
- Chemical composition control .
- Efficiency of cupola varies from 30 to 50%.
- Less floor space requirements.

Disadvantages

- Since molten iron and coke are in contact with each other, certain elements like si , Mn are lost and others like sulphur are picked up. This changes the final analysis of molten metal.
- Close temperature control is difficult to maintain

Melting of Al & Al alloys

Alumimium & its Characteristics

- Aluminium is a silvery-white , soft, nonmagnetic, ductile metal
- It is the third most abudent element in the earth's crust
- Aluminium weighs about one-third that of steel, hence it is light weight material
- It posses good electrical & high thermal conductivity
- It is resistance to corrosion
- Higher coefficient of expansion as compared to steel
- Tensile strength as high as those of structural steels
- Most common alloying elements are Cu, Cr, Ni, Fe, Zn, Mn, Si, & mg
- Aluminium & its alloys can be cast in sand moulds, shell moulds, & permanent metal moulds filled under gravity or pressure
- Its shrinkage rate is 5/32" per foot

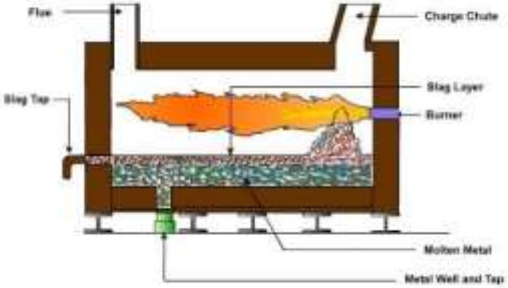
Aluminium base casting alloys

- Al-Mg(9.5-11.5%) alloy. Remaining is aluminium
- Al-Si-Mg alloy
- Al-Si-Cu alloy(4.5 to 6% Si, 1 to3% Cu, rest aluminium)
- Al-Mg-Mn alloy
- Al-Cu alloy
- Al-Cu-Ni alloy

Melting of Aluminium Alloys

- Aluminium alloys may be melted in indirect or direct fuel fired furnace or in electrically heated furnaces, such as
  - (a)Crucible Furnaces
  - (b)Reverberatory Furnaces
  - (c)Pot Furnaces
  - (d)Induction heating Furnaces
- Electric resistance furnace & Induction furnace is commonly used

Pot furnace



Reverberatory furnace

Drossing

- Drossing is the formation of aluminium oxide and other oxides which collect on the surface of molten metal
- This can be mechanically removed
- Melting with minimum dross formation occurs when

  (a) Melting is fast

  (b) metal is protected from products of combustion (in the melting furnace)

Degassing

- As the aluminium is very reactive ,it dissociates moisture(i.e H_2O) present above molten melt into active hydrogen and oxygen
  - $2Al + 3H_2O = Al_2O_3 + 6H$
- So this hydrogen penetrates into the molten melt and it dissolve in the melt
- As the metal solidifies the solubility of gaseous hydrogen falls sharply. As a result hydrogen tries to escape from the metal leaving the porosity
- This gives bad properties to the casting
- In order to minimize this effect degasing technique is carried out
- Degasing is the process of removing dissolved hydrogen in molten aluminium
- There are two methods of degasing :- Degasing by fluxes & Degassing using Rotary Degasser

Degassing

Degassing by Fluxes

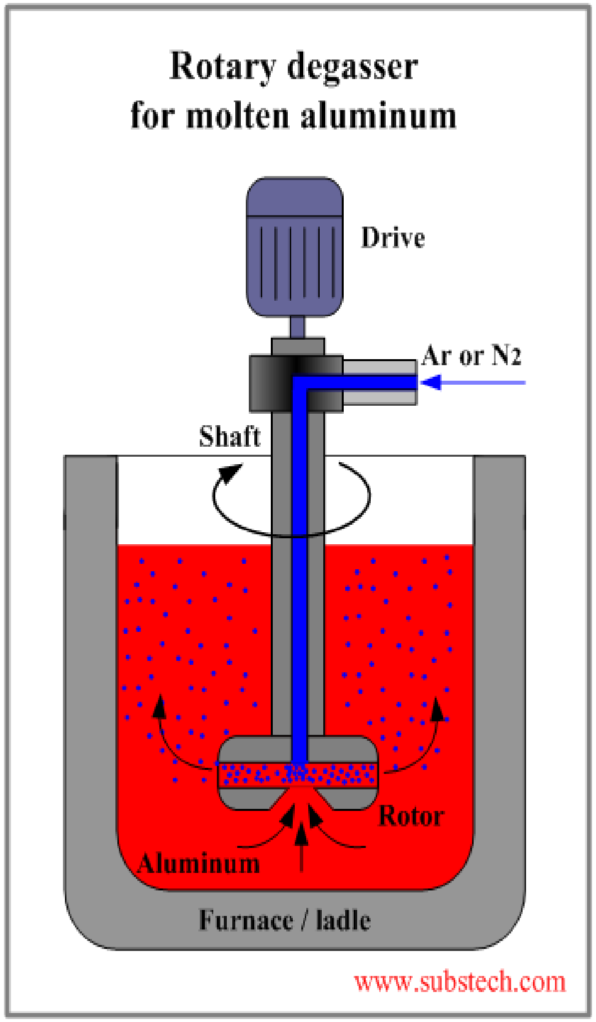
- Fluxes composed of chlorine & fluorine containing salts are added in the molten melt in the form of tablets
- This tablets goes in the bottom of the container
- The flux components react with aluminium forming gaseous compounds(aluminium chlorides, aluminium fluoride)
- Partial pressure of hydrogen in the formed bubbles is very low therefore it diffuses from molten aluminium into bubbles
- The bubbles escape from the melt and the gas is then removed by the exhausting system
- The process continues till bubbling ceases

