Foundry Technology Unit 1

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Syllabus Unit 1

- **General:**
  - Introduction to metal casting and foundry industry in modern industrial scenario.
  - Advantages and limitations of casting methods. Classification of foundries.
  - Different sections in a foundry and their functions.
  - Important cast metals and alloys-their composition, properties and uses.
- **Patternmaking:**
  - Patterns: Types.
  - Pattern making materials and their selection,
  - Color code
  - Pattern allowances
  - Core-boxes and their types.

INTRODUCTION TO METAL CASTING AND FOUNDRY INDUSTRY

- The metal casting industry plays a key role in all the major sectors of our economy. There are castings in locomotives, cars, trucks, aircraft, factories, and everywhere. Metal casting is one of the oldest manufacturing methods.
- In metal casting, metal is melted and poured into a cavity and after solidification of the metal in the cavity, the metal takes the exact shape of the cavity.
- The solidified object is then taken out from the cavity either by breaking the cavity or taking the cavity apart. The solidified object is called the casting. The cavity is also known as mould.

- The shape and size of the mould matches with the product requirement. However, depending upon the shape complexity and the metal the size of the mould may differ with the size of the product requirement. the mould into which the molten metal is poured is made of heat resistant material. Sand, being the heat resistant, is the most often used material for making the mould.
- However, permanent mould made of metal can also be used to cast various products. This process allows to produce the complex parts in one go.

Classification of metal shaping processes:

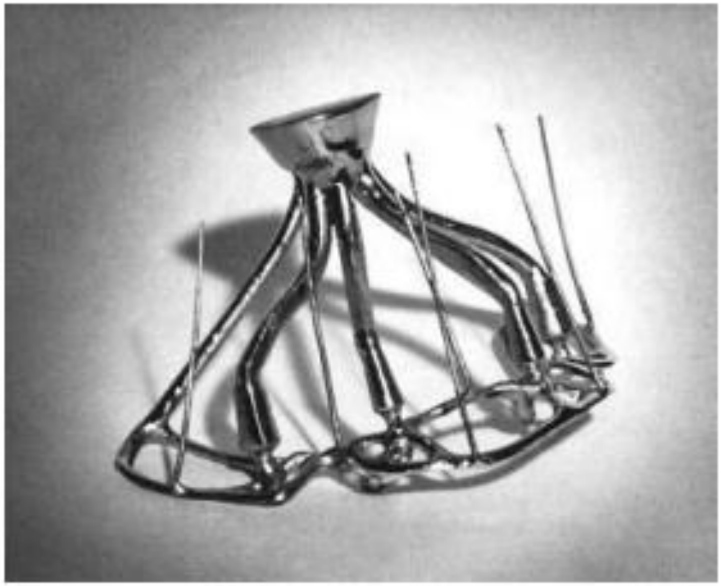
- 1. Casting : Pouring molten metal into mould and freezing it there.
- 2. Mechanical Working : Plastic deformation above or below Recrystallization temp.(Hot working/cold working,) Starting material is cast ingot or billet. Example, Bars, Plates, Sheets and Sections, other methods are – extrusion and forging
- 3. Fabrication by joining: Joining Smaller Components manufactured by other ways.(Riveting, bolting and other fastening devices)

- 4. Machining: Production of shaped articles by cutting from plain or roughly shaped forms using machine tools. It is also a finishing operation to develop final dimensions.
- 5. Powder metallurgy: Metal Powders are compacted in the die and the compacts are sintered to get the desired products.
- 6. Hybrid Process: Semi mould processing and squeeze casting, advantage is both cast and wrought product combination in the same manufactured component.

Major Characteristics of Casting Process

- Weight Range:

weight 280 tonnes, poured weight 467 tonnes



Investment casting for dental implant in cobalt–chromium alloy finished weight 9 g

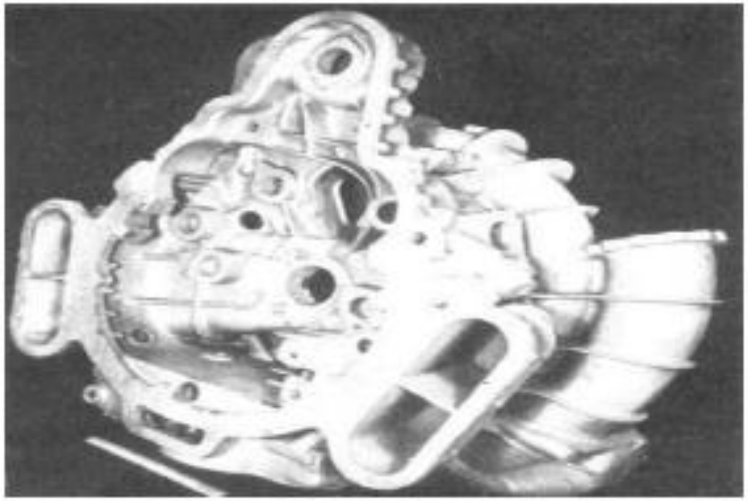
- Shape and Intricacy: Elaborate contours and intricate details are included. Used for difficult to machine alloys.

Cast iron gate assembly

Railway crossing fabricated from manganese steel cast sections

Set of steel castings for paper mill stockbreaker

pump filter and valve



Super-charger casing

SCOPE OF METAL CASTING INDUSTRY

- Metal casting process is the oldest manufacturing process. metal cast products find their application in most of the application product and almost all automobile product use cast product (s) as its component. It can be said that Foundry industry is the mother of all industries.
- In India, There are around 5100 foundries both large as well small units registered in India. Of these, around 3000 units are grey iron foundries, producing about 5.1 million tons of grey iron casting. About 300 foundries are in the large sector. Out of total units, 80 percent are small units, 15 percent are medium- size and only 5 percent are in large sector.

- In India the scope of metal casting industry is increasing as the government has made tremendous efforts to improve infrastructure including power generation. The efforts will help metal casting industries, which are power extensive industries, to grow.
- The knowledge and application of technology in the area of metal casting will help the industries to excel in all of its application areas. The scope of metal casting industry has widen up. It is now-a-days not limited to metal products, but the application of cast product also include, plastic products, composite, civil and building infrastructure development, bridge construction etc.
- The new initiatives and additional scope of foundry industry will require the skilled manpower in this field. This will enhance the metal casting industry jobs to huge number of metal casting professionals.

THE PRESENT CHALLENGES TO INDIAN METAL CASTING INDUSTRIES

- The high cost of technology and related modern equipment
- The cost of energy, which is increasing every time
- High rate of interest on loans
- Industry and Taxation law policies has become a barrier in the growth and export business
- Irregular supply of raw material
- Environment Pollution

The Focus of Metal Casting Industries must be on

- quality not on the quantity with a spirit of producing right first time and every time
- waste reduction and on improving the productivity
- defect prevention not on defect rectification
- competition on pricing as well reduction in lead time
- there should not be any tolerance on defects or defectives or delays

History

- The history of metal casting reaches back almost 5,000 years BC. A brief development of metal casting technology is given below:
- **3200 B.C.** A frog made from copper metal, the oldest known casting in existence, was cast in
- Mesopotamia.
- **233 B.C.** Cast iron plowshares are poured in China.
- **500 A.D.** Cast crucible steel was first produced in India

- **1455** The cast iron pipe to transport the water was used in Dillenburg Castle in Germany.
- **1480** The Vannoccio Biringuccio "father of the foundry industry," in Italy is the first man to
- document the foundry process.
- **1709** The first foundry flask for sand and loam molding was created by Englishman Abraham Darby.

- **1809** A. G. Eckhardt of Soho, England developed the Centrifugal casting process.
- **1896** American Foundrymen's Association (Now American Foundrymen's Society) was formed.
- **1897** B.F. Philbrook of Iowa rediscovered the Investment casting process. Though the roots of
- investment casting process can be traced when bronze dancing girl found at Mohen-jo-daro
- around 3000 BC .

- **1947** The Shell process was invented by J. Croning of Germany during WWII.
- **1958** H.F. Shroyer was granted a patent for the full mold process.
- **1968** The Coldbox process was introduced by L. Toriello and J. Robins for high production core making.
- **1971** The Japanese developed V-Process molding. This method uses unbounded sand and the sand was bind by vacuum.
- **1971** Rheocasting was developed at Massachusetts Institute of Technology

Advantages

- The metal casting process is extensively used in manufacturing because of its many advantages.
  1. Very thin sections, because of the flowability of the liquid metal, can be cast by the metal casting process, which otherwise are difficult to produced by other shaping processes.
  2. Intricate and complex shapes can be made by this process.
  3. Any material that is ferrous or non-ferrous can be cast.
  4. The tooling required for casting molds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.
  5. There are certain parts made from metals and alloys that can only be processed this way.
  6. Size and weight of the product is not a limitation for the casting process.
  7. Metal casting is a process highly adaptable to the requirements of mass production.

LIMITATIONS

- Dimensional accuracy and surface finish of the castings made by casting processes are a limitation to this technique. Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish. Some of these processes are die casting process, investment casting process, vacuum-sealed molding process, and shell molding process.
- The metal casting process is a labor intensive process

Classification of Foundry

1. **Type of Metal used**
   1. **Ferrous**
   2. **Non Ferrous**
2. **Nature of Production**
   1. **Jobbing** (Normally Produces small number of castings of given type for different customers)
   2. **Production** (Is highly mechanised and can produces castings economically on a large scale)
   3. **Semi Production** (It is a combination of Jobbing and Production Foundry)
   4. **Captive** (It is an integral part of some manufacturing organization, it makes casting for the same)
3. **Casting Process**
   1. Centrifugal,
   2. Die Casting,
   3. Investment Casting etc

Foundry Flow Chart and Sections

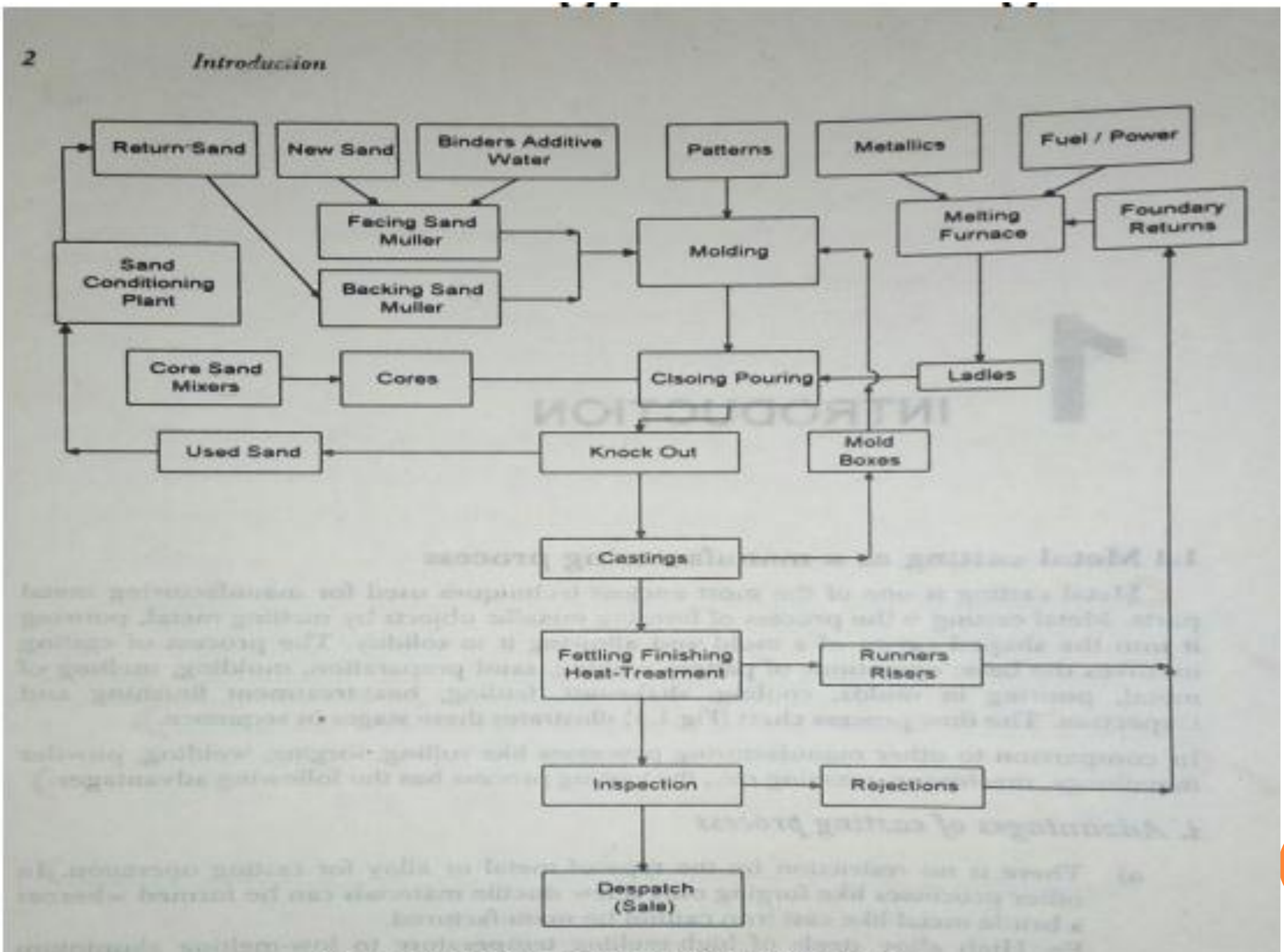
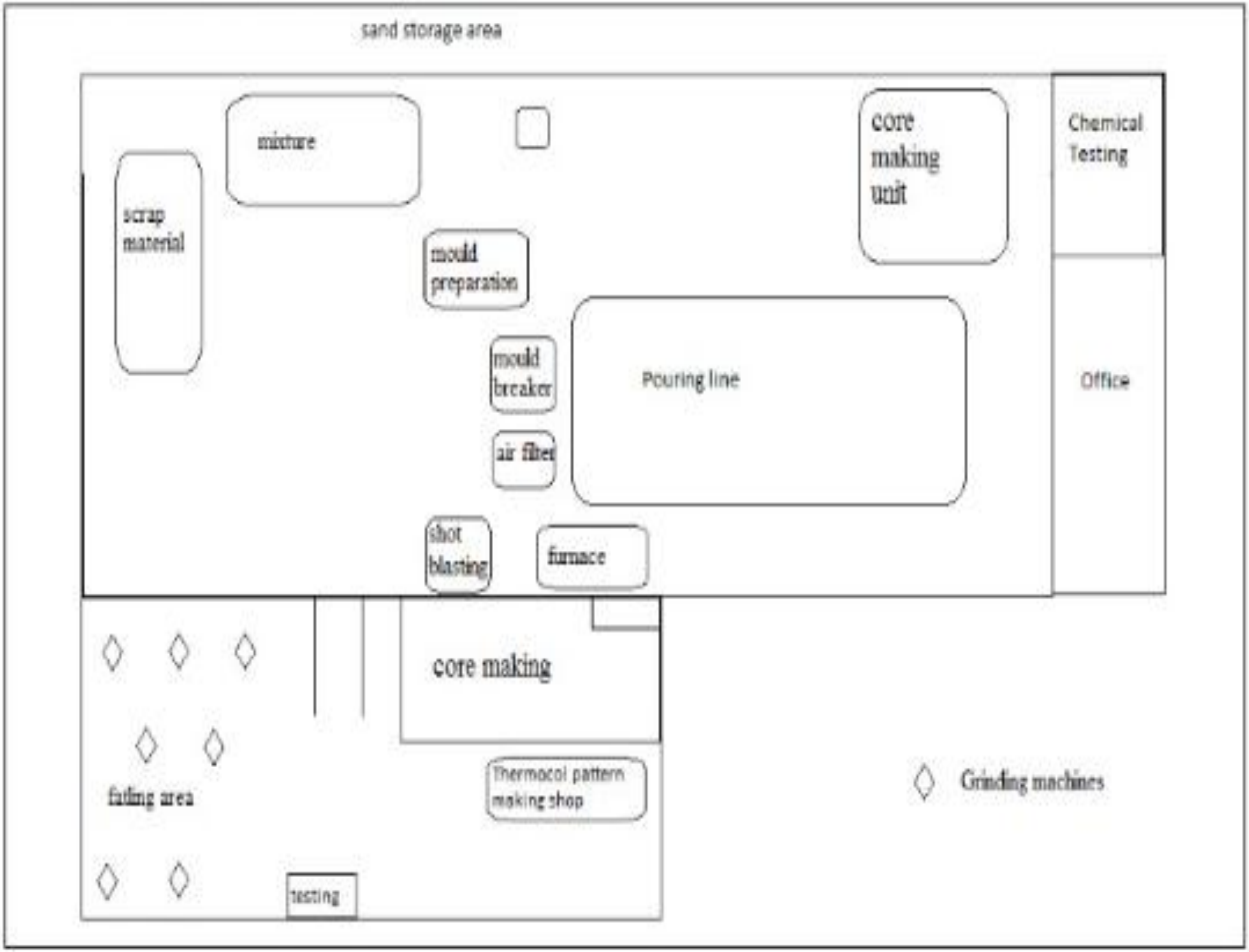


Fig.1.1 Flow Chart for Major Foundary Activities


sand storage area
mixture
scrap material
mould preparation
core making unit
Chemical Testing
mould breaker
Pouring line
Office
air filter
shot blasting
furnace
core making
fatling area
Thermocol pattern making shop
Grinding machines
testing

Materials Used In Castings

- **Casting** is broadly defined as the process of forming a substance into a specific shape using a mold. Metal casting employs a variety of metals to create the molded end product and dates back thousands of years.

