MEM 261: WORKSHOP PRACTICE II

CHAPTER 3

INTRODUCTION TO METAL CASTING.

Chapter Outline

3.1 Overall safety in metal casting

3.2 Melting practice

3.3 Sand casting

- 3.3.1 Process cycle
- 3.3.2 Elements of gating system
- 3.3.3 Molding material
- 3.3.4 Pattern
- 3.3.5 Core

3.4 Die casting

3.5 Basic design rule in casting

3.6 Cleaning and casting defects

OBJECTIVES & LEARNING OUTCOMES

1. **Have a basic understanding on casting terminology and processes.**
2. **Have acquired knowledge on casting defects and design rules.**

3. 1 METAL CASTING OVERALL SAFETY GUIDE

1. Aprons, gloves and leggings should be leather as this offers the most protection is a spillage of molten metal occurs.
2. Wear protective clothing and devices like safety glasses and full face shields.
3. Cloths made of natural fibers like cotton are to be preferred over synthetics that can melt and stick to the skin.
4. Strong, leather shoes should be worn at all times in the workshop as they offer the best protection for feet. Do not distract anybody during a pour.
5. Do not look into the furnace without appropriate eye safety gear for splattering and infrared radiation.
6. Always operate in a well-ventilated area. Fumes and dusts from combustion and other foundry chemicals, processes and metals can be toxic.
7. Spilled molten metal can travel for a great distance. Operate in a clear work area.

3. 2 MELTING PRACTICE

FURNACE ? – Where melting stock of liquid and/or solid metal, alloying element and others related material forming together.

FURNACE SELECTION DEPEND ON:

1. Economic consideration (less cost during operation)
2. Composition and melting point of the metal/alloy
3. Capability to control furnace atmosphere
4. Capacity
5. Environmental consideration (environment pollution)
6. Maintenance (less)
7. Safety (high)

METHOD OF MELTED AND PREPARED OF ALLOY IN FURNACE:

1. Electric arc
2. Induction
3. Crucible
4. Cupola

➢ ELECTRIC ARC FURNACE:

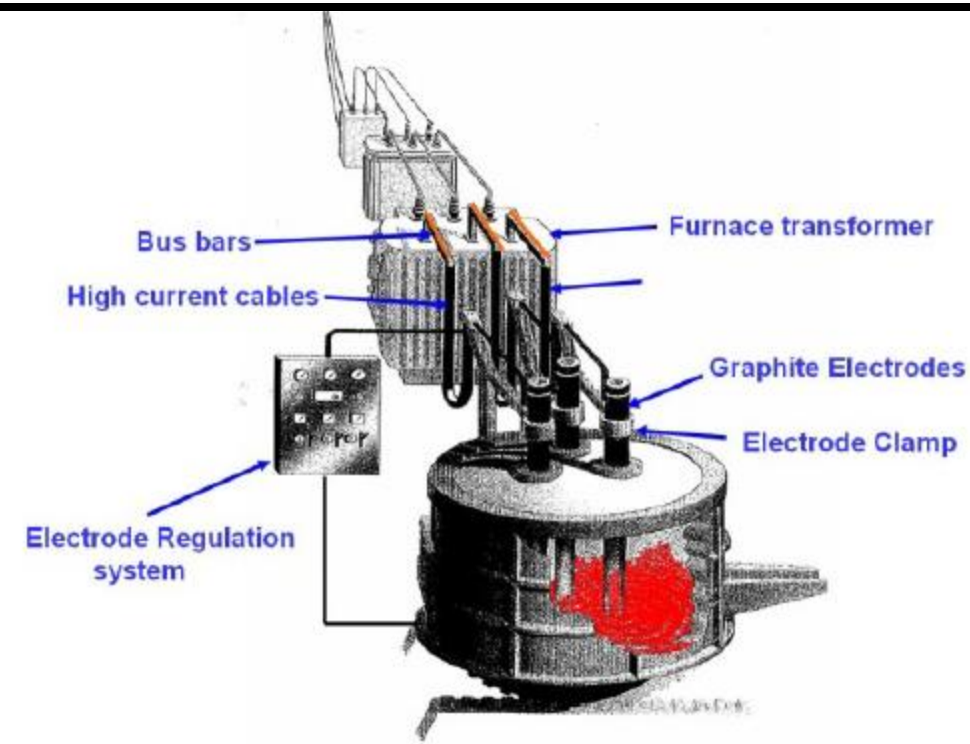


Figure 1 : Electric arc furnace

MECHANISM OF ELECTRIC ARC FURNACE:

1. Electric arc furnace : The furnace is charged with ingots, scrap, alloy metals and fluxing agents. An arc is produced between three electrodes and the metal charge, melting the metal. A slag with fluxed covers the surfave of the molten metal to prevent oxidation, to refine the metal and to protect the furnace roof from excessive heat. When ready, the electrodes are raised and the furnace tilted to pour the molten metal into the receiving ladle.

Other characteristics : High rate of melting, much less pollution and the ability to hold the molten metal for any length of time for alloying purposes.

➢ INDUCTION FURNACE:

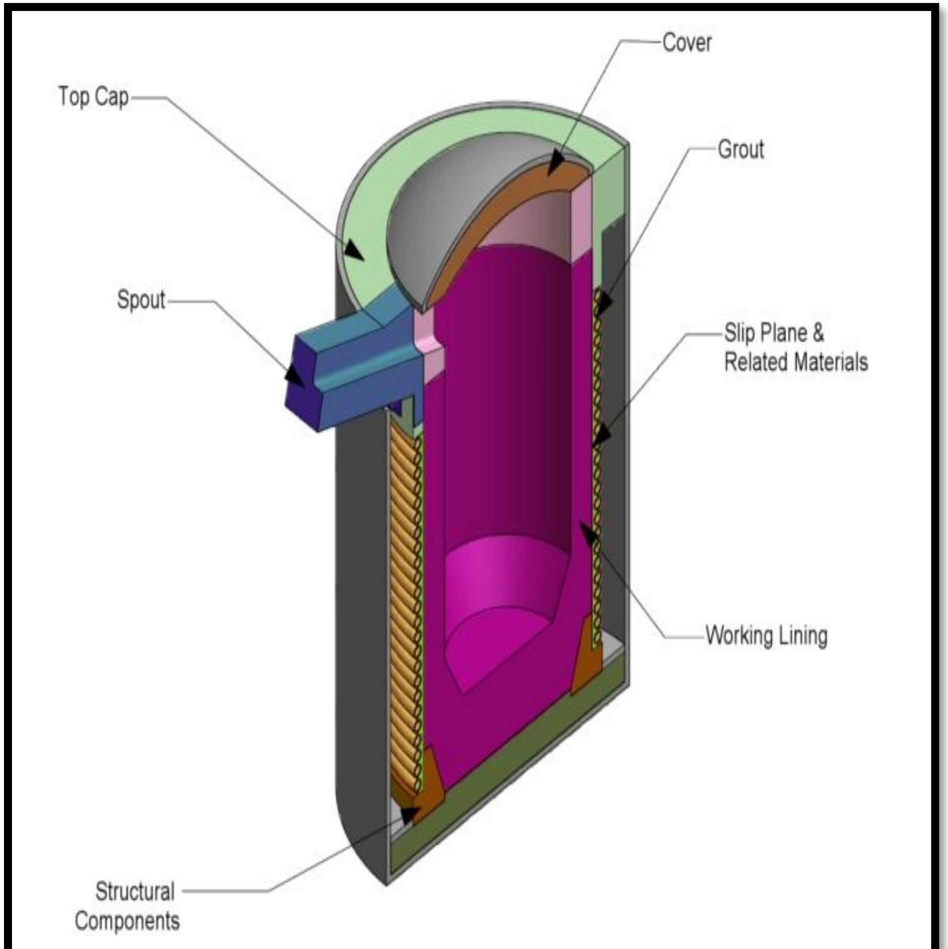


Figure 2 : Induction furnace

➢ MECHANISM OF INDUCTION FURNACE:

2. Induction furnace : It melts the metal by passing a high electric current through copper coils on the outside of the furnace, including an electric current in the outer edge of the metal charge that heats the metal because of the high electrical resistance of the metal charge. Melting progresses from the outside of the charge to the inside. Special hazards include metal fumes.