Degassing

Rotary Degasser

- In the rotary degassing method an inert or chemically inactive gas (Argon, Nitrogen) is purged through a rotating shaft or rotor
- Energy of the rotating shaft causes formation of a large number of fine bubbles providing very high surface area to volume ratio
- Large surface area promotes fast and effective diffusion of hydrogen into the gas bubbles resulting in equalizing activity of hydrogen in liquid and gaseous phase
- The process continues till bubbling ceases
- This process is more effective compared to degassing by flux

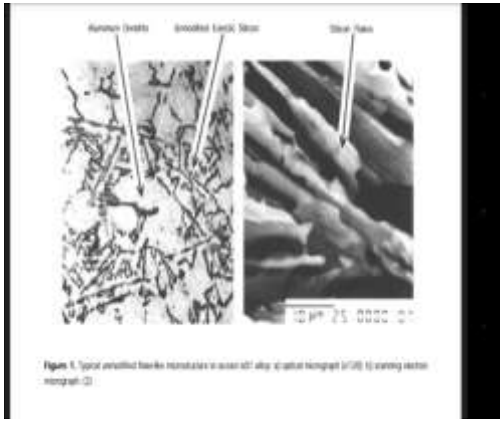
Degassing



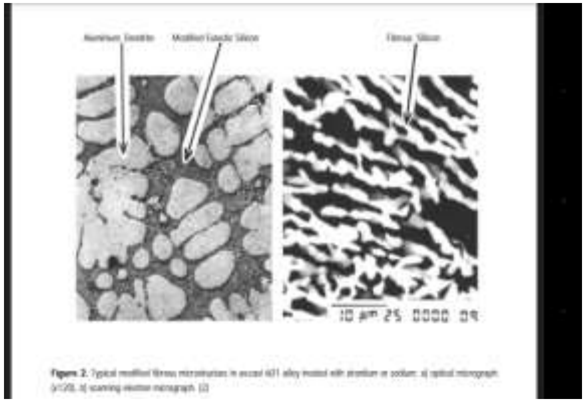
Rotary degasser
for molten aluminum
Drive
Ar or N2
Shaft
Rotor
Aluminum
Furnace / ladle
www.substech.com

MODIFICATION

- The term “Modification” of alloys describes the change in the morphology of metals
- It is generally carried out for Al-Si alloy(13% Si)
- In Al-Si alloy it changes the morphology of the eutectic Si from a coarse flake like structure to a fibrous or fine flake structures