  Some of the metal casting processes and materials used in ancient times are still in use today. There are numerous reliable and effective metal casting materials that are used for industrial purposes. The most commonly used resources are:
- **Metal and Non- Metals**
  - Gray iron
  - Ductile iron
  - Aluminum
  - Steel
  - Copper
  - Zinc
- **Refractories,**
- **Fuel,**
- **Fluxes**

Gray Iron Casting

- Gray iron is one of the most frequently used casting materials in industrial manufacturing. Accounting for a large portion of casting supply markets, it is a strong, versatile substance. Gray iron can be machined easily, tested for quality without using destructive methods, formulated to meet specific application requirements, and is cost-effective at high volumes. It is suited to a variety of applications, including those that require:
  - Damping or vibration control
  - High strength to weight ratios
  - Dimensional stability

Ductile Iron Casting

- For processes requiring greater strength than that provided by gray iron casting, ductile iron casting may be a useful alternative. Ductile iron shares similar traits with gray iron, and thus has many of the same advantages. However, ductile iron differs from gray iron casting in the following ways:

  - Greater strength
  - Improved wear resistance
  - Stronger toughness
  - Superior ductility
  - Reduced weight
  - Reduced shrinkage
  - Lower cost

Aluminum Casting

- Aluminum casting is also a widely used method, due in large part to the superior versatility of the metal. As one of only a few materials able to undergo most metal casting processes, aluminum is a relatively adaptable substance to work with. Aluminum's corrosion resistance, high thermal/electrical conductivity, good mechanical properties and strength at high temperatures make it an effective choice for:
  - Die casting
  - Permanent mold casting
  - Investment casting
  - Sand casting
  - Lost foam casting
  - Squeeze casting
  - Hot isotonic pressing

Steel Casting

- Steel is a tough casting material well-suited for parts that will be subjected to exceptional wear, shock or heavy loads. It is useful for its corrosion resistance in aqueous environments and for applications involving elevated temperatures. Steel is often mixed with chromium, iron, and nickel to further improve its corrosion or heat resistance.

Copper Casting

- A major advantage of copper as a casting material is that it offers excellent electrical conductivity. As a result, the construction industry often uses copper for electrical components. Other benefits of copper include:

  - Good malleability
  - Superior ductility
  - Good conduction of heat

  However, copper and castings can be subject to surface cracking, porosity and formation of internal cavities. Consequently, it is often mixed with other metals (silicon, nickel, zinc, chromium, tin and silver) to alleviate these issues.

Zinc Casting

- Zinc's low melting point (425 degrees Celsius) makes it a suitable material for die-cast applications. It is a relatively easy alloy to cast due to its fast fill and fast cooling capabilities. In terms of cost, zinc may be an economical option for casting small, high-volume parts.

Industrial Casting Applications

- Casting is used in a large number of manufacturing processes and plays an important role in construction. Many industries depend heavily on casting to create uniform products. Some of the leading markets for casting materials are:

  - Automotive and Light Truck
  - Pipe and Fittings
  - Construction, Mining and Oilfield Machinery
  - Internal Combustion Engines
  - Railroad
  - Valves
  - Farm Equipment
  - Municipal Castings

Things to Consider When Choosing Casting Materials

- Selecting the proper cast and mold materials for a particular project can be an important concern. Some of the factors to consider when making a casting decision include:

  - Level of volume required
  - Cost-effectiveness
  - Melting temperature
  - Cooling speed
  - Wear resistance
  - Weight
  - Damping capabilities

- Zinc is an efficient choice for die cast operations, however, its low wear resistance and durability may not be ideal for certain applications, such as those involving a high risk of corrosion or material strain. For die cast projects that focus on performance and resilience, aluminum can be a helpful option. For example, aluminum alloy is a frequently used casting material for lawnmower housings, dental equipment, frying skillets, aircraft hardware and marine hardware.

  For structural applications or other tasks that emphasize strength and durability, gray iron or ductile iron may be worthwhile considerations. Gray iron can be effective for projects that require shrinkage-free, intricate castings such as those found in motor blocks. Ductile cast iron is useful for parts that stress strength and toughness, such as critical engine components (crankshafts, truck axles, disk brake calipers, etc.).

- Metal Composition

Alloy group	*Main types of alloy*	*Principal British Standards for castings*	*Some alloying elements*
Cast irons	Grey cast irons; malleable cast irons; spheroidal graphite cast irons; austempered ductile cast irons	BS EN 1561 BS EN 1562 BS EN 1563 BS EN 1564	C, Si, P, Ni, Cr
Steels	Carbon and low alloy steels; high alloy steels, including stainless and heat resisting alloys	BS 3100	C, Mn, Cr, Ni, Mo

Copper base alloys	Brasses, including high tensile brasses; miscellaneous bronzes and gunmetals, including aluminium and silicon bronzes	BS EN 1982	Zn, Sn, P Pb, Ni, Al, Fe, Mn, Si
Aluminium base alloys	Alloys for sand and die casting	BS EN 1706	Si, Cu, Mg, Mn, Zn, Ni
Magnesium base alloys	Alloys for sand and die casting	BS EN 1753	Al, Zn, Zr, Mn, rare earths
Zinc base alloys	Pressure die casting alloys	BS EN 12844	Al, Mg, Cu
Nickel base alloys	High temperature alloys; corrosion resisting alloys		Cr, Co, C, Ti, Al; Cu, Cr, Mo, Si

Miscellaneous	Lead and tin base alloys, especially for bearings;	Sn, Pb, Sb, Cu
	cobalt base alloys for heat, corrosion and wear resistance;	Cr, Ni, Mo, W, Nb
	permanent magnet alloys;	Fe, Co, Ni, Al
	titanium, chromium, molybdenum and other special materials for high temperature and corrosion resistance	

REFRACTROIES

- A refractory material or refractory is a heat-resistant material: that is, a mineral that is resistant to decomposition by heat, pressure, or chemical attack, most commonly applied to a mineral that retains strength and form at high temperatures.
- ASTM C71 defines refractories as "...non-metallic materials having those chemical and physical properties that make them applicable for structures, or as components of systems, that are exposed to environments above 1,000 °F (811 K; 538 °C)."
- Refractory materials are used in furnaces, kilns, incinerators, and reactors.
- Refractories are also used to make crucibles and moulds for casting glass and metals and for surfacing flame deflector systems for rocket launch structures. Today, the iron- and steel-industry and metal casting sectors use approximately 70% of all refractories produced

Applications

Refractories are meant to sustain at high temperature so the very common applications are

- Used in furnaces such as blast furnace and coke oven.
- Used in boilers.
- Mostly used in cement industry in
    - Preheater
    - Rotary Kiln
    - Burner pipe
    - Clinker cooler

FUELS

- A **fuel** is any material that can be made to react with other substances so that it releases energy as heat energy or to be used for work. The concept was originally applied solely to those materials capable of releasing chemical energy but has since also been applied to other sources of heat energy such as nuclear energy

- Oil
- Coke
- Coal
- Gas
- Electricity

Fluxes

- In metallurgy, a **flux** (derived from Latin *fluxus* meaning "flow") is a chemical cleaning agent, flowing agent, or purifying agent. Fluxes may have more than one function at a time. They are used in both extractive metallurgy and metal joining.
- Limestone is used as a flux in cupola furnace.
- Sodium Carbonate
- Nitrogen, Helium and chlorine are used as gaseous fluxes.
- Fluxes used for melting magnesiusm are KCL, MgO, $MgCl_{2,}$ CaF_2

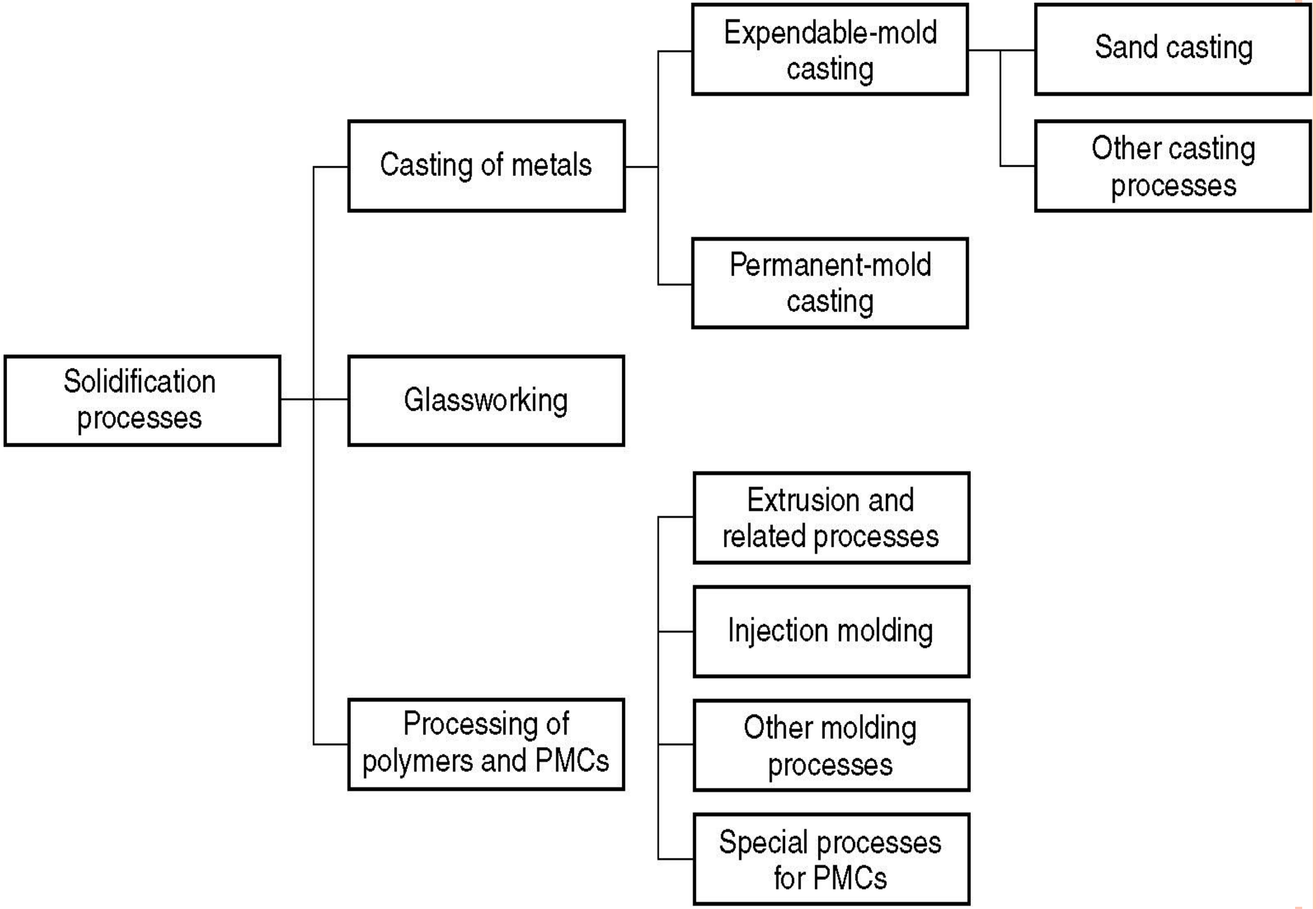
FUNDAMENTALS OF METAL CASTING

1. Overview of Casting Technology
2. Heating and Pouring
3. Solidification and Cooling

Solidification Processes

Starting work material is either a liquid or is in a highly plastic condition, and a part is created through solidification of the material

- Solidification processes can be classified according to engineering material processed:
  - Metals
  - Ceramics, specifically glasses
  - Polymers and polymer matrix composites (PMCs)



Classification of solidification processes.

Parts Made by Casting

- Big parts
  - Engine blocks and heads for automotive vehicles, wood burning stoves, machine frames, railway wheels, pipes, church bells, big statues, pump housings
- Small parts
  - Dental crowns, jewelry, small statues, frying pans
- All varieties of metals can be cast, ferrous and nonferrous

Overview of Casting Technology

- Casting is usually performed in a foundry

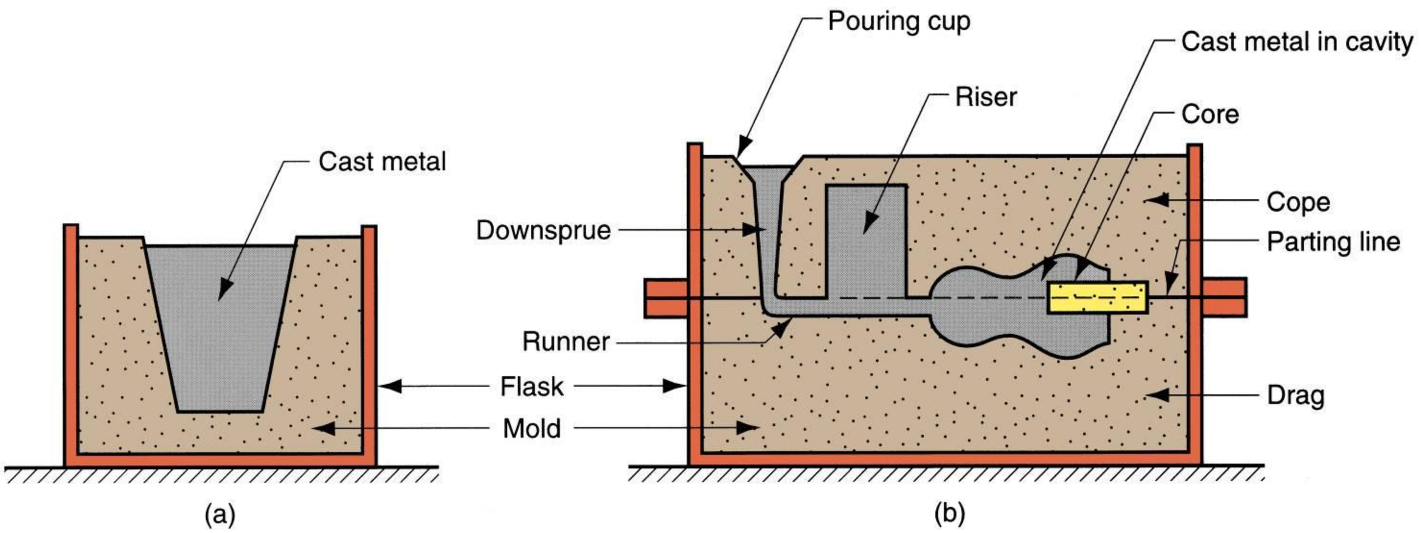
Foundry = factory equipped for making molds, melting and handling molten metal, performing the casting process, and cleaning the finished casting

- Workers who perform casting are called *foundrymen*

The Mold in Casting

- Contains cavity whose geometry determines part shape
  - Actual size and shape of cavity must be slightly oversized to allow for shrinkage of metal during solidification and cooling
  - Molds are made of a variety of materials, including sand, plaster, ceramic, and metal

Open Molds and Closed Molds



Two forms of mold: (a) open mold, simply a container in the shape of the desired part; and (b) closed mold, in which the mold geometry is more complex and requires a gating system (passageway) leading into the cavity.