Other characteristics : Used in smaller foundries, produce composition controlled smaller melts, do not introduce dust and noise emissions in operation. Heating is safe and efficient with no open flame to endanger the operator or obscure the process. Production rates can be maximized because induction works so quickly.

➢ CRUCIBLE FURNACE:

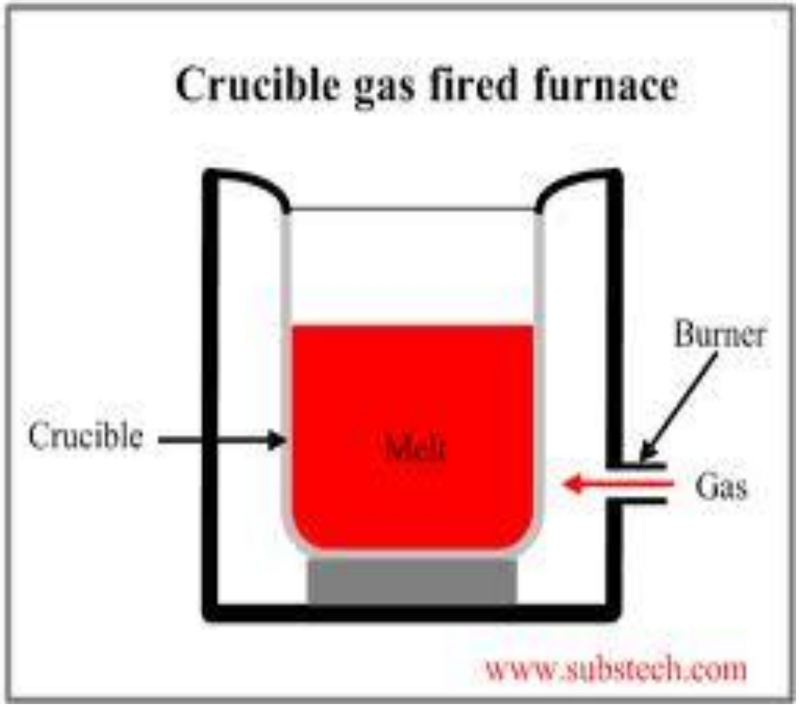


Figure 3: Crucible furnace

➢ MECHANISM OF CRUCIBLE FURNACE:

3. Crucible furnace : The crucible or container holding the metal charge is heated by a gas or oil burner. When ready, the crucible is lifted out of the furnace and tilted for pouring into the molds.

Other characteristics : Used for ferrous and nonferrous metals. Special hazards include carbon monoxide, metal fumes, noise and heat.

➢ **CUPOLA FURNACE:**

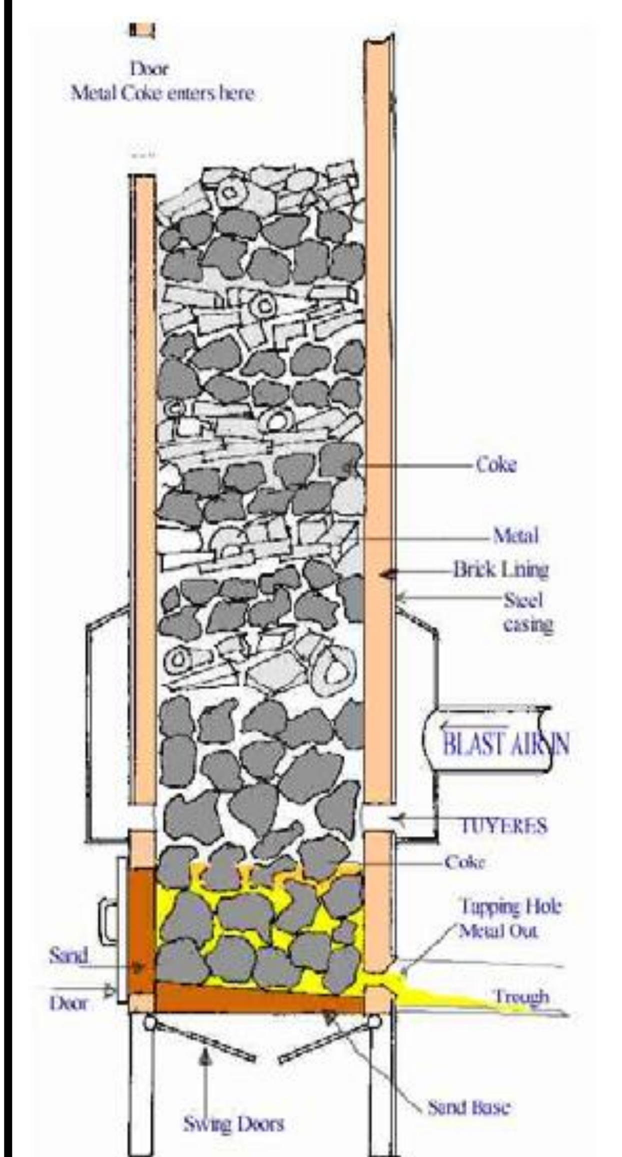


Figure 4 : Cupola furnace

➢ MECHANISM OF CUPOLA FURNACE:

4 Cupola : Furnace is a tall, vertical furnace, open at the top with hinged doors at the bottom. It is charged from the top with alternate layers of coke, limestone and metal. The molten metal is removed at the bottom.

Other characteristics : They operate continuously, have high melting rates and produce large amounts of molten metal. Special hazards include carbon monoxide and heat.

3. 3 SAND CASTING

SAND CASTING:

- Form complex metal parts that can be made of nearly any alloy (aluminum, cast iron, stainless steel).
- Involves the use of a furnace, metal, pattern and sand mold.
- Produce automobile components, such as engine blocks, engine manifolds, cylinder heads, and transmission cases

Advantages	Disadvantages
• Create big component with complex shape. • Can used with many variety of metal. • Cost is relatively cheaper • Scrap metal can reused and time taken is short.	• Produced product not strong as others technique product. • Rate production is relatively low. • Requires additional process before final product is complete.