Before Modification

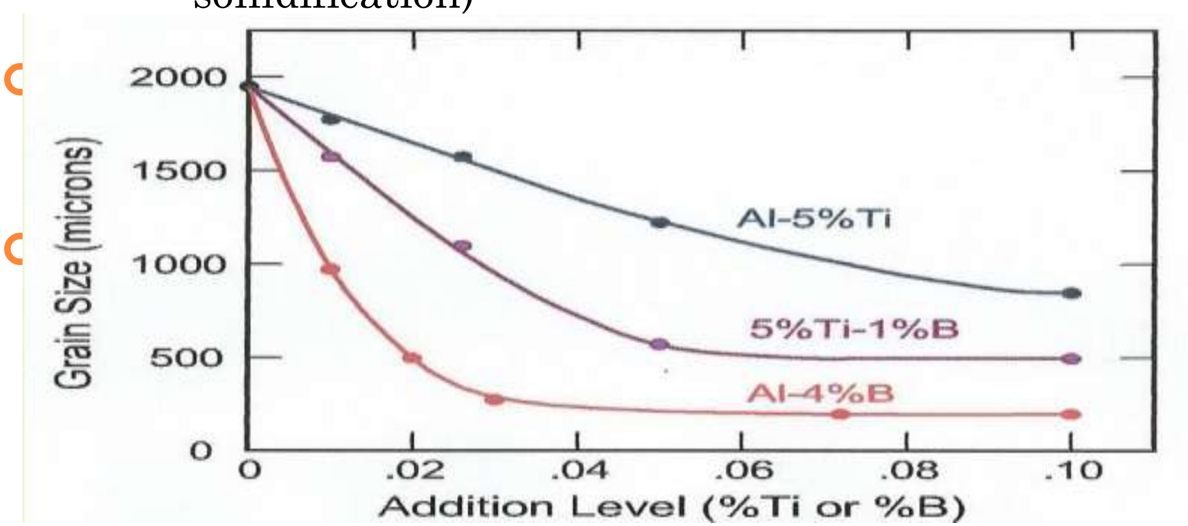


After Modification

- Sodium as modifier can change the needle structure into eleptical structure, hence reducing the stress in material & also provides ductility to the material
- This is shown in figure as before

Grain Refinement

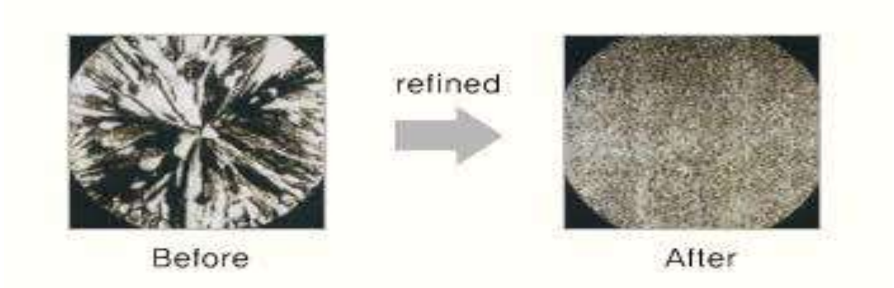
- Grain refinement is the process used for grain boundary strengthening of casting material
- There are three methods of grain refinement
    - Thermal method that is control on cooling rate
    - By adding some grain refiners that is chemical method
    - Mechanical method (by agitating of melt during soliidification)
- n,
- ct



Grain Refinement

<u>Benefits of Grain refinement</u>

- Better distribution of porosity
- Improved fluidity
- Improved surface finish & machinability
- Better mechanical properties
- High strength



Processes for casting Aluminium alloys

- The processes for casting aluminium alloys are:-
  - Sand Casting
  - Permanent mold casting
  - Die casting
  - Investment casting
  - Low pressure die casting
  - High pressure die casting

- As aluminium metal is the metal with high turbulence so for that unpressurized gating systems are used

Melting of Cu & Cu alloys

- **Furnace:**
- Coke or gas fired pit f/c, coke, gas, oil fired tilting furnace. Reverberatory f/c, Direct flame, electric arc & induction f/c.
- **Melting procedure:**
- Charge consists of: virgin metals, clean foundry scrap(gates, sprue, etc.)
- Charge is melted in graphite crucible as rapidly as possible under thick layer of charcoal.
- Alloying addition of Zn, tin, Lead, etc. are added as hardeners.
- Then heat at 60°C above the pouring temperature.
- Pour in mould as required pouring temperature.

- **Difficulties in melting:**

a) Drossing

b) Gas absorption

c) a)Drossing. : Copper base alloys have the tendency.

- Oxides of alloying elements(Zn,Sn,Al,Mg&Mn)form dross on the metal surface.
- Dross separation easy because of it low sp.gr.
- Charcoal cover serves as insulator,protecter and minimises Zn loss.

b)Gas absorption:

- Oxygen is not soluble in Cu base alloys to a great extent.
- Readily combines with copper to form Cu_2O(miscible in Cu melt)
- Solidification forms a eutectic with Cu containing 0.39% oxygen.No O_2 is evolved on solidification.
- Presence of H_2 +Cu_2O gives much gas porosity
- $Cu_2O + H_2$ ……… $H_2O + 2Cu$.

- This rxn does not take place in alloys containing Al,Si such as Al-Bronze, Si-Bronze. Only H_2 dissolves in these and gives unsoundness in castings. (Reaction unsoundness)
- Removal of hydrogen