Two Categories of Casting Processes

1. Expendable mold processes – uses an expendable mold which must be destroyed to remove casting
   - Mold materials: sand, plaster, and similar materials, plus binders
2. Permanent mold processes – uses a permanent mold which can be used over and over to produce many castings
   - Made of metal (or, less commonly, a ceramic refractory material

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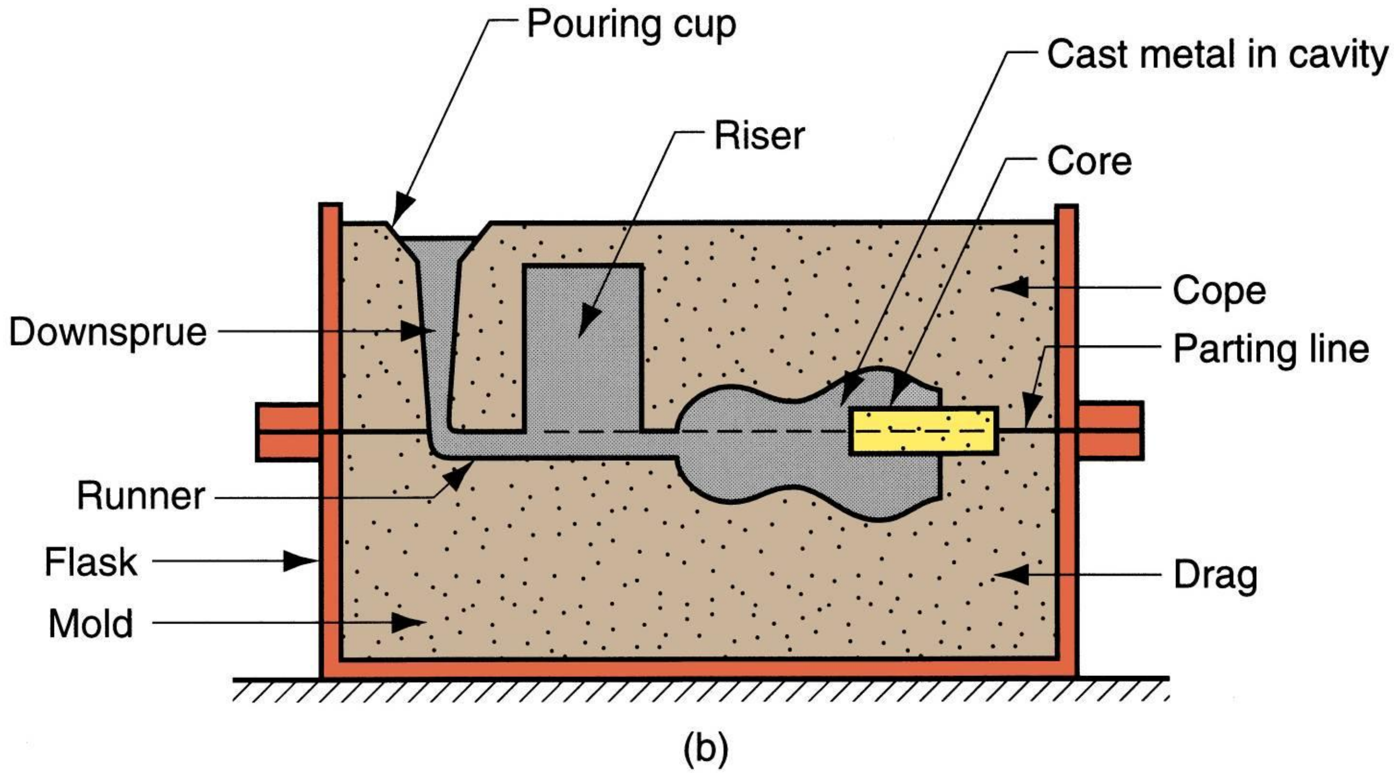
Advantages and Disadvantages

- More intricate geometries are possible with expendable mold processes
- Part shapes in permanent mold processes are limited by the need to open the mold
- Permanent mold processes are more economic in high production operations

Sand Casting Mold



Sand casting mold.

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Sand Casting Mold Terms

- Mold consists of two halves:
  - *Cope* = upper half of mold
  - *Drag* = bottom half
- Mold halves are contained in a box, called a *flask*
- The two halves separate at the *parting line*

Forming the Mold Cavity

- Mold cavity is formed by packing sand around a *pattern*, which has the shape of the part
- When the pattern is removed, the remaining cavity of the packed sand has desired shape of cast part
- The pattern is usually oversized to allow for shrinkage of metal during solidification and cooling
- Sand for the mold is moist and contains a binder to maintain its shape

Use of a Core in the Mold Cavity

- The mold cavity provides the external surfaces of the cast part
- In addition, a casting may have internal surfaces, determined by a *core*, placed inside the mold cavity to define the interior geometry of part
- In sand casting, cores are generally made of sand

Gating System

Channel through which molten metal flows into cavity from outside of mold

- Consists of a *downsprue*, through which metal enters a *runner* leading to the main cavity
- At the top of downsprue, a *pouring cup* is often used to minimize splash and turbulence as the metal flows into downsprue

Riser

Reservoir in the mold which is a source of liquid metal to compensate for shrinkage of the part during solidification

- The riser must be designed to freeze after the main casting in order to satisfy its function

Heating the Metal

- Heating furnaces are used to heat the metal to molten temperature sufficient for casting
- The heat required is the sum of:
  1. Heat to raise temperature to melting point
  2. Heat of fusion to convert from solid to liquid
  3. Heat to raise molten metal to desired temperature for pouring

Pouring the Molten Metal

- For this step to be successful, metal must flow into all regions of the mold, most importantly the main cavity, before solidifying
- Factors that determine success
  - Pouring temperature
  - Pouring rate
  - Turbulence

Solidification of Metals

Transformation of molten metal back into solid state

- Solidification differs depending on whether the metal is
  - A pure element or
  - An alloy

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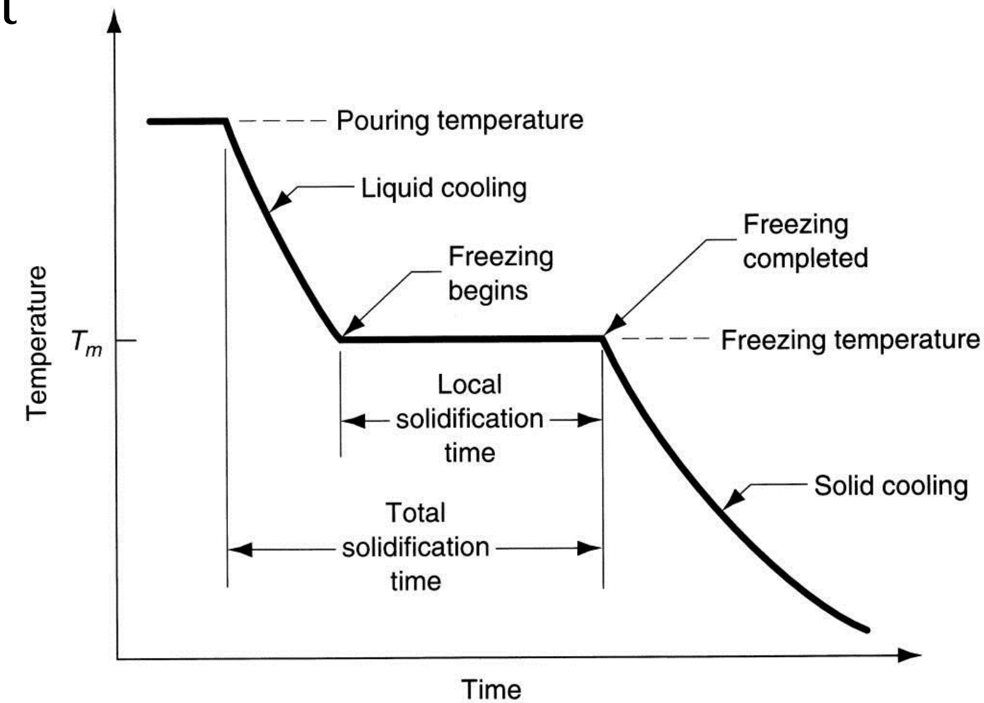
Cooling Curve for a Pure Metal

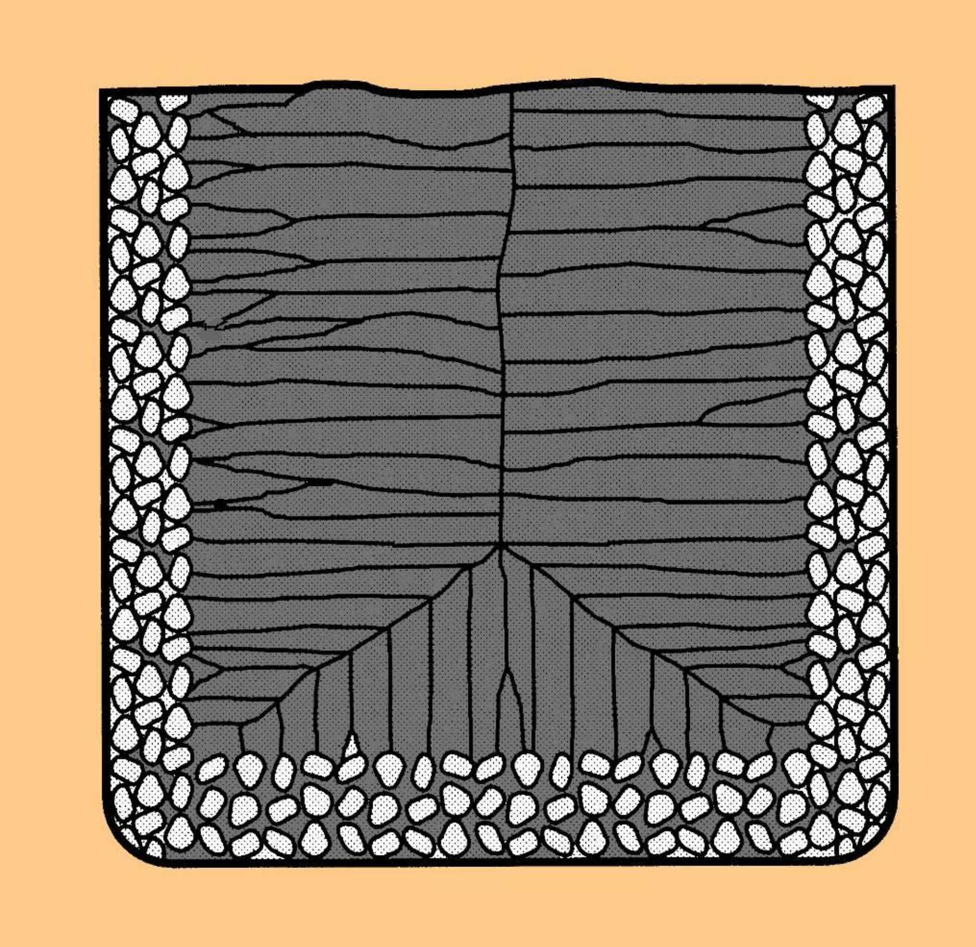
- A pure metal solidifies at a constant temperature equal to its freezing point (same as melt



Cooling curve for a pure metal during casting.

Solidification of Pure Metals

- Due to chilling action of mold wall, a thin skin of solid metal is formed at the interface immediately after pouring
- Skin thickness increases to form a shell around the molten metal as solidification progresses
- Rate of freezing depends on heat transfer into mold, as well as thermal properties of the metal



Characteristic grain structure in a casting of a pure metal, showing randomly oriented grains of small size near the mold wall, and large columnar grains oriented toward the center of the casting.

Solidification of Alloys

- Most alloys freeze over a temperature range rather than at a single temperature

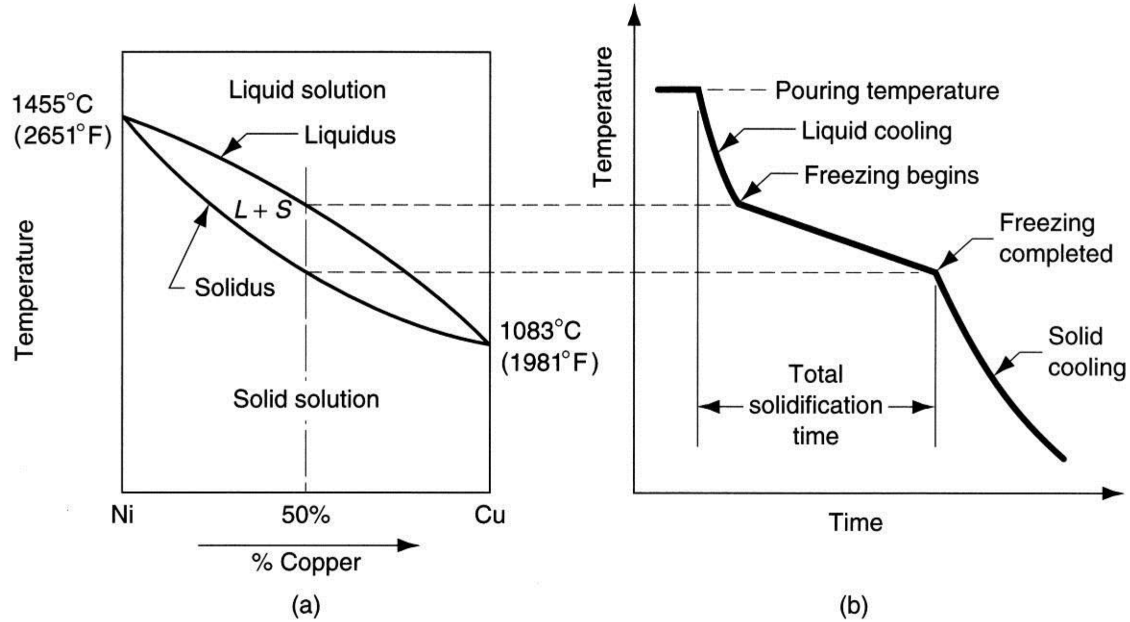
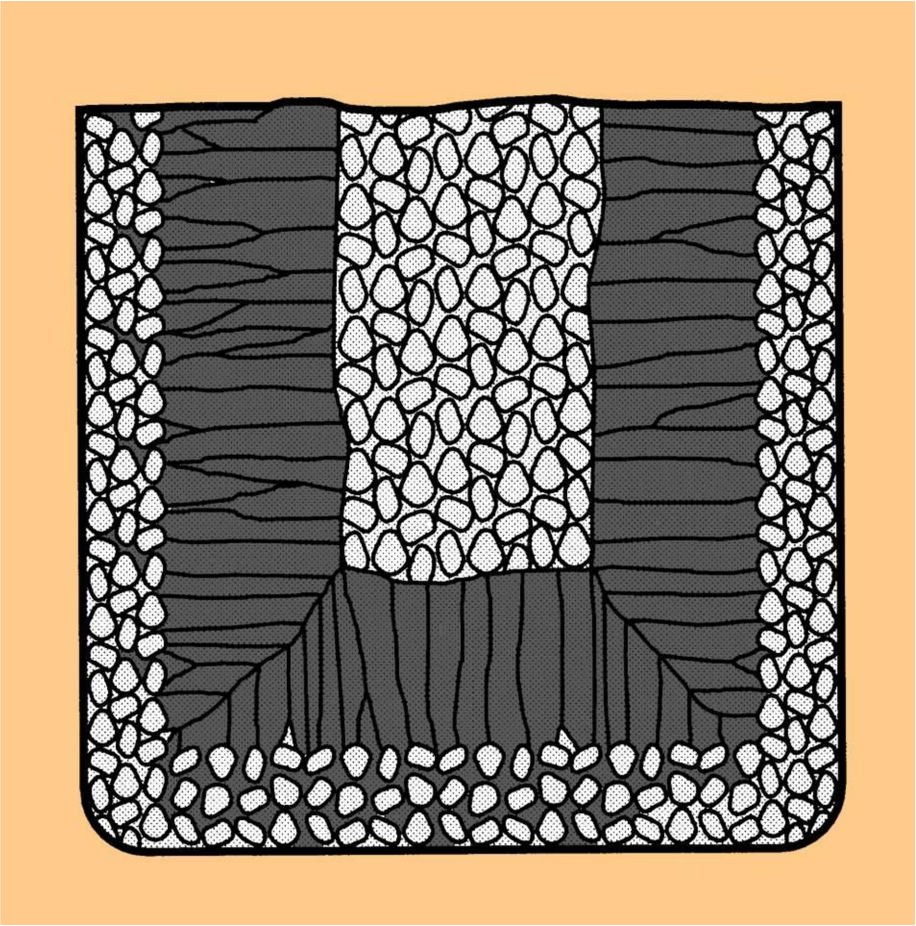
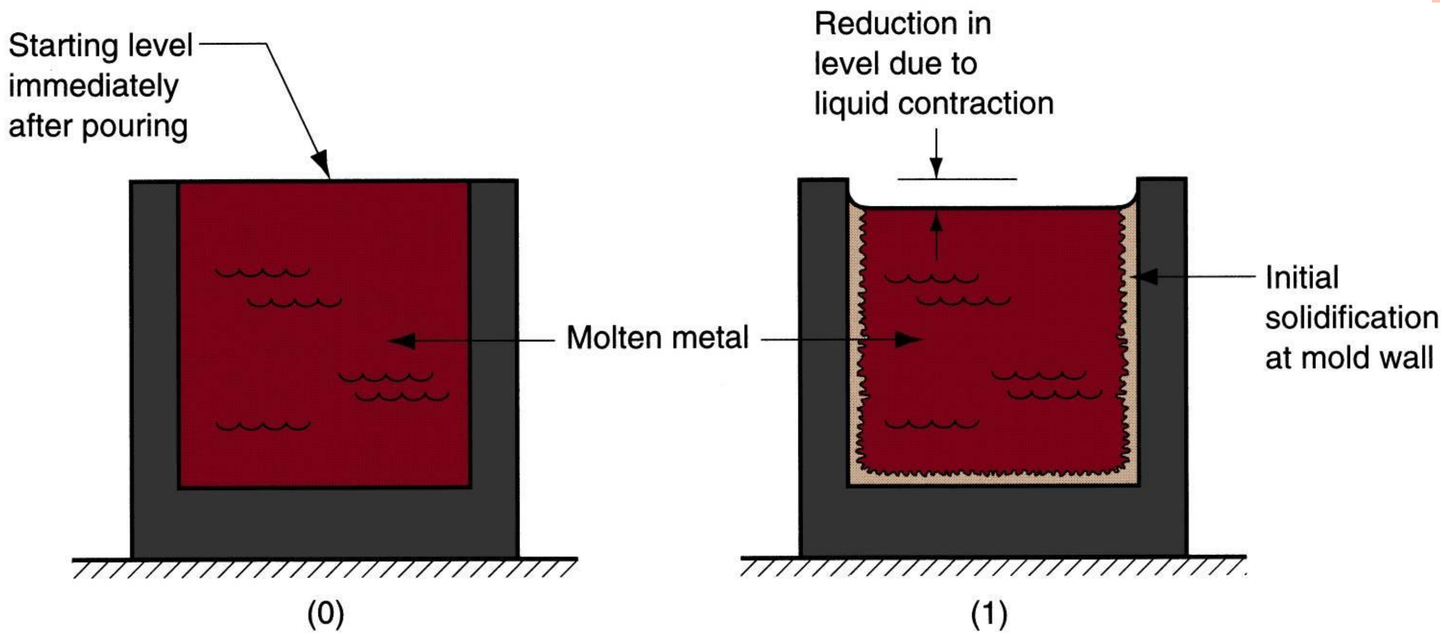