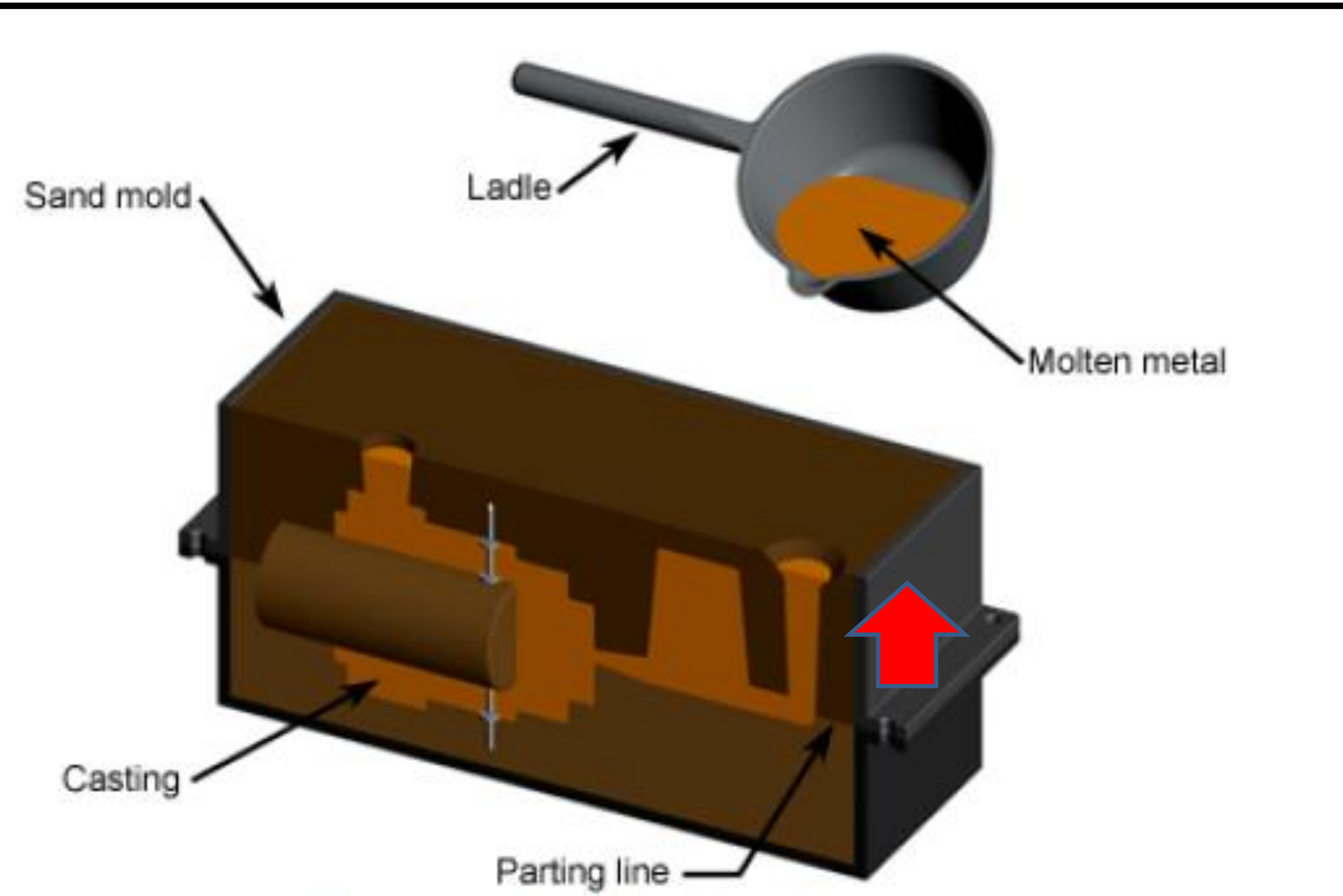
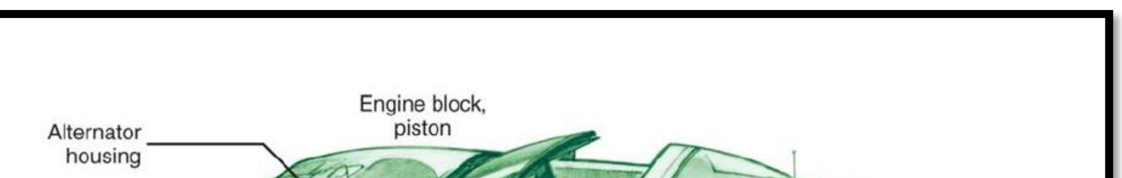


Figure 5 : Sand casting



➢ 3.3.1 SAND CASTING PROCESS CYCLE

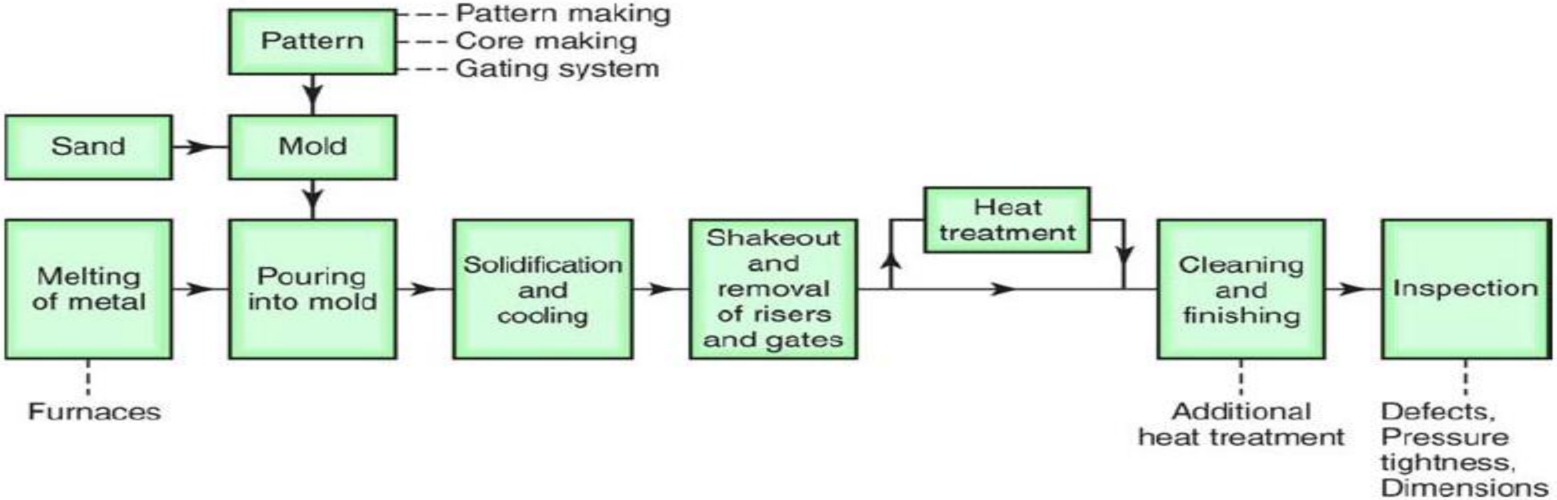


Figure 8 : Process cycle in sand casting

1. Mold making - Shape of casting was perform with pattern & core
2. Clamping - To prevent any loss of casting
3. Pouring - Enough molten metal must be poured
4. Cooling - Shorter cooling time may exhibit severe shrinkage
5. Removal - Sand mold can simply be broken and the casting removed
6. Trimming - Excess material must be trimmed from the casting

➢ 3.3.2 ELEMENT OF GATING SYSTEM

- **Mold cavity** : Mold cavity is formed by packing sand around the pattern.
- **Flask** : Consist of upper half & bottom half which meet at *'parting line'*
- **Core** : To formed internal surfaces (e.g. : holes, passages)
- **Sprue** : Carry the molten metal from basin down to the main channel
- **Runner** : Carry the molten metal into the cavity
- **Riser** : Supply an additional source of metal during solidification
- **Vent** : Carry off gases produced when the molten metal contacts with sand.

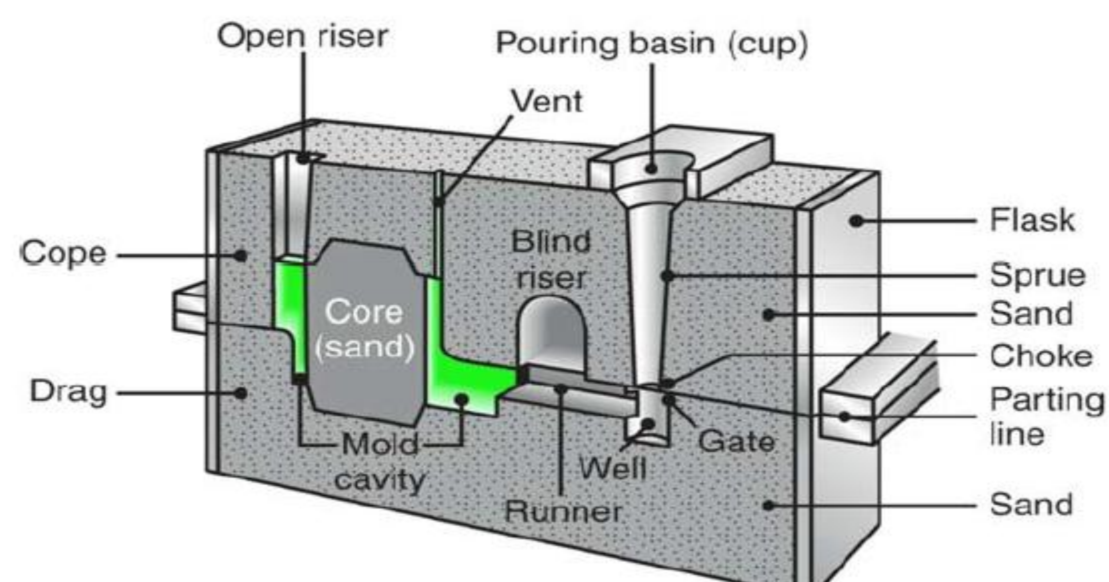


Figure 9 : Elements of gating system used in sand casting

➢ 3.3.3 MOLDING MATERIAL

MOLDING ? – Process a pattern is pressed into sand so as to form the desired shape.