Figure 10.6 (a) Phase diagram for a copper-nickel alloy system and (b) associated cooling curve for a 50%Ni-50%Cu composition during casting.



Characteristic grain structure in an alloy casting, showing segregation of alloying components in center of casting.

Shrinkage in Solidification and Cooling



Shrinkage of a cylindrical casting during solidification and cooling: (0) starting level of molten metal immediately after pouring; (1) reduction in level caused by liquid contraction during cooling (dimensional reductions are exaggerated for clarity).

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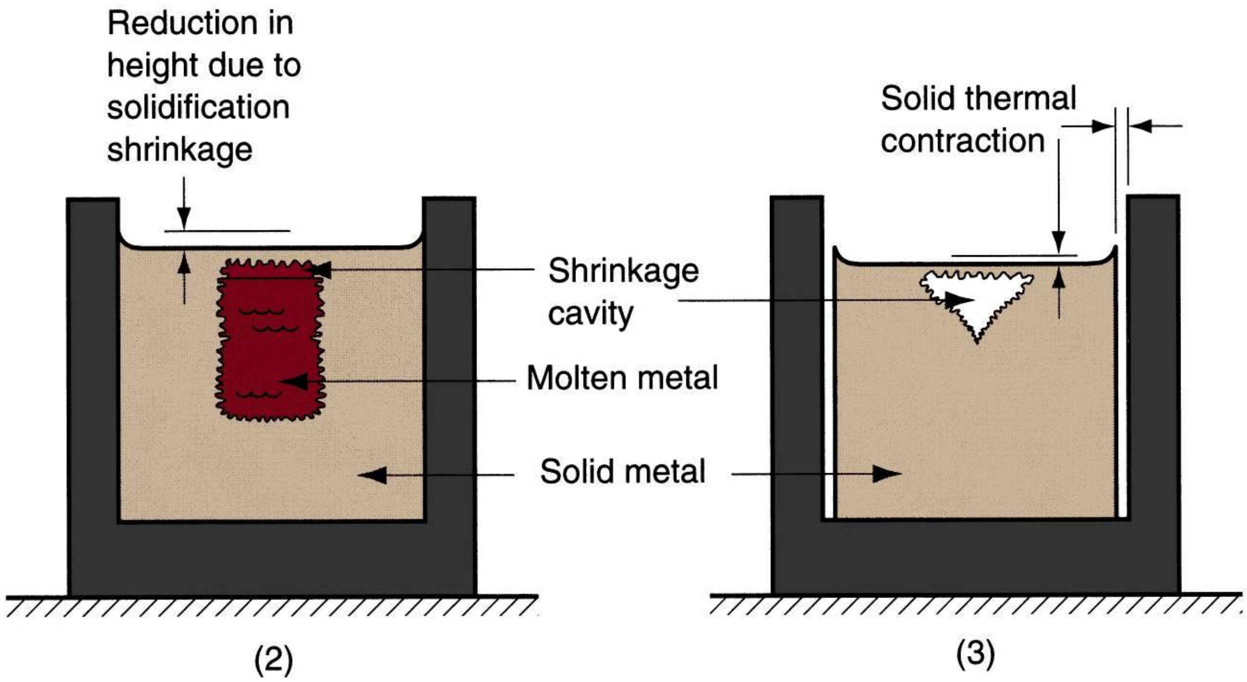
Shrinkage in Solidification and Cooling



reduction in height and formation of shrinkage cavity caused by solidification shrinkage; (3) further reduction in height and diameter due to thermal contraction during cooling of solid metal (dimensional reductions are exaggerated for clarity).

Solidification Shrinkage

- Occurs in nearly all metals because the solid phase has a higher density than the liquid phase
- Thus, solidification causes a reduction in volume per unit weight of metal
- Exception: cast iron with high C content
  - Graphitization during final stages of freezing causes expansion that counteracts volumetric decrease associated with phase change

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Shrinkage Allowance

- Patternmakers account for solidification shrinkage and thermal contraction by making mold cavity oversized
- Amount by which mold is made larger relative to final casting size is called *pattern shrinkage allowance*
- Casting dimensions are expressed linearly, so allowances are applied accordingly

Directional Solidification

- To minimize damaging effects of shrinkage, it is desirable for regions of the casting most distant from the liquid metal supply to freeze first and for solidification to progress from these remote regions toward the riser(s)
  - Thus, molten metal is continually available from risers to prevent shrinkage voids
  - The term *directional solidification* describes this aspect of freezing and methods by which it is controlled

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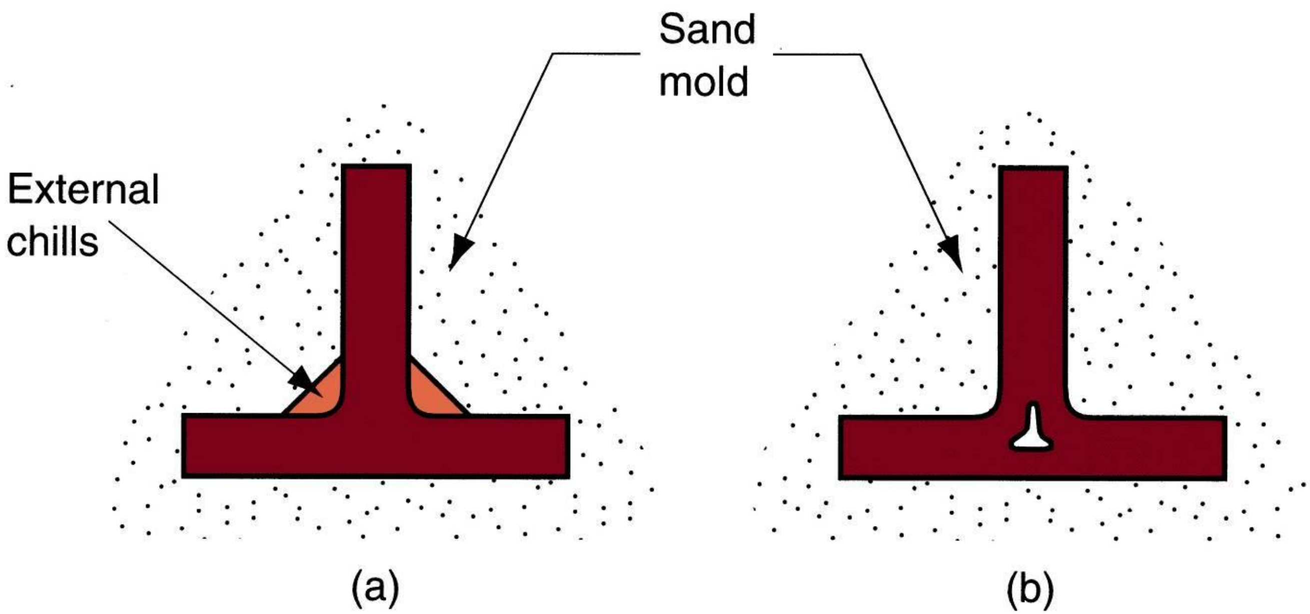
Achieving Directional Solidification

- Desired directional solidification is achieved using Chvorinov's Rule to design the casting itself, its orientation in the mold, and the riser system that feeds it
- Locate sections of the casting with lower *V/A* ratios away from riser, so freezing occurs first in these regions, and the liquid metal supply for the rest of the casting remains open
- *Chills* - internal or external heat sinks that cause rapid freezing in certain regions of the casting

External Chills



External chill to encourage rapid freezing of the molten metal in a thin section of the casting; and (b) the likely result if the external chill were not used.

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Riser Design

- Riser is waste metal that is separated from the casting and remelted to make more castings
- To minimize waste in the unit operation, it is desirable for the volume of metal in the riser to be a minimum
- Since the geometry of the riser is normally selected to maximize the *V/A* ratio, this allows riser volume to be reduced to the minimum possible value

P A T T E R N

PATTERN:

- A Pattern is a model or the replica of the object to be cast.
- Except for the various allowances a pattern exactly resembles the casting to be made (slightly larger).
- Patterns may be in two or three pieces, where as casting are in a single piece.
- A pattern is required even if one object has to be cast.
- The quality of casting and the final product will be effected to a great extent by the planning of pattern.

Functions of Patterns:

- A Pattern prepares a mould cavity for the purpose of making a casting.
- A Pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.
- Risers, runners and gates may form a part of the pattern.
- Patterns properly made and having finished and smooth surfaces reduce casting defects.
- Properly constructed patterns minimize overall cost of the casting.

Selection of Pattern Materials:

The following factors assist in selecting proper pattern material:

- No. of castings to be produced.
- Metal to be cast.
- Dimensional accuracy & surface finish.
- Shape, complexity and size of casting.
- Casting design parameters.
- Type of molding materials.
- The chance of repeat orders.
- Nature of molding process.
- Position of core print.

The pattern material should be:

1. Easily worked, shaped and joined.
2. Light in weight.
3. Strong, hard and durable.
4. Resistant to wear and abrasion .
5. Resistant to corrosion, and to chemical reactions.
6. Dimensionally stable and unaffected by variations in temperature and humidity.
7. Available at low cost.

PATTERN MATERIALS

Materials for making patterns:

a. Wood
b. Metal
c. Plastic
d. Plaster
e. Wax.

1. Wood Patterns:

These are used where the no. of castings to be produced is small and pattern size is large.

__Advantages__:

- ✓ Inexpensive
- ✓ Easily available in large quantities
- ✓ Easy to fabricate
- ✓ Light in weight
- ✓ They can be repaired easily
- ✓ Easy to obtain good surface finish

Limitations:

- Susceptible to shrinkage and swelling
- Possess poor wear resistance
- Abraded easily by sand action
- Absorb moisture, consequently get warped
- Cannot withstand rough handling
- Life is very short

Commonly used woods for making patterns:

a. Teak
b. Pine
c. Mahogony
d. Deodar
e. Shisham
f. Kail etc..

2. Metal Patterns:

These are employed where large no. of castings have to be produced from same patterns.

Advantages:

- ✓Do not absorb moisture
- ✓More stronger
- ✓Possess much longer life
- ✓Do not warp, retain their shape
- ✓Greater resistance to abrasion
- ✓Accurate and smooth surface finish
- ✓Good machinability

Limitations:

- Expensive
- Require a lot of machining for accuracy
- Not easily repaired
- Ferrous patterns get rusted
- Heavy weight , thus difficult to handle

Commonly used metals for making patterns:

i. Cast iron
ii. Aluminium and its alloys
iii. Steel
iv. White metal
v. Brass etc..

3. Plastic Patterns:

Advantages:

- ✓ Durable
- ✓ Provides a smooth surface
- ✓ Moisture resistant
- ✓ Does not involve any appreciable change in size or shape
- ✓ Light weight
- ✓ Good strength
- ✓ Wear and corrosion resistance
- ✓ Easy to make
- ✓ Abrasion resistance
- ✓ Good resistance to chemical attack

Limitations:

- Plastic patterns are Fragile
- These are may not work well when subject to conditions of severe shock as in machine molding (jolting).

4. Plaster Patterns:

Advantages:

- ✓ It can be easily worked by using wood working tools.
- ✓ Intricate shapes can be cast without any difficulty.
- ✓ It has high compressive strength.

- *Plaster may be made out of Plaster of paris or Gypsum cement.*
- *Plaster mixture is poured into a mould made by a sweep pattern or a wooden master pattern, in order to obtain a Plaster pattern.*

5. Wax patterns:

Advantages:

- ✓ Provide very good surface finish.
- ✓ Impart high accuracy to castings.
- ✓ After being molded, the wax pattern is not taken out of the mould like other patterns;
- ✓ rather the mould is inverted and heated; the molten wax comes out and/or is evaporated.
- ✓ Thus there is no chance of the mould cavity getting damaged while removing the pattern.

- ➢ *Wax patterns find applications in **Investment casting** process.*

TYPES OF PATTERNS

Types of patterns depend upon the following factors:

1. The shape and size of casting
2. No. of castings required
3. Method of moulding employed
4. Anticipated difficulty of moulding operation

Types of Patterns:

1. Single piece pattern.
2. Split piece pattern.
3. Loose piece pattern.
4. Match plate pattern.
5. Sweep pattern.
6. Gated pattern.
7. Skeleton pattern
8. Follow board pattern.
9. Cope and Drag pattern.

1. Single piece (solid) pattern:

- Made from one piece and does not contain loose pieces or joints.
- Inexpensive.
- Used for large size simple castings.
- Pattern is accommodated either in the cope or in the drag.

Examples:

1. Bodies of regular shapes.
2. stuffing box of steam engine.

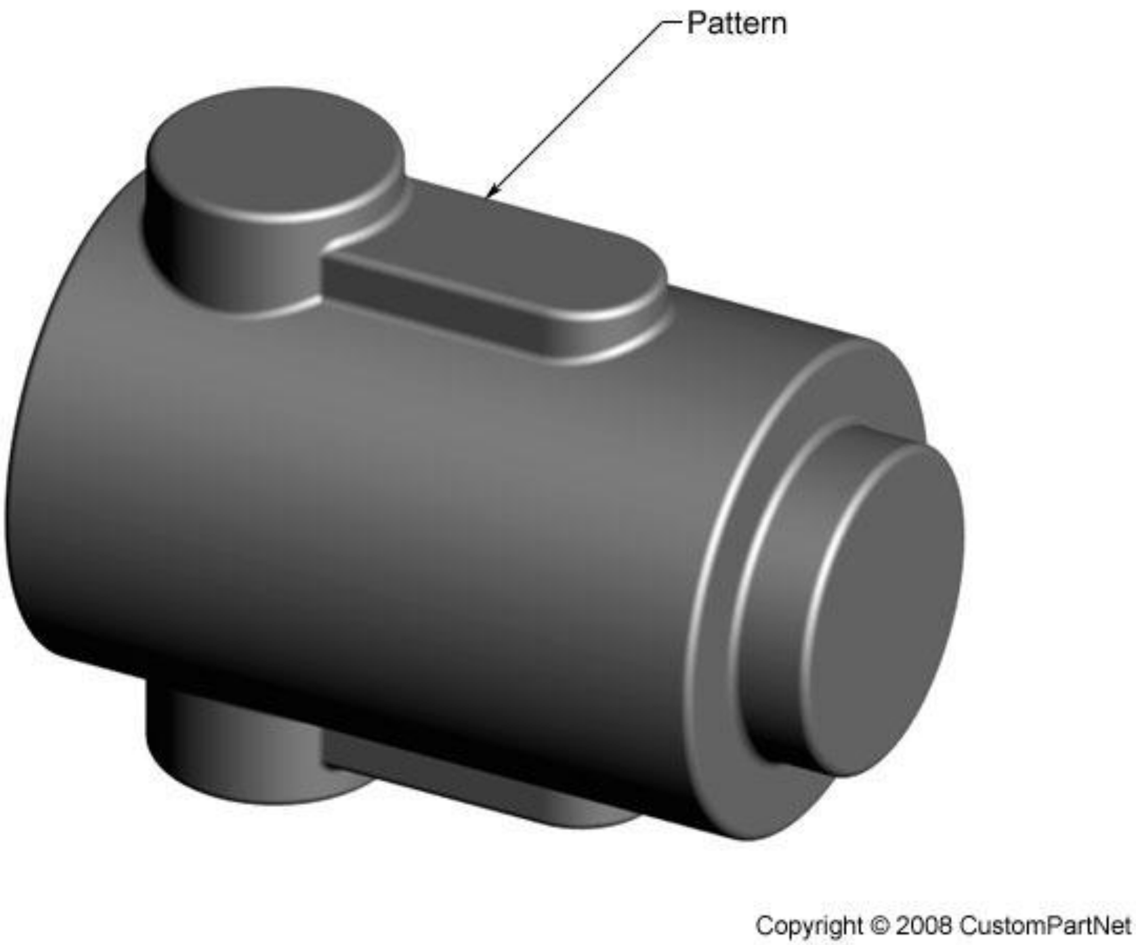
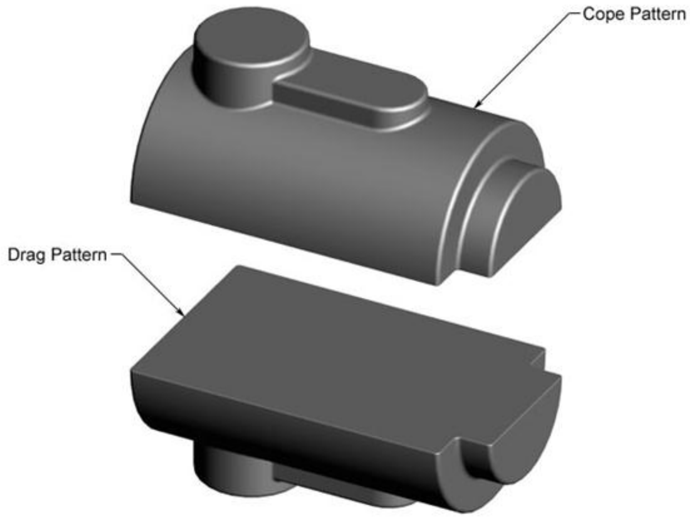


Fig: Single piece pattern

2. Split piece pattern:

- Patterns of intricate shaped castings cannot be made in one piece because of the inherent difficulties associated with the molding operations (e.g. withdrawing pattern from mould).
- The upper and the lower parts of the split piece patterns are accommodated in the cope and drag portions of the mold respectively.
- Parting line of the pattern forms the parting line of the mould.
- Dowel pins are used for keeping the alignment between the two parts of the pattern.
- Examples:
  1. Hollow cylinder
  2. Taps and water
  - stop cocks etc.,



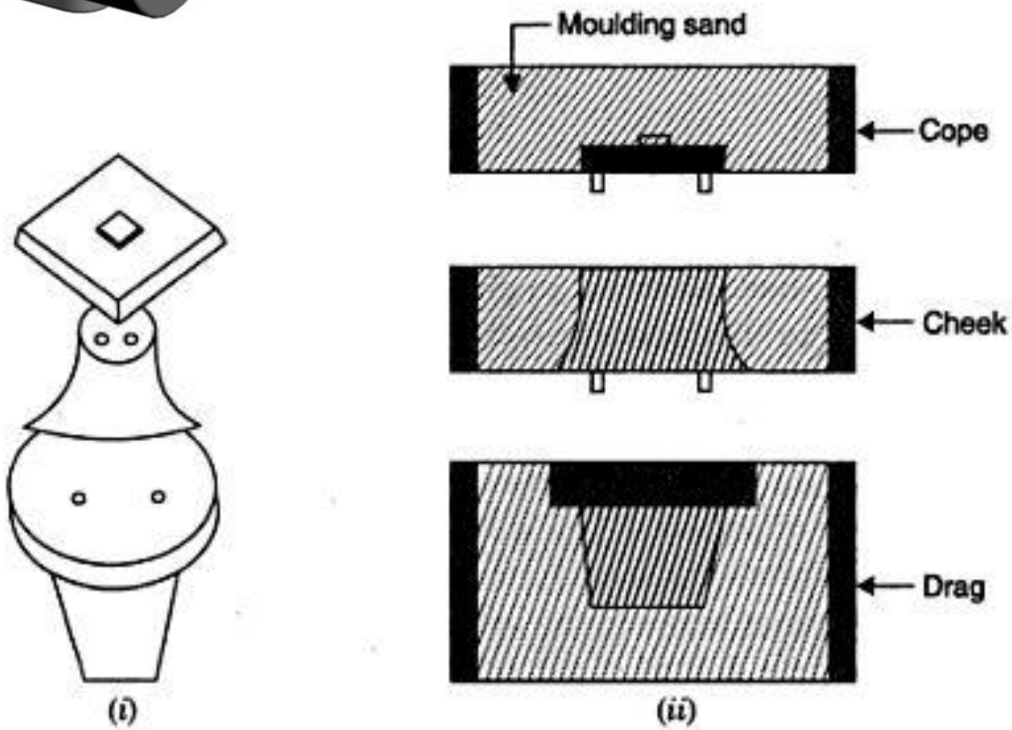
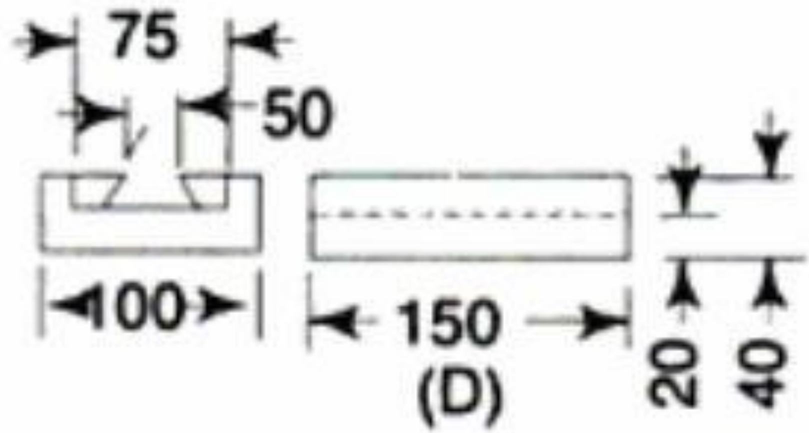
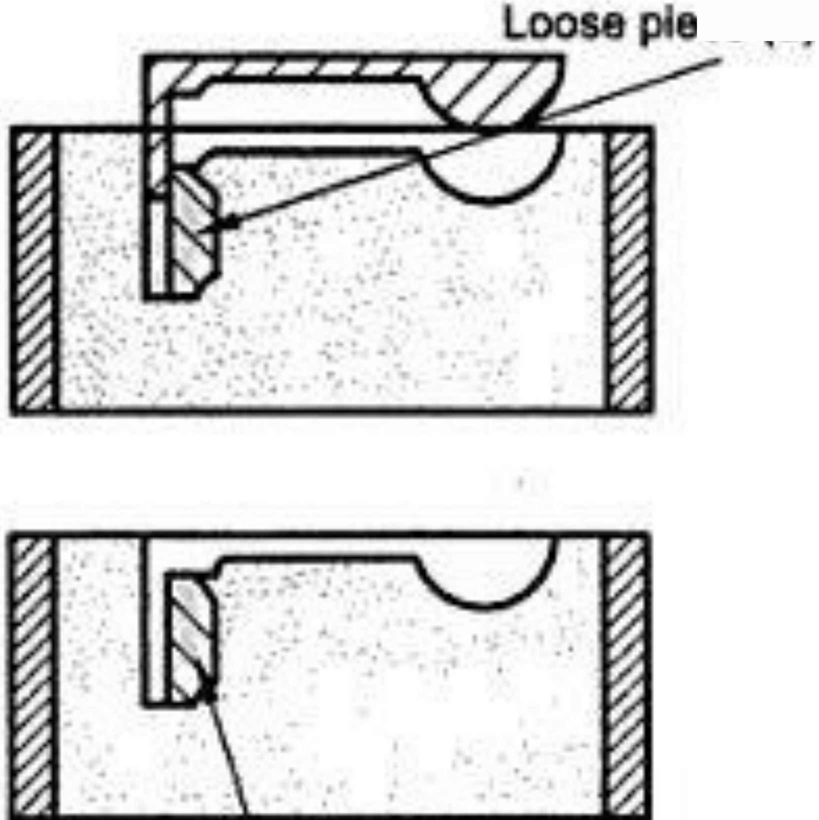


Fig. 2.3. Multipiece pattern.

3.Loose piece pattern:

- Certain patterns cannot be withdrawn once they are embedded in the molding sand. Such patterns are usually made with one or more loose pieces for facilitating removal from the molding box and are known as loose piece patterns.
- Loose parts or pieces remain attached with the main body of the pattern, with the help of dowel pins.
- The main body of the pattern is drawn first from the molding box and thereafter as soon as the loose parts are removed, the result is the mold cavity.





Loose piece left in the mold after pattern removal (b)

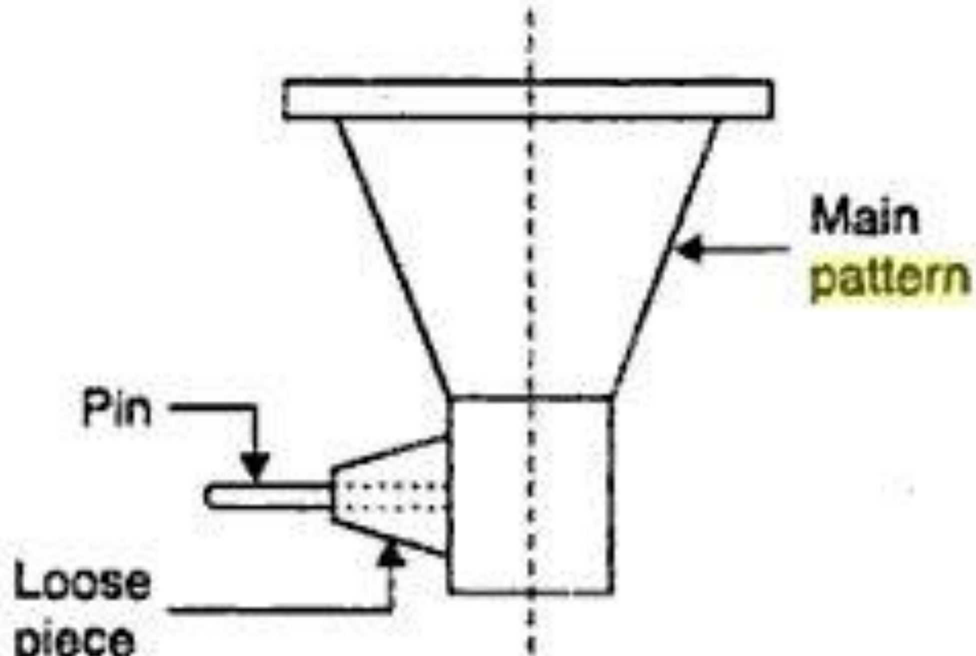


Fig. 1.75. Loose piece pattern.

4. Match plate pattern:

- It consists of a match plate, on either side of which each half of split patterns is fastened.
- A no. of different sized and shaped patterns may be mounted on one match plate.
- The match plate with the help of locator holes can be clamped with the drag.
- After the cope and drag have been rammed with the molding sand, the match plate pattern is removed from in between the cope and drag.
- Match plate patterns are normally used in machine molding.
- By using this we can eliminate mismatch of cope and drag cavities.

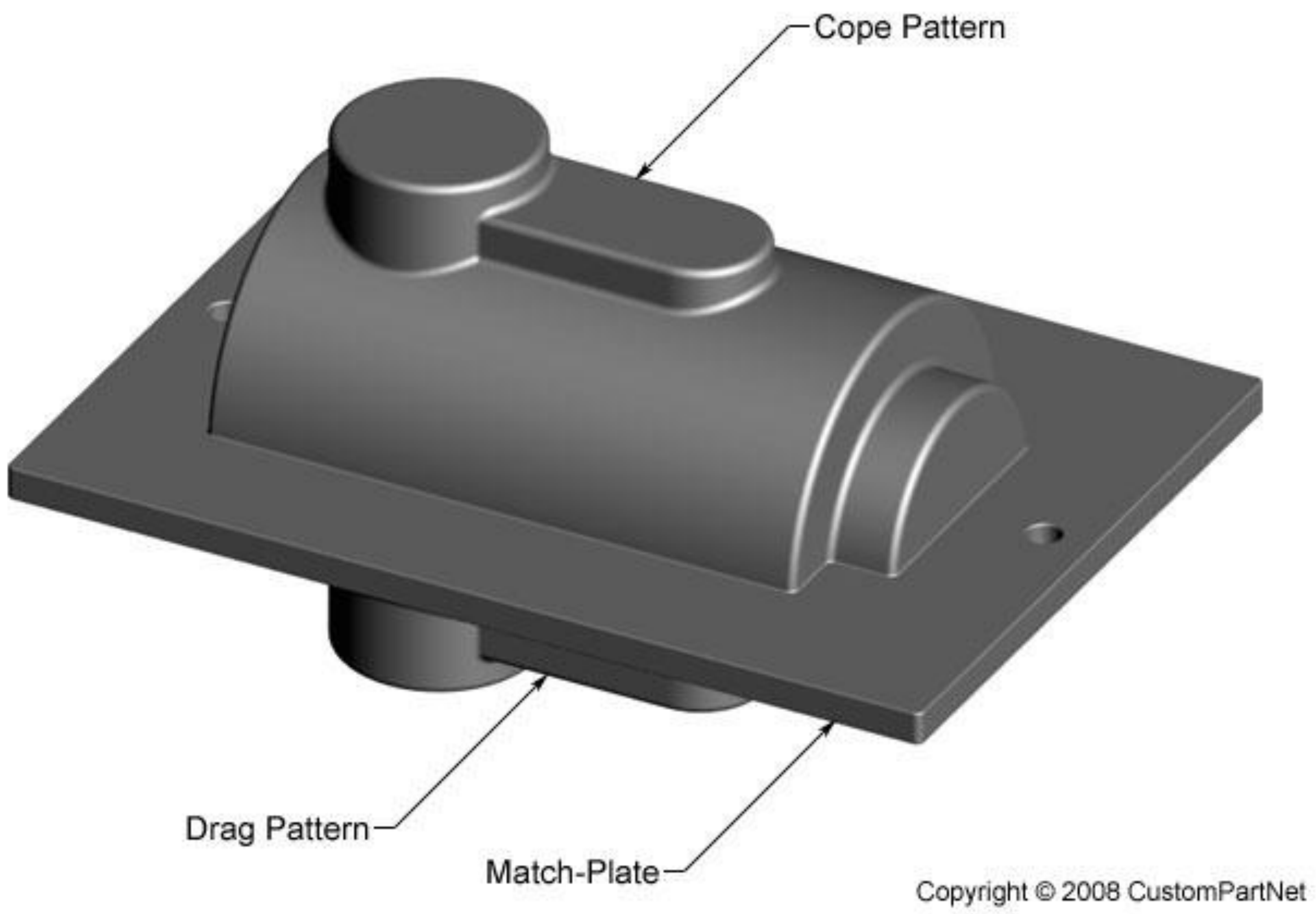


Fig: Match plate pattern

5. Sweep pattern:

- A sweep pattern is just a form made on a wooden board which sweeps the shape of the casting into the sand all around the circumference. The sweep pattern rotates about the post.
- Once the mold is ready, Sweep pattern and the post can be removed.
- Sweep pattern avoids the necessity of making a full, large circular and costly three-dimensional pattern.
- Making a sweep pattern saves a lot of time and labour as compared to making a full pattern.
- A sweep pattern is preferred for producing large casting of circular sections and symmetrical shapes.