After the pattern has been carefully extracted, molten metal is poured into the cavity thus formed and the metal on cooling solidifies. The sand is then removed and the resulting product formed by the metal is known as a "casting".

Molding materials (depend on type of mold) :

1. Sand (silica sand, zircon sand, etc)
2. Clay (as a binder: Bentonite, kaolin, etc)
3. Water (active the clay)
4. Additives

Table 1 : Additives used in casting process

Additives	*Purpose served*
Molasses Cereals Ethylene glycol	Enhancement of bench life and resistance to drying out
Iron oxide Silica flour	Hot strength development
Coal dust Silica flour	Surface finish and resistance to metal penetration
Cereals Saw dust	Collapsibility and resistance to expansion defects

➢ **TWO TYPES OF MOLD: A. GREEN SAND MOLD**

B. DRY SAND MOLD

A) Green sand mold :

- Mixture of sand (90%), water (3%) and a clay (7%)
- Widely used
- Cheap
- Surface finish of the castings obtained by this process is not good and machining is often required to achieve the finished product

B) Skin dried mold (also known as dried green sand) :

- Additional bonding materials (or binder) are added
- Cavity surface is dried by a torch or heating lamp directed to the mold surface to increase mold strength.
- This improves the dimensional accuracy and surface finish.
- More expensive and require more time, thus lowering the production rate.

➢ 3.3.4 PATTERN

PATTERN ? – Is a replica of the object to be cast, used to prepare the cavity into which molten material will be poured during the casting process. First step that need to be considered in making sand casting.

- **Determined by number of castings to be made.**

- **Have 2 types:**

Wood pattern(Cheap but not dimensionally stable)
Metal pattern(Expensive but dimensionally stable)

Types of pattern :

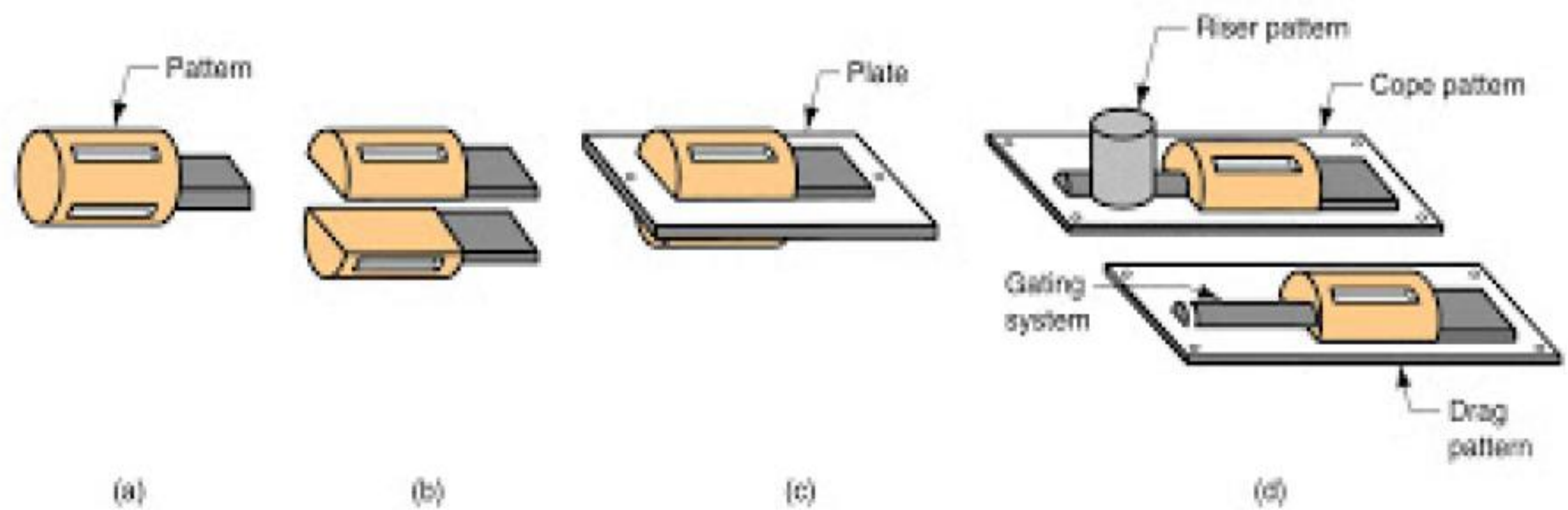


Figure 10 : Types of pattern a) Single piece, b) Split, c) Match-plate, d) Cope and Drag pattern

a) Single piece pattern :

This is the simplest type of pattern, exactly like the desired casting. For making a mould, the pattern is accommodated either in cope or drag. Used for producing a few large castings, for example, stuffing box of steam engine. This is generally used for casting simple shapes and the productivity rate is low by using single piece pattern and the removal of the pattern from the mold cavity is difficult when complex pattern shapes are inserted. Used for producing a few large castings, for example, stuffing box of steam engine.

b) Split pattern :

The disadvantage of single piece pattern can be avoided by using split piece pattern by splitting the complex shape in to two parts that is one of them is attached to the cope part and the other to the drag part and both of them are joined together by using dowel pin (dowel pin is a temporary fastener used for joining of two parts). Gated system is incorporated after the cope and drag part are joined together. Example, taps, bushings, gears, flywheels.

c) Match plate pattern :

A match plate pattern is a split pattern having the cope and drags portions mounted on opposite sides of a plate (usually metallic), called the *"match plate"* that conforms to the contour of the parting surface. The gates and runners are also mounted on the match plate, so that very little hand work is required. This results in higher productivity. This type of pattern is used for a large number of castings. Because the moulding is done on machines, match plate patterns produce castings which are more accurate than those produced by hand moulding. Example, piston rings, engine.

d) Cope and drag pattern :

A cope and drag pattern is a split pattern having the cope and drag portions each mounted on separate match plates. These patterns are used when in the production of large castings. The complete molds are too heavy and cannot be handled by a single worker.

3.3.5 CORE

CORE? – For casting of hollow type cores are employed which form the inner pattern by providing for molten metal to run into cavity formed between the core outer face and the inner sand formation of the mold.

- **Made from sand (silica) and binder (core oil, resin).**

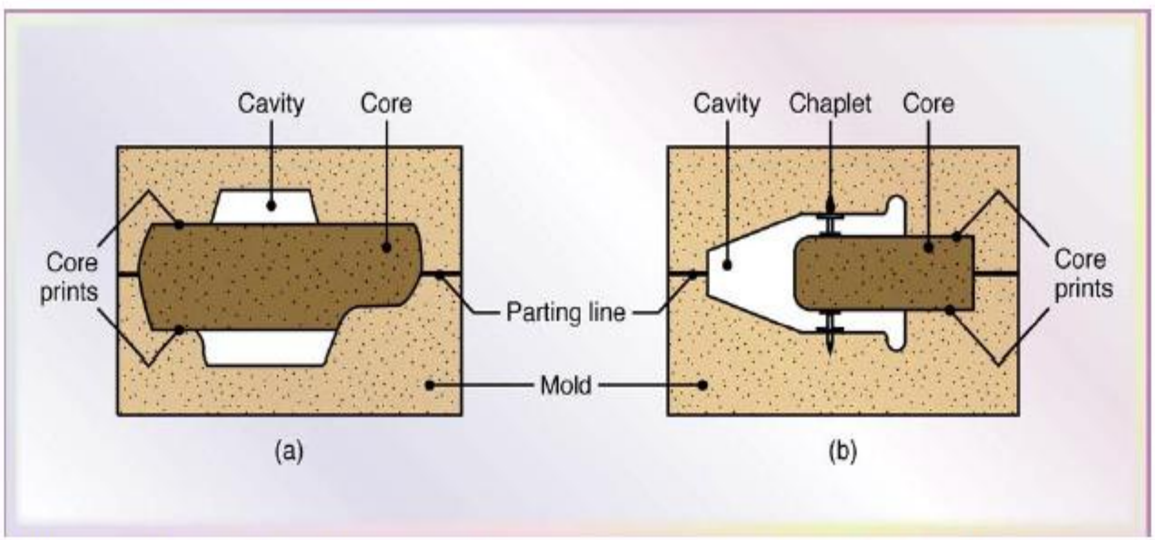


Figure 11 : Examples of sand cores showing core prints and chaplets to support cores