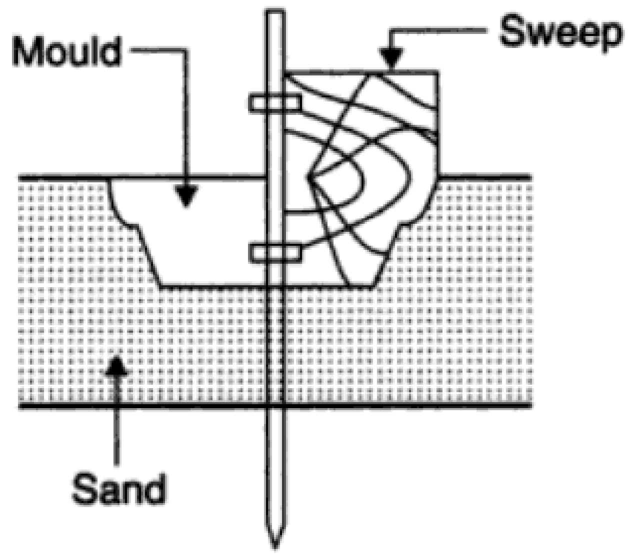


Fig. 2.8. Sweep pattern.

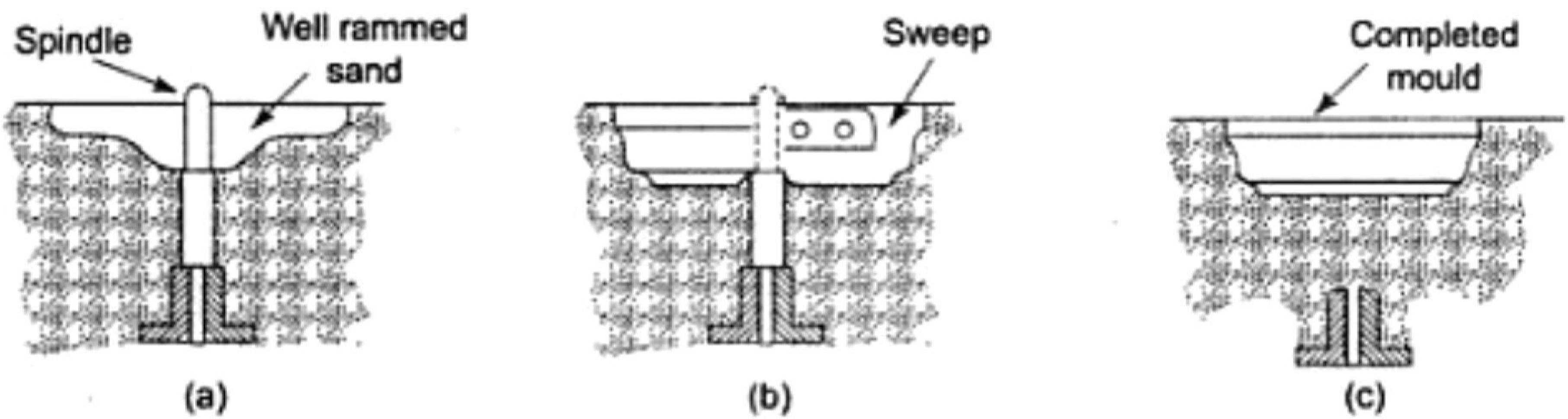


Fig. 3.15 *Sweep pattern*

6. Gated pattern:

- The sections connecting different patterns serve as runner and gates.
- This facilitates filling of the mould with molten metal in a better manner and at the same time eliminates the time and labour otherwise consumed in cutting runners and gates.
- A gated pattern can manufacture many casting at one time and thus it is used in mass production systems.
- Gated patterns are employed for producing small castings.

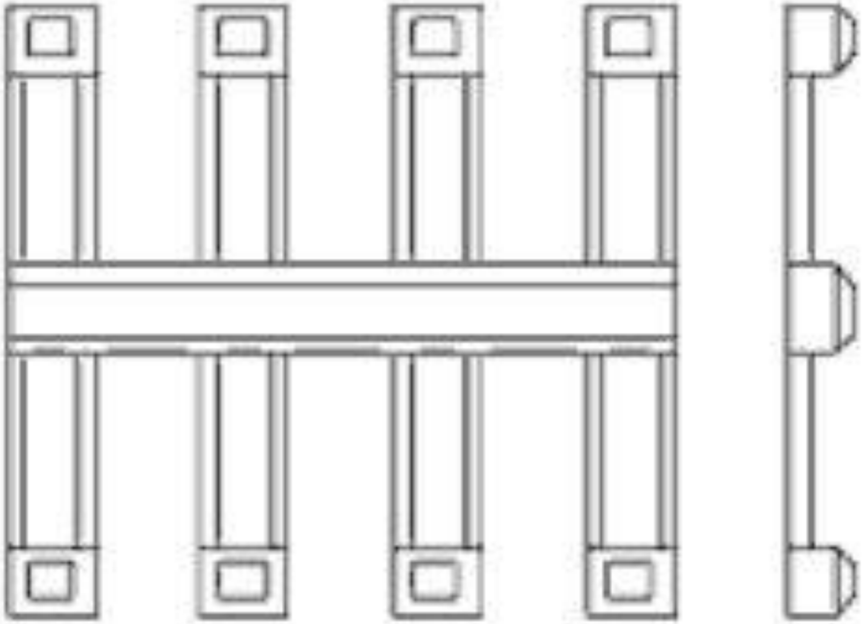
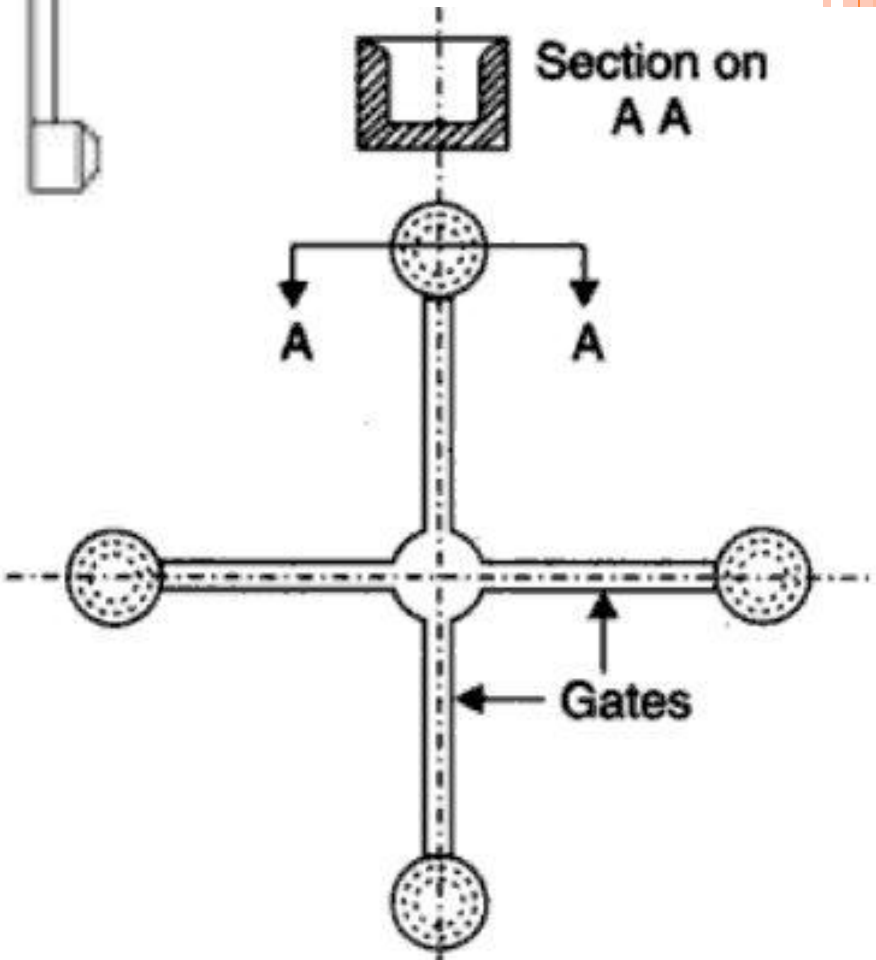


Fig. 1.10 Gated pattern



CASTINGS

Gating system

:::Skeleton pattern:::

- A skeleton pattern is the skeleton of a desired shape which may be S-bend pipe or a chute or something else. The skeleton frame is mounted on a metal base.
- The skeleton is made from wooden strips, and is thus a wooden work.
- The skeleton pattern is filled with sand and is rammed.
- A strickle (board) assists in giving the desired shape to the sand and removes extra sand.
- Skeleton patterns are employed for producing a few large castings.
- A skeleton pattern is very economical, because it involves less material costs.

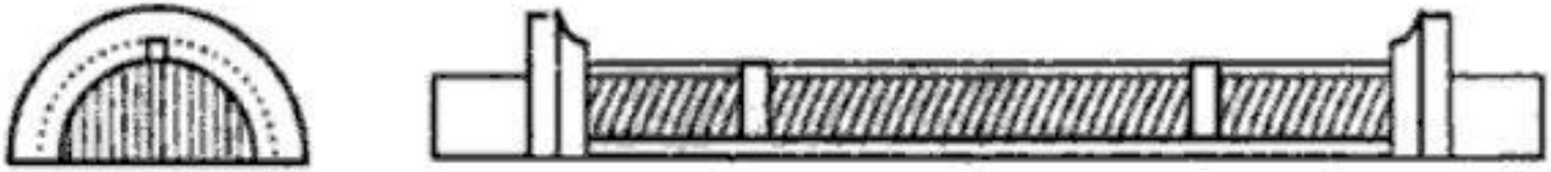


Fig. 1.78. A skeleton pattern for a flanged pipe.

8. Follow board pattern:

- A follow board is a wooden board and is used for supporting a pattern which is very thin and fragile and which may give way and collapse under pressure when the sand above the pattern is being rammed.
- With the follow board support under the weak pattern, the drag is rammed, and then the follow board is with drawn, The rammed drag is inverted, cope is mounted on it and rammed.
- During this operation pattern remains over the inverted drag and get support from the rammed sand of the drag under it.
- Follow boards are also used for casting master patterns for many applications.

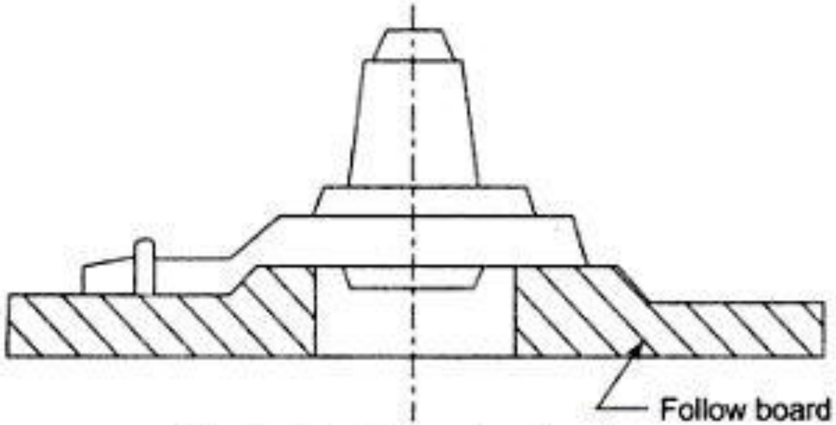


Fig. 3.14 *Follow board pattern*

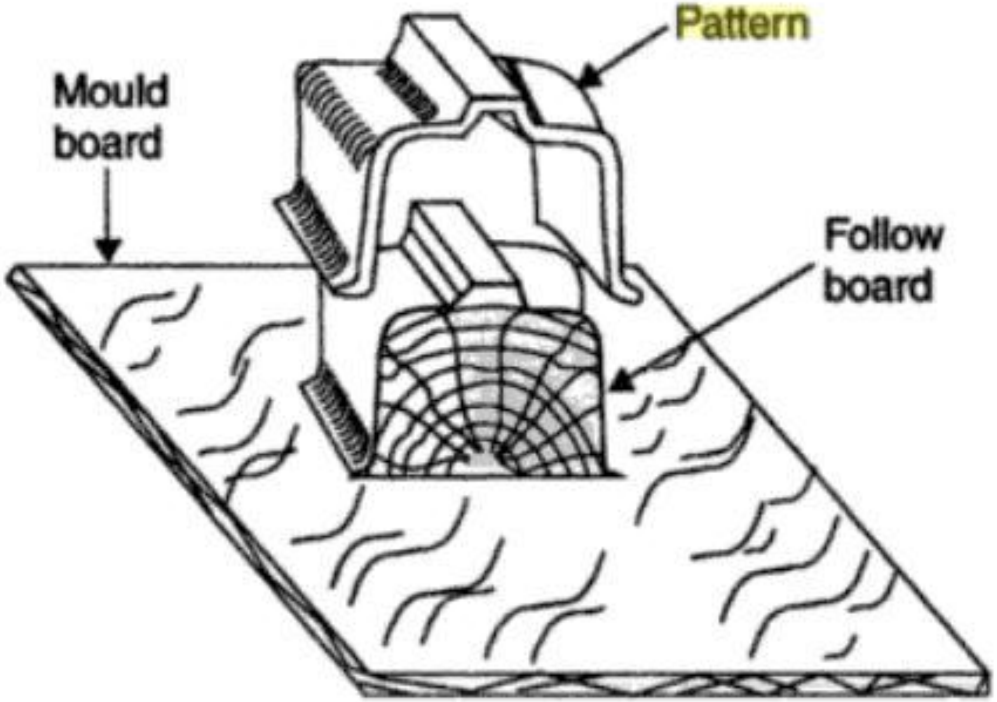


Fig. 1.80. A follow board pattern.

9. Cope and Drag patterns:

- A cope and drag pattern is another form of split pattern.
- Each half of the pattern is fixed to a separate metal/wood plate.
- Each half of the pattern(along the plate) is molded separately in a separate molding box by an independent molder or moulders.
- The two moulds of each half of the pattern are finally assembled and the mould is ready for pouring.
- Cope and drag patterns are used for producing big castings which as a whole cannot be conveniently handled by one moulder alone.

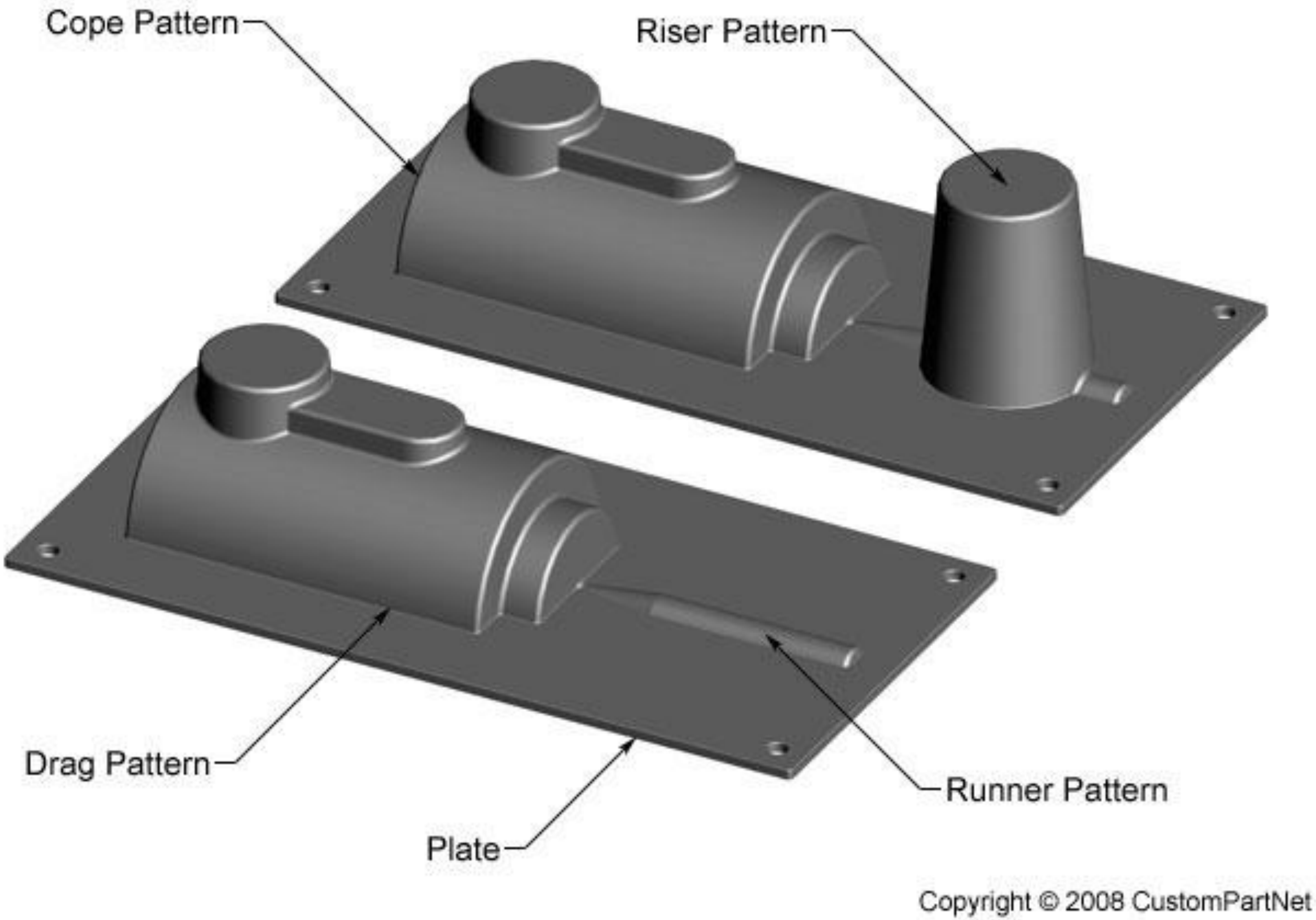
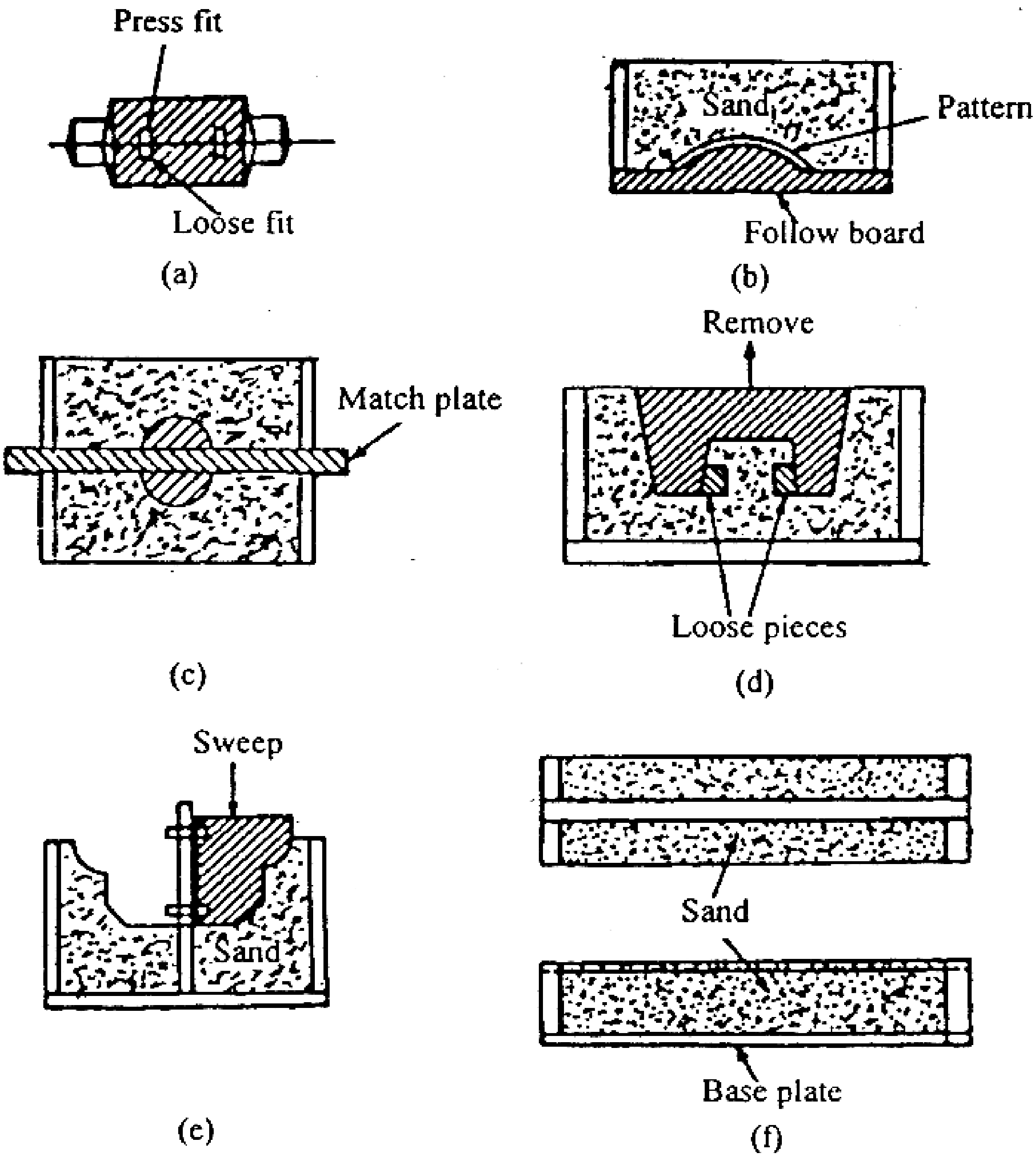


Fig: Cope and drag pattern



(A)SPLIT PATTERN

(B) FOLLOW-BOARD

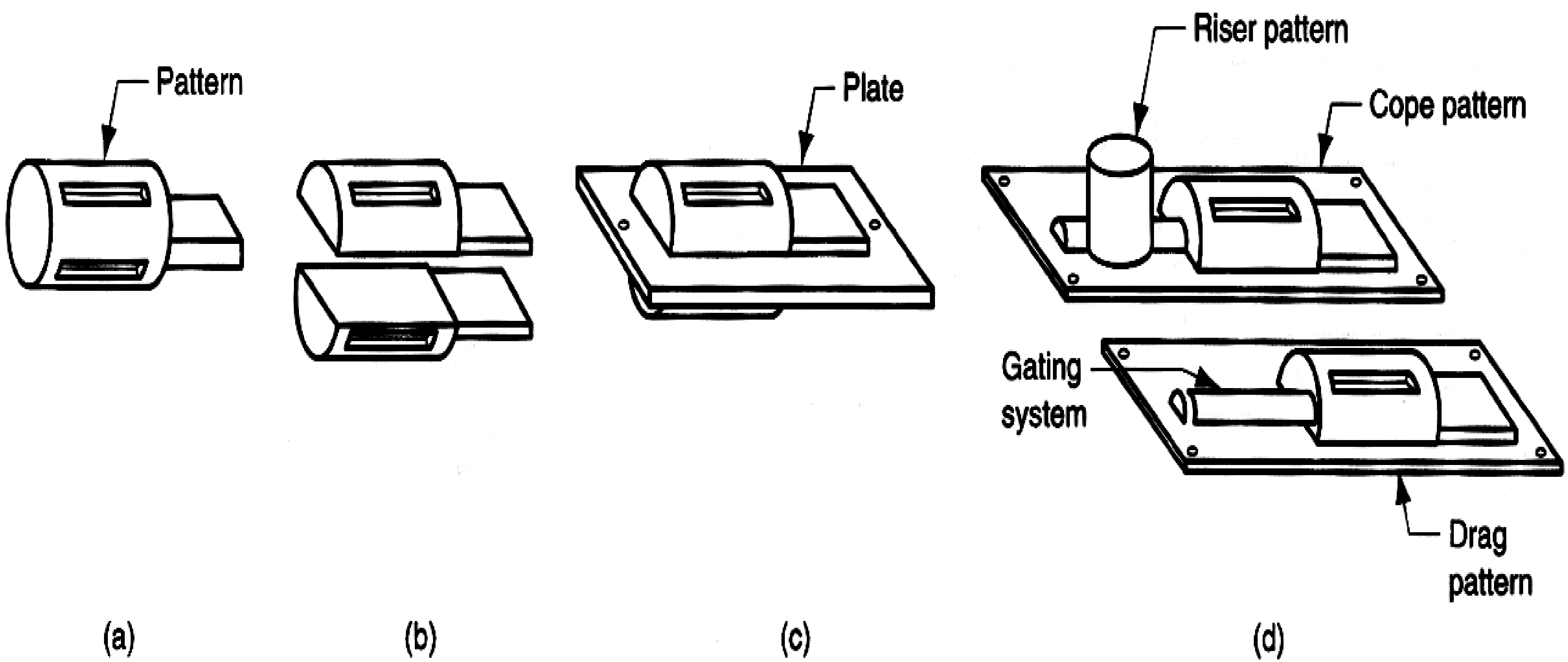
(C) MATCH PLATE

(D) LOOSE-PIECE

(E) SWEEP

(F) SKELETON PATTERN

Types of patterns used in sand casting: (a) solid pattern, (b) split pattern, (c) match-plate pattern, and (d) cope-and-drag pattern.



PATTERN ALLOWANCES

Pattern Allowances:

A pattern is larger in size as compared to the final casting, because it carries certain allowances due to metallurgical and mechanical reasons for example, shrinkage allowance is the result of metallurgical phenomenon where as machining, draft, distortion, shake and other allowances are provided on the patterns because of mechanical reasons.

Types of Pattern Allowances:

The various pattern allowances are:

1. Shrinkage or contraction allowance.
2. Machining or finish allowance.
3. Draft or taper allowances.
4. Distortion or chamber allowance.
5. Shake or rapping allowance.

1.Shrinkage Allowance:

All most all cast metals shrink or contract volumetrically on cooling.

The metal shrinkage is of two types:

1. *Liquid Shrinkage*:

It refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mold.

2. *Solid Shrinkage*:

It refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

- Almost all cast metals shrink or contract volumetrically after solidification and therefore the pattern to obtain a particular sized casting is made oversize by an amount equal to that of shrinkage or contraction.
- Different metals shrink at different rates because shrinkage is the property of the cast metal/alloy.
- *The metal shrinkage depends upon*:

1. The cast metal or alloy.
2. Pouring temp. of the metal/alloy.
3. Casted dimensions(size).
4. Casting design aspects.
5. Molding conditions(i.e., mould materials and molding methods employed)

Table 3. Contraction Allowance for Different Metals

S. No.	Metals/Alloys	Contraction allowance mm/metre
1.	Grey cast iron	7 to 10.5
2.	While cast iron	21
3.	Malleable iron	15
4.	Steel	20
5.	Copper	16
6.	Brass	16
7.	Bronze	10.5 to 21
8.	Zinc	24
9.	Lead	24
10.	Aluminium	16
11.	Magnesium	18

The contraction of metals/alloys is always volumetric, but the contraction allowances are always expressed in linear measures.

2. Machining Allowance:

A Casting is given an allowance for machining, because:

i. Castings get oxidized in the mold and during heat treatment; scales etc., thus formed need to be removed.
ii. It is the intended to remove surface roughness and other imperfections from the castings.
iii. It is required to achieve exact casting dimensions.
iv. Surface finish is required on the casting.

How much extra metal or how much machining allowance should be provided, depends on the factors listed below:

i. Nature of metals.
ii. Size and shape of casting.
iii. The type of machining operations to be employed for cleaning the casting.
iv. Casting conditions.
v. Molding process employed

Machining Allowances of Various Metals:

Table 2.3

Material	***Dimensions (in mm)***	***Machining allowance (in mm)***
Cast Iron	Up to 300 300 to 600	2.5 4.0
Aluminium	Up to 300 300 to 600	1.5 3.0
Cast Steel	Up to 300 300 to 600	3.0 4.5

3. Draft or Taper Allowance:

- It is given to all surfaces perpendicular to parting line.
- Draft allowance is given so that the pattern can be easily removed from the molding material tightly packed around it with out damaging the mould cavity.
- The amount of taper depends upon:
  - i. Shape and size of pattern in the depth direction in contact with the mould cavity.
  - ii. Moulding methods.
  - iii. Mould materials.
  - iv. Draft allowance is imparted on internal as well as external surfaces; of course it is more on internal surfaces.

The taper provided by the pattern maker on all vertical surfaces of the pattern so that it can be removed from the sand without tearing away the sides of the sand mold and without excessive rapping by the molder. Figure 3 (a) shows a pattern having no draft allowance being removed from the pattern. In this case, till the pattern is completely lifted out, its sides will remain in contact with the walls of the mold, thus tending to break it.

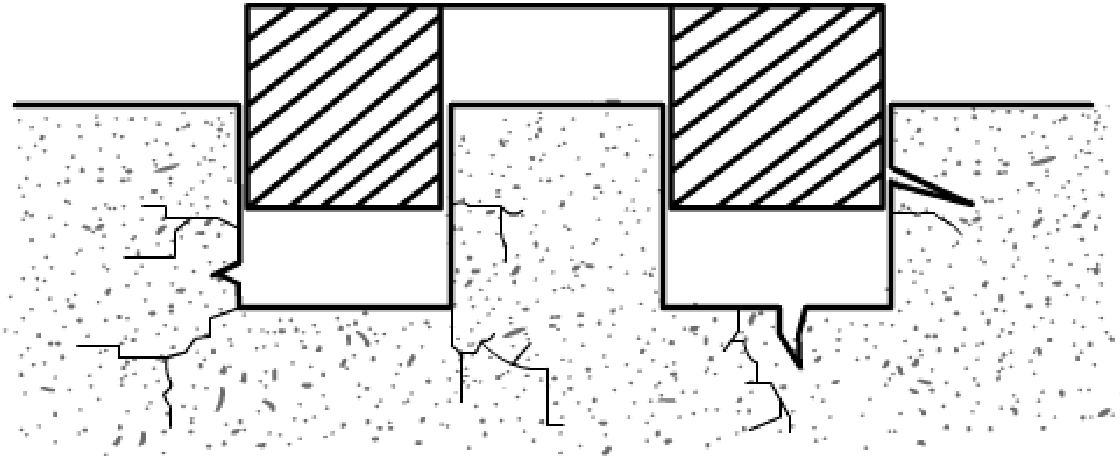


Figure 3 (a) Pattern Having No Draft on Vertical Edges

Figure 3 (b) is an illustration of a pattern having proper draft allowance. Here, the moment the pattern lifting commences, all of its surfaces are well away from the sand surface. Thus the pattern can be removed without damaging the mold cavity.