3. 4 DIE CASTING

DIE CASTING:

1. A process which the molten metal is **injected** into the mold cavity at an **increased pressure** up to 200 Mpa (30000psi).
2. Suitable for application that many **small and medium** sized parts are needed with **good detail, fine surface quality and consistence in dimension.**
3. Product: **Piston, automotive connecting rod, plumbing fitting.**

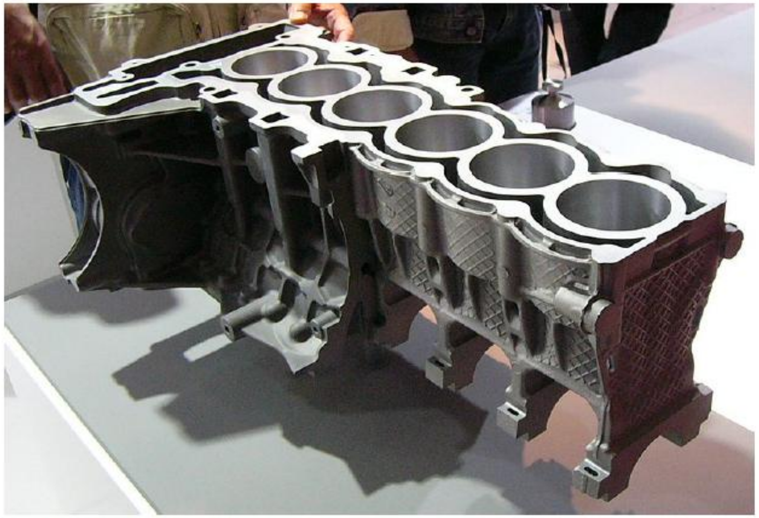
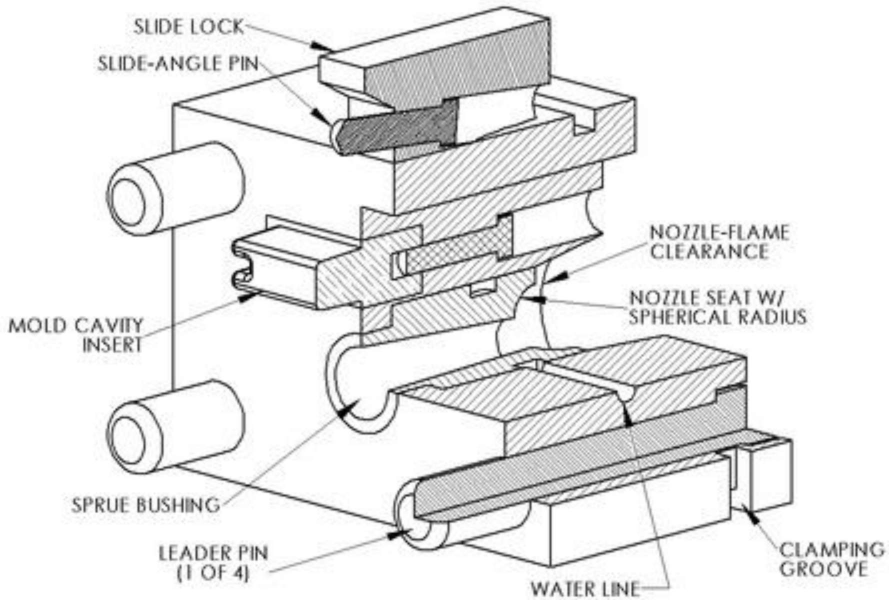
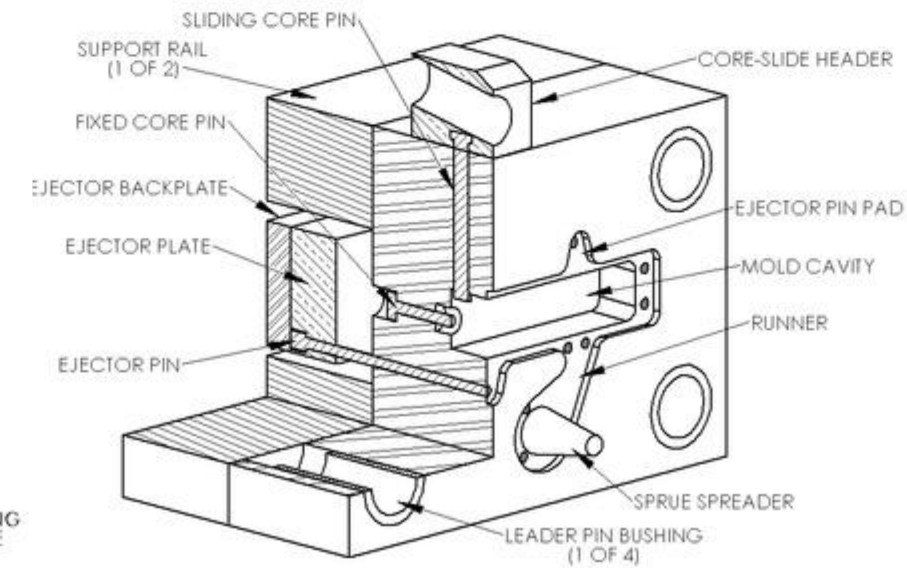


Figure 12 : An engine block with aluminium and magnesium die castings.





The reusable steel mold used in the die casting process is called a die. The dies are fabricated from tool and die steels. The die life is determined the ability of the material to withstand wear caused by the molten alloys and fatigue caused by multiple heating and expansion. he cores are made of refractory ceramic materials. Sand based cores are not applicable due to their insufficient strength under pressure applied in die casting.

Advantages :

1. Near net shaped components
2. High production rate
3. Design can reduce machining and assembly operations (welding, fastening, etc.)
4. Good dimensional control
5. Good surface finish
6. Can cast thin walled components (<0.050")

Disadvantages :

1. Not applicable for high melting point metals and alloys (e.g. : steel)
2. Long wait for first production parts (too long lead time)
3. Casting defects (e.g. : air entrapment, gas and shrinkage porosity can be prevalent causing lower mechanical properties)
4. Component size limitations
5. High die cost

PRINCIPLE OF DIE CASTING: 1. Hot chamber 2.Cold chamber

i) Hot chamber machine

- Used for alloys with low melting temperature, which are chemically inert to the material of the plunger and other parts of the casting machine : zinc alloys (except zinc alloys containing more than 10% of aluminum), tin alloys and magnesium alloys.
- In the hot chamber die casting machines, the pressure chamber (cylinder) and the plunger are submerged in the molten metal in the pot (crucible).
- Hot chamber machines have short casting cycle (about 1 sec.). They are capable to cast thin wall casting with good filling the cavity under precise temperature control of the molten metal.
- Maintenance of hot chamber machines is more expensive as compared to the cold chamber process.
- Process :

  It relies upon a pool of molten metal to feed the die. At the beginning, the plunger goes up allowing the melt to fill the cylinder space. The die is closed at this stage. The plunger goes down forcing the melt to flow through the gooseneck into the die cavity. After the die has been filled with the molten metal, the plunger is held under a pressure until the solidification is completed. The die opens. The casting stays in the die part equipped with ejectors. The plunger goes up and the melt residuals return through the gooseneck back to the pot. The ejectors push the casting out of the die.

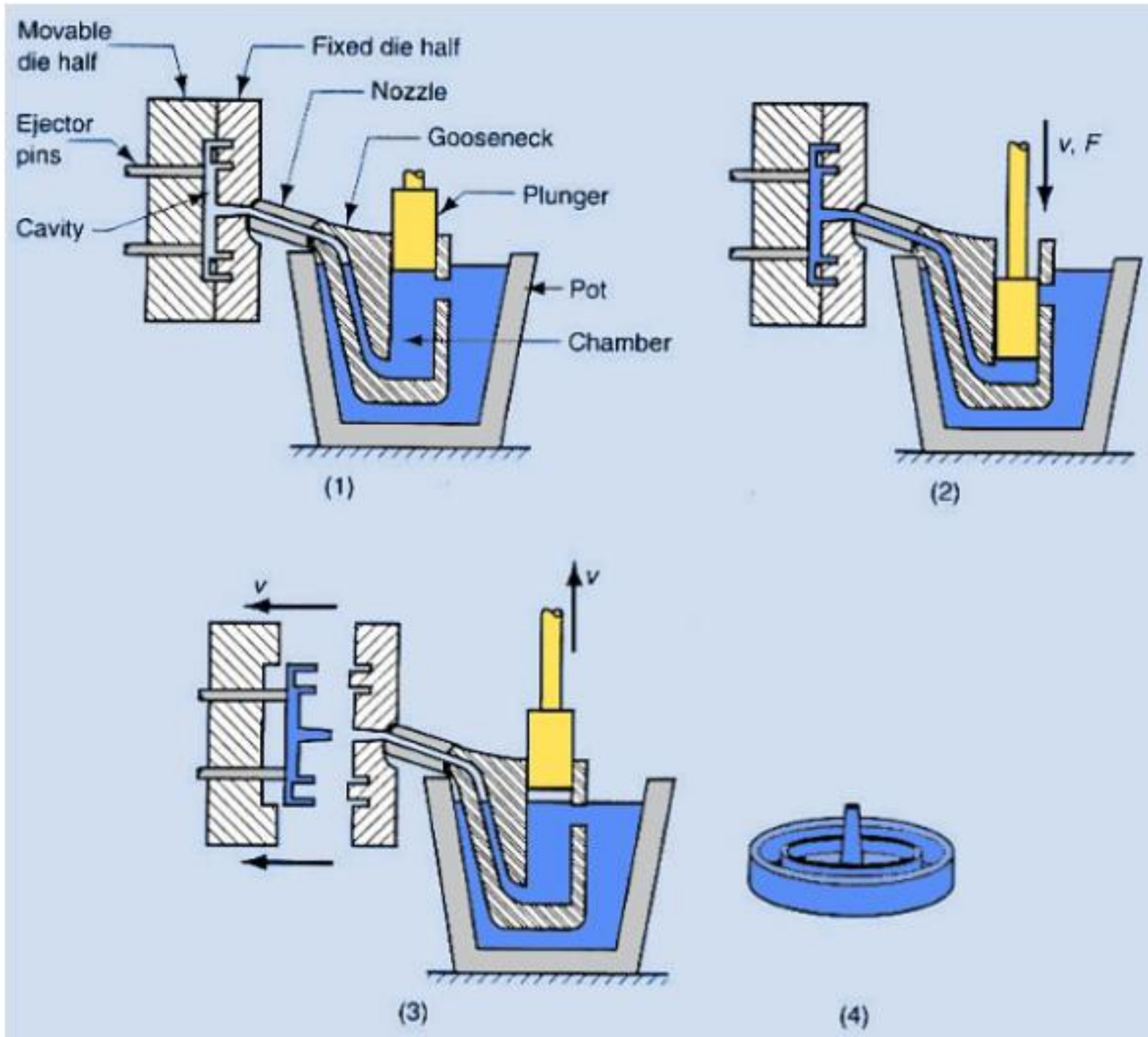


Figure 13 : Hot chamber machine used in die casting

ii) Cold chamber machine

- Used for alloys with high melting temperature include aluminum alloys, magnesium alloys, copper alloys and zinc alloys (including zinc-aluminum alloys).
- Process :
  The process for these machines starts with melting the metal in a separate furnace. Then a precise amount of molten metal is transported to the cold-chamber machine. When the pressure chamber is filled with a molten metal, the plunger starts traveling forward and builds up a pressure forcing the metal to flow to the die cavity. After the metal has solidified, the plunger returns to its initial position allowing a new portion of the molten metal to fill the pressure chamber. The die then opens and the ejector pins removes the casting from the die. The casting cycle now may be repeated.

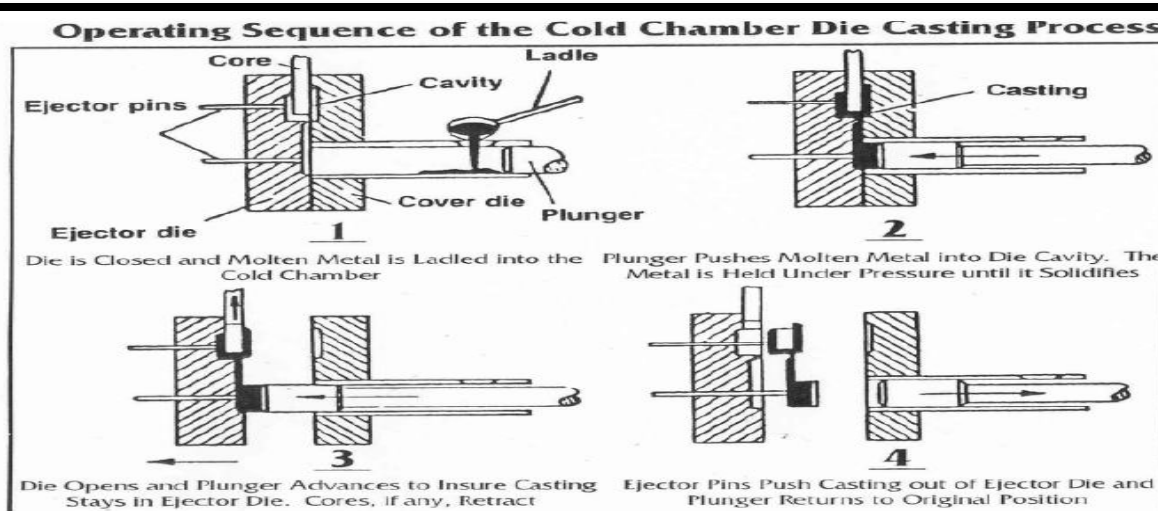


Figure 14 : Cold chamber machine used in die casting

Comparison between sand casting and die casting

Table 2

	Sand Casting	Die Casting
Startup Time	A few days	Several weeks
Initial Expense	Inexpensive	Expensive
Labor Costs	Higher labor costs on long runs	Lower labor costs on long runs
Finish	Pebbly	Smooth
Alloys	High temperatures	High fluidity materials; Better life with lower temperatures (e.g. zinc)
Product Size	Unlimited	Casting weight must be between 30 grams (1 oz) and 10 kg (20 lb). Casting must be smaller than 600 mm (24 in.).
Wall Thickness	Thicker than die casting	Thinner than sand casting

3. 5 BASIC DESIGN RULE IN CASTING

i) Wall thickness

Uniform wall thickness will ensure uniform cooling and reduce defects. A thick section, often referred to as a hot spot, causes uneven cooling and can result in shrinkage, porosity or cracking.

Figure 15 : Wall thickness

ii) Pattern draft

Draft is the taper allowed in vertical faces of a pattern to permit its removal from the sand or other molding medium without tearing the mold cavity surfaces. Apply a draft angle of 2° - 3° to all walls parallel to the parting direction to facilitate removing the part from the mold.

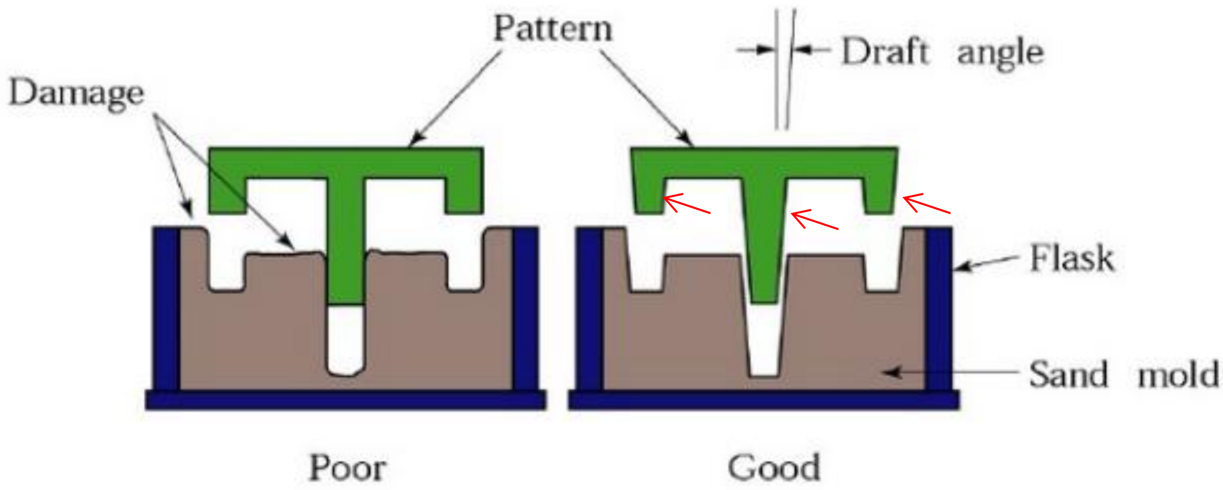
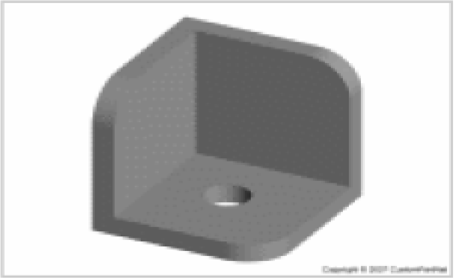


Figure 16 : Taper on patterns for ease of removal from the sand mold

iii) Corner

- Round corners to reduce stress concentrations and fracture.
- Inner radius should be at least the thickness of the walls



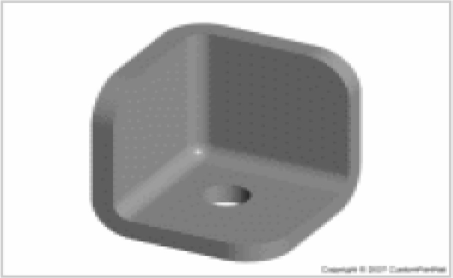


Figure 17 : Corner

3. 6 CLEANING AND CASTING DEFECT

➢ 3.6.1 CLEANING

The complete process of the cleaning of castings, called *"fettling"*. It involves the removal of the cores, gates and risers, cleaning of the casting surface and chipping of any of the unnecessary projections on surfaces.

Figure 18 : Aluminum piston for an internal combustion engine: (a) as cast and (b) after machining. The part on the left is as cast, including risers, sprue, and well, as well as a machining allowance; the part on the right is the piston after machining.

3.6.2 CASTING DEFECT

1) Misrun

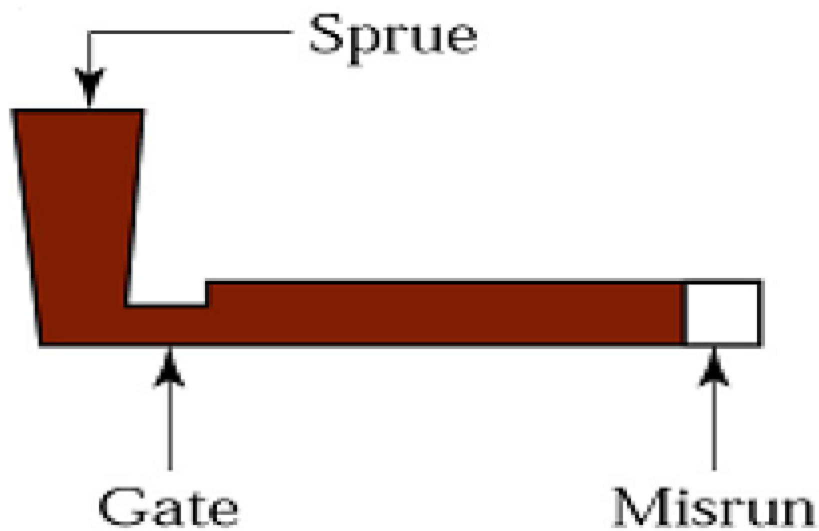
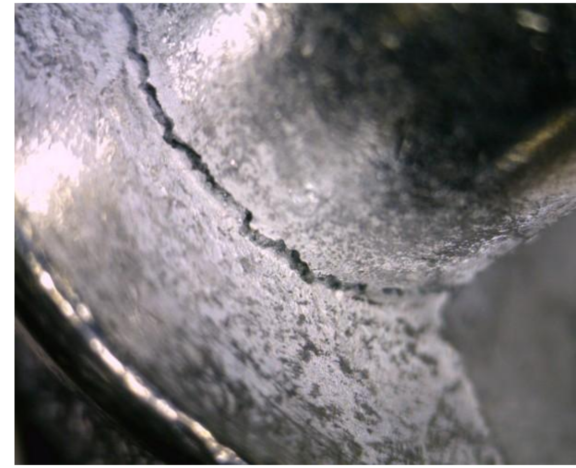


Figure 19 : Misrun

- Also known as cold sheet or short run
- This defect is incomplete cavity filling.
- The reasons can be: - inadequate metal supply, too low mold or melt temperature, improperly designed gates, .or length to thickness ratio of the casting is too large.
- When molten metal is flowing from one side in a thin section, it may loose sufficient heat resulting in loss of its fluidity, such that the leading edge of the stream may freeze before it reaches the end of the cavity.

2) Shrinkage cavity



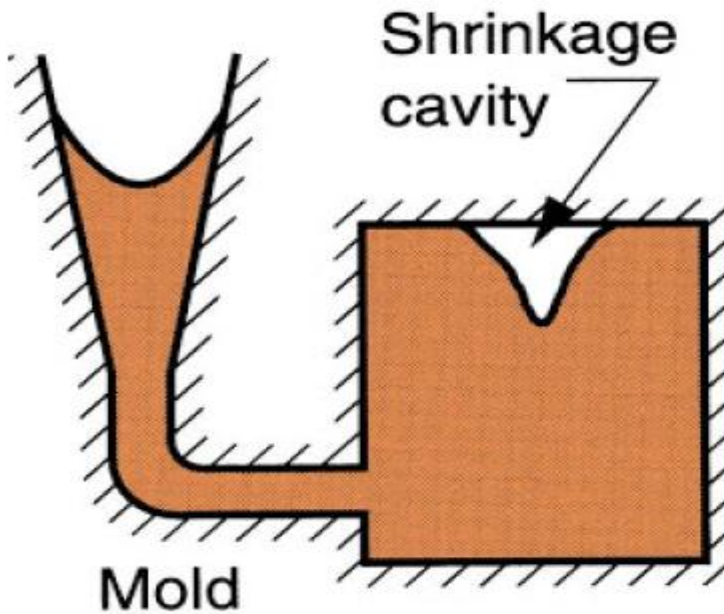


Figure 20 : Shrinkage cavity

- A shrinkage cavity is a depression or an internal void in a casting that results from the volume contraction that occurs during solidification.

3) Cold shut

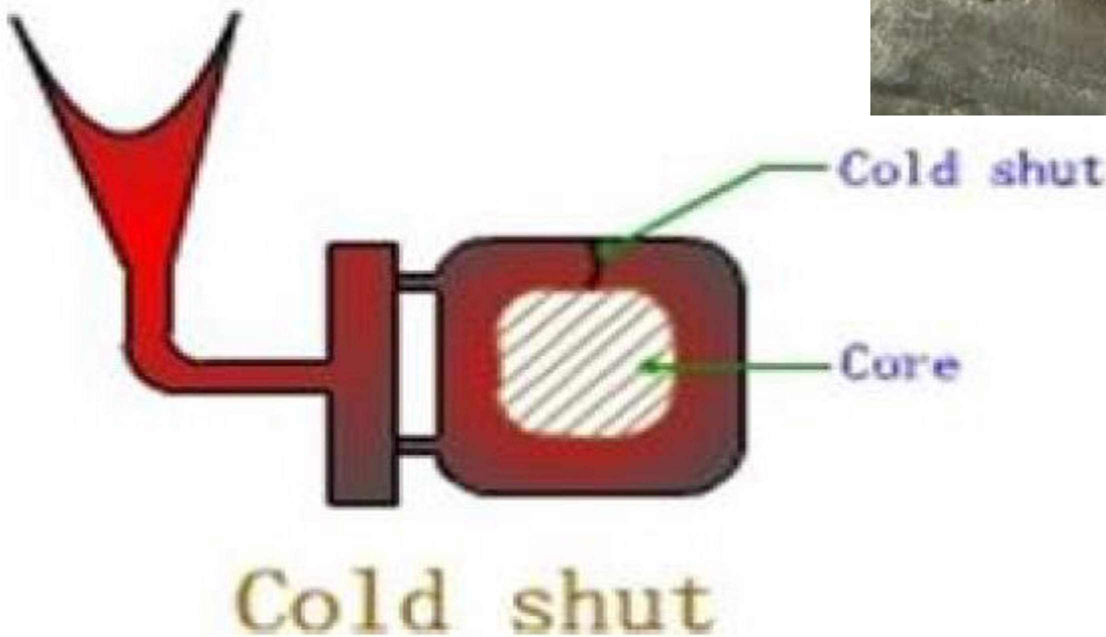


Figure 21 : Cold shut

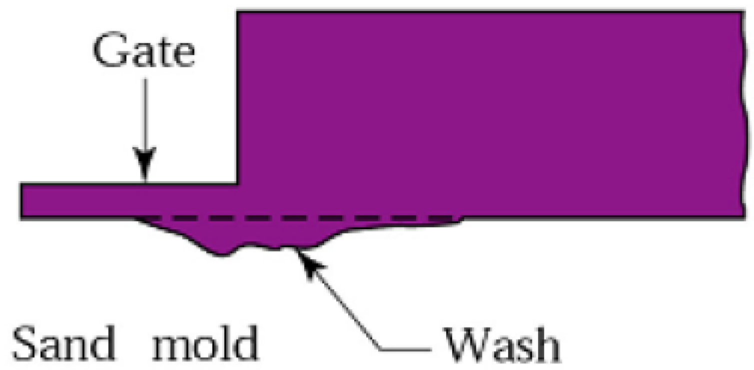
- Occur when two fronts of liquid metal do not fuse properly in the mold cavity, leaving a weak spot.
- Solution: avoid narrow cross-section

4) Microporosity

Figure 22 : Microporosity

- Caused by air entrained in the melt/mold
- Solution: Proper foundry practices, e.g. : melt preparation and mold design

5) Sand wash



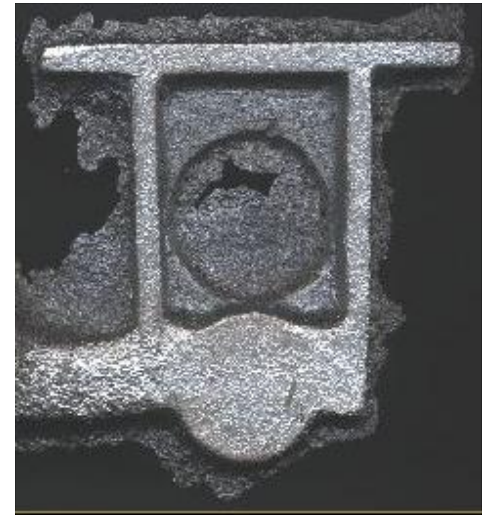
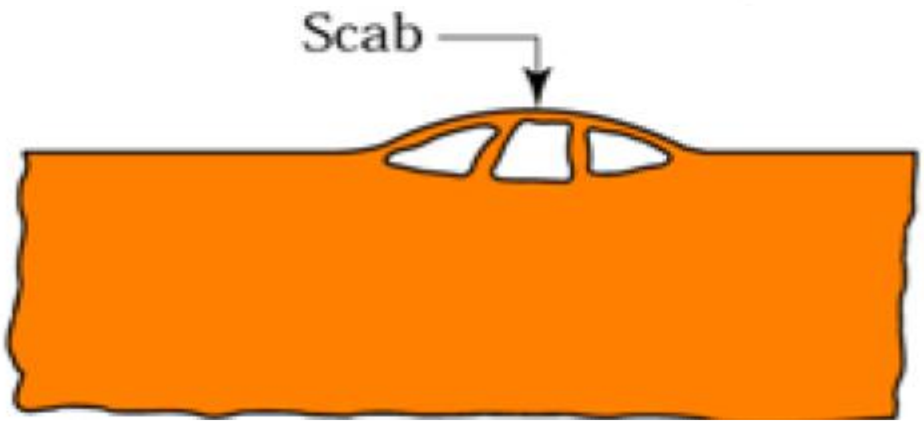


Figure 23 : Sand wash

- It is a projection on the drag face of a casting that extends along the surface, decreasing in height as it extends from one side of the casting to the other end.
- It usually occurs with bottom gating castings in which the molding sand has insufficient hot strength and when too much metal is made to flow through one gate into the mold cavity.

6) Scab



- Occurs when a portion of the face of a mold lifts or breaks down and the recess thus made is filled by metal.
- When the metal is poured into the cavity, gas may be disengaged with such violence as to break up the sand which is then washed away and the resulting cavity filled with metal.
- The reasons can be : Too fine sand, low permeability of sand, high moisture content of sand and uneven molds ramming.

7) Sand blow

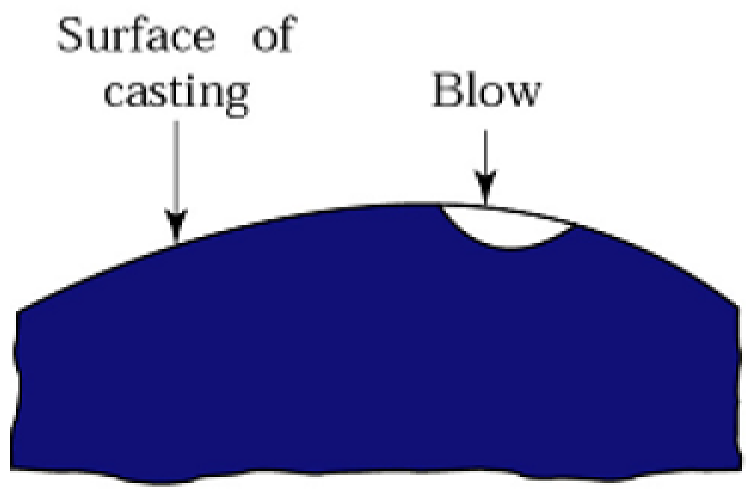
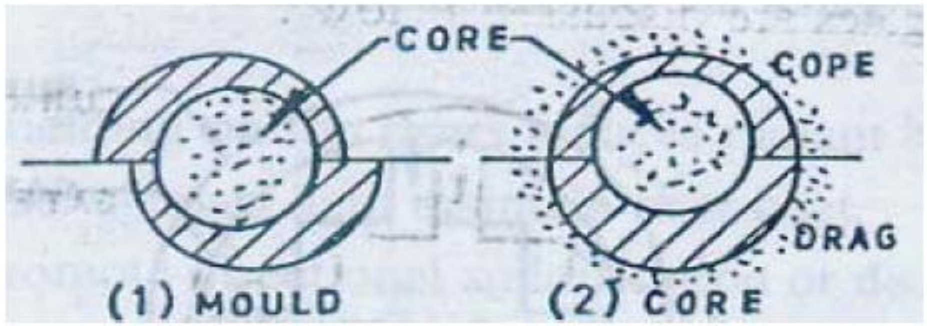


Figure 25 : Sand blow

- Blow is relatively large cavity produced by gases which displace molten metal form.

8) **Shift (mold shift, core shift)**



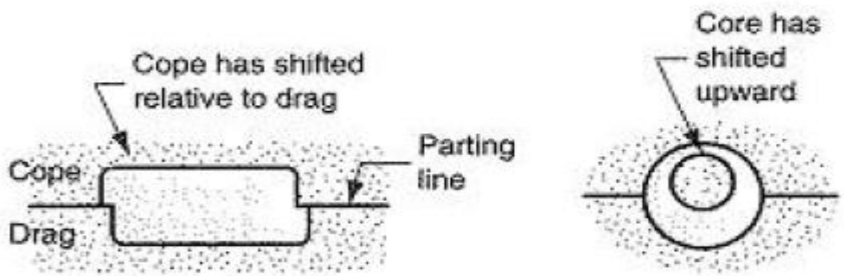


Figure 26 : Mold shift and core shift

- Mold shift refers to a defect caused by a sidewise displacement of the mold cope relative to the drag, the result of which is a step in the cast product at the parting line.
- Core shift is similar to mold shift, but it is the core that is displaced, and (he displacement is usually vertical. Core shift and mold shift are caused by buoyancy of the molten metal

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