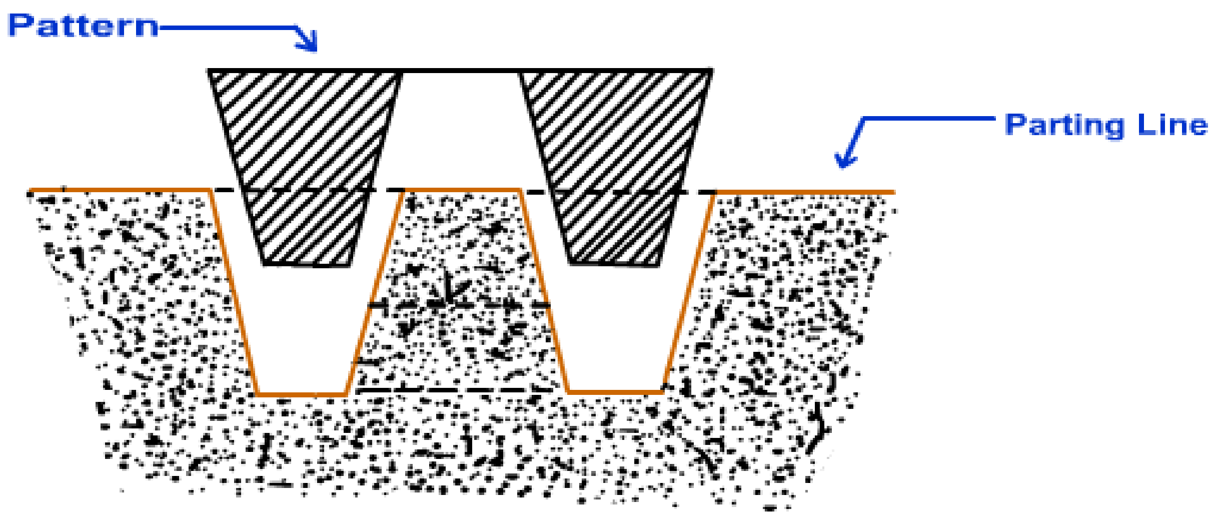


Figure 3 (b) Pattern Having Draft on Vertical Edges

Table 7.2 Suggested draft values for patterns

Pattern material	Height of the given surface, mm	Draft angle of surfaces, degrees	
		External surface	Internal surface
Wood	upto 20	3.00	3.00
	21 to 50	1.50	2.50
	51 to 100	1.00	1.50
	101 to 200	0.75	1.00
	201 to 300	0.50	1.00
	301 to 800	0.50	0.75
	801 to 2000	0.35	0.50
	over 2000	—	0.25
Metal and plastic	20	1.50	3.00
	21 to 50	1.00	2.00
	51 to 100	0.75	1.00
	101 to 200	0.50	0.75
	201 to 300	0.50	0.75
	301 to 800	0.35	0.50

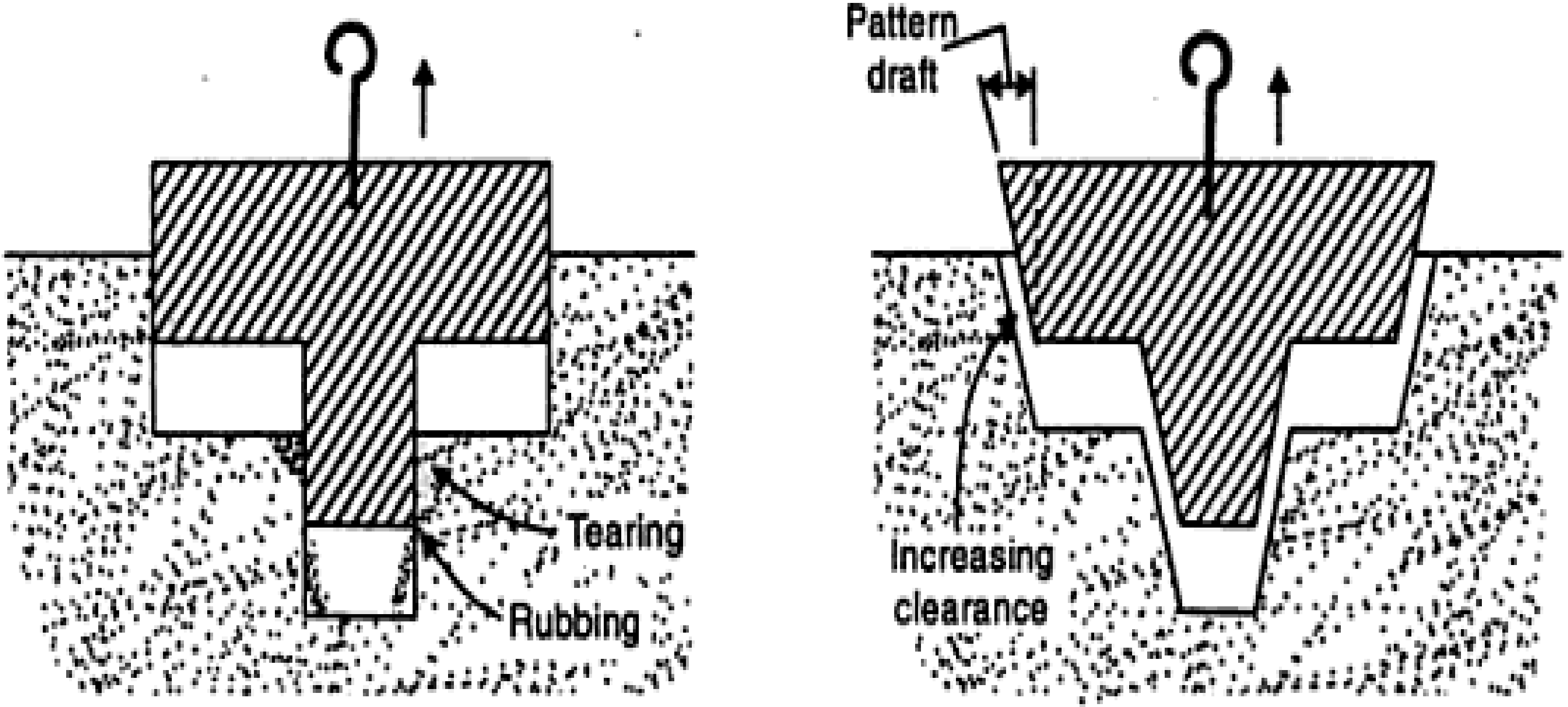


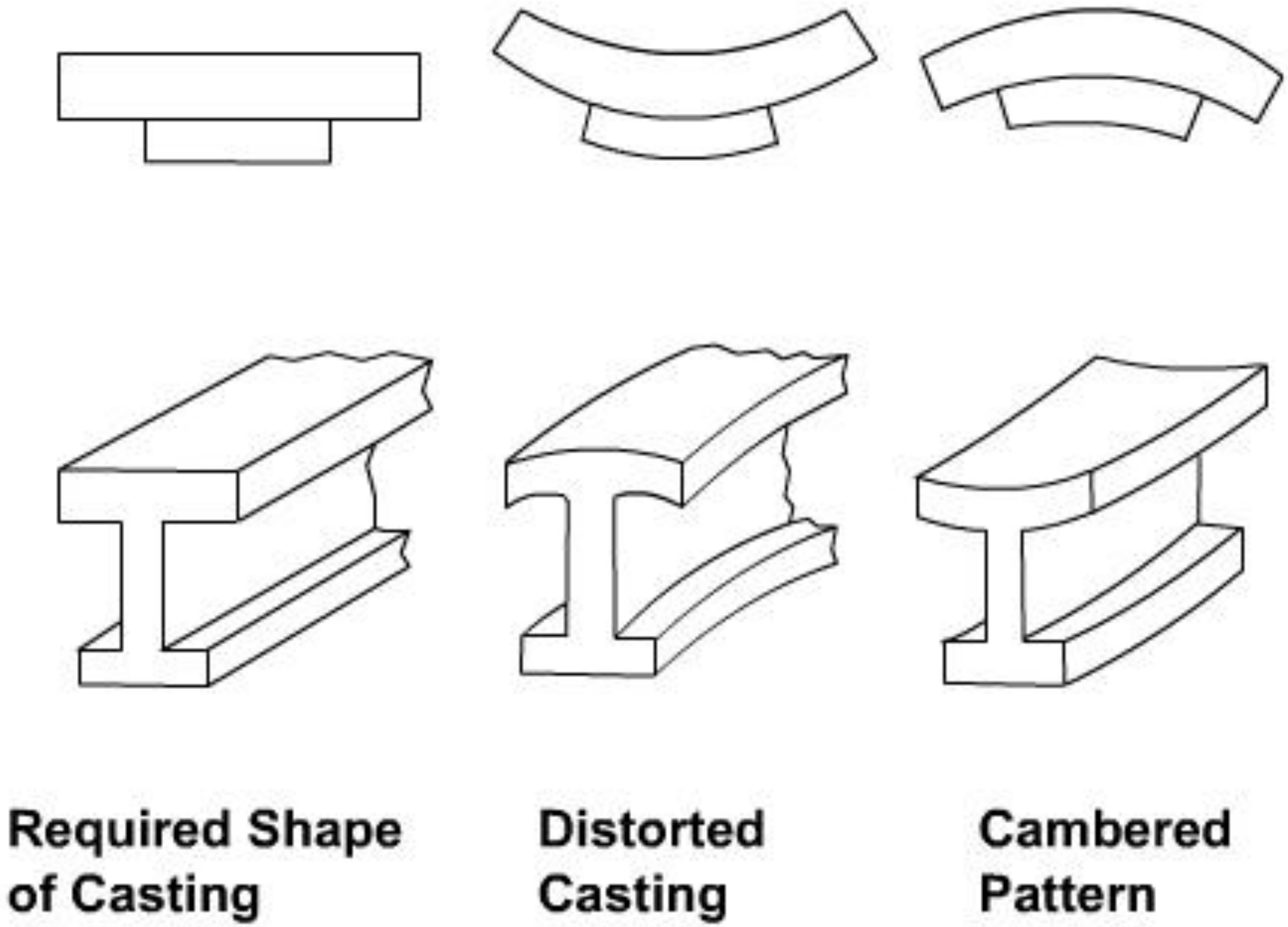
Fig. 2.9 *Draft Allowance*.

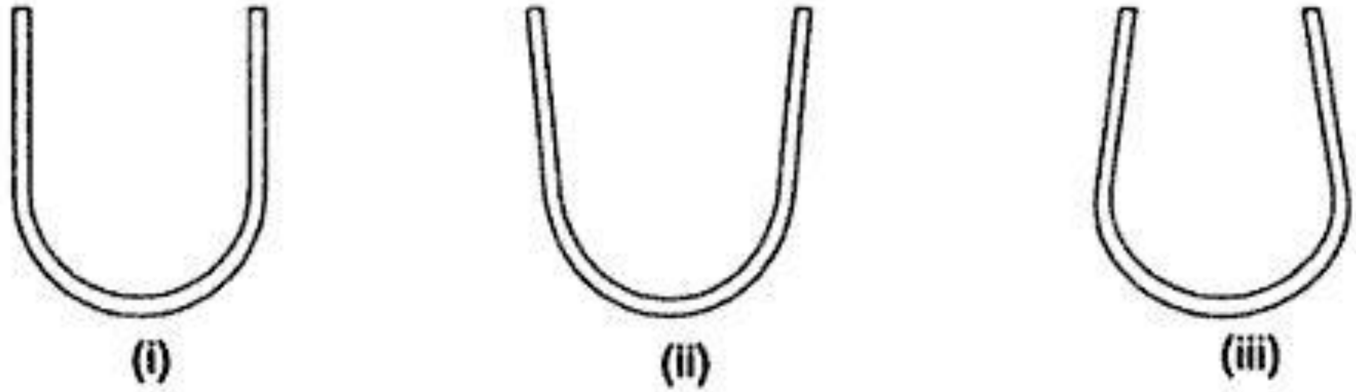
FIG: TAPER IN DESIGN

4. Distortion or cambered allowance:

A casting will distort or wrap if :

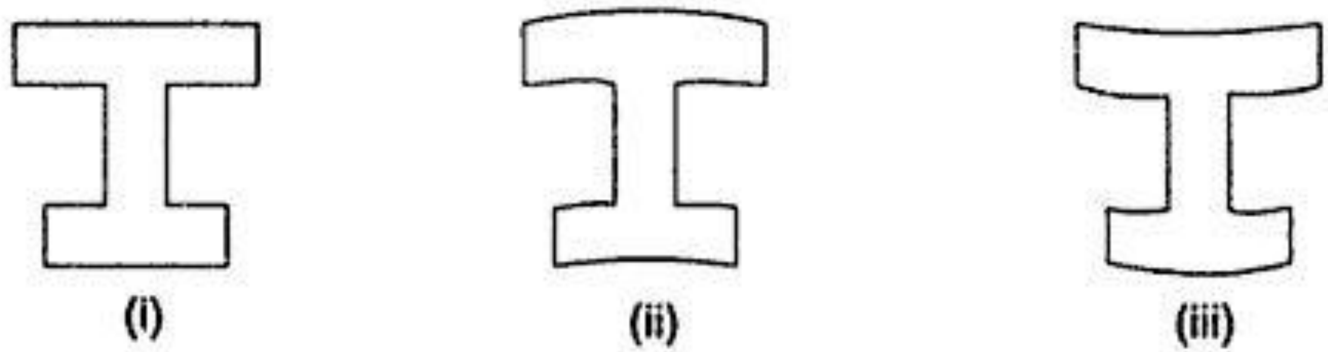
i. It is of irregular shape,
ii. All it parts do not shrink uniformly i.e., some parts shrinks while others are restricted from during so,
iii. It is u or v-shape,
iv. The arms possess unequal thickness,
v. It has long, rangy arms as those of propeller strut for the ship,
vi. It is a long flat casting,
vii. One portion of the casting cools at a faster rate as compared to the other.


Required Shape
of Casting
Distorted
Casting
Cambered
Pattern



(a) *U-shaped Casting*

(i) Required shape of casting
(ii) Casting produced with distortion
(iii) Pattern provided with Camber allowance



(b) *I-section Casting*

5. Shake allowance:

- A patter is shaken or rapped by striking the same with a wooden piece from side to side. This is done so that the pattern a little is loosened in the mold cavity and can be easily removed.
- In turn, therefore, rapping enlarges the mould cavity which results in a bigger sized casting.
- Hence, a –ve allowance is provided on the pattern i.e., the pattern dimensions are kept smaller in order to compensate the enlargement of mould cavity due to rapping.
- The magnitude of shake allowance can be reduced by increasing the tapper.

PATTERN LAYOUT AND PATTERN CONSTRUCTION

Pattern Layout:

Steps involved:

- Get the working drawing of the part for which the pattern is to be made.
- Make two views of the part drawing on a sheet, using a *shrink rule*. A shrink rule is modified form of an ordinary scale which has already taken care of shrinkage allowance for a particular metal to be cast.
- Add machining allowances as per the requirements.
- Depending upon the method of molding, provide the draft allowance.

Pattern Construction:

- Study the pattern layout carefully and establish,
    a. Location of parting surface.
    b. No. of parts in which the pattern will be made.
- Using the various hand tools and pattern making machines fabricate the different parts of the pattern.
- Inspect the pattern as regards the alignment of different portions of the pattern and its dimensional accuracy.
- Fill wax in all the fillets in order to remove sharp corners.
- Give a shellac coatings(3 coats) to pattern.
- impart suitable colors to the pattern for identification purposes and for other informations.

PATTERN COLORS

Pattern Colors:

Patterns are imparted certain colors and shades in order to:

i. Identify quickly the main body of pattern and different parts of the pattern.
ii. Indicate the type of the metal to be cast.
iii. Identify core prints, loose pieces, etc.,
iv. Visualise the surfaces to be machined, etc.

the patterns are normally painted with contrasting colors such that the mould maker would be able to understand the functions clearly.

The color code used is,

1. Red or orange on surface not to be finished and left as cast
2. Yellow on surfaces to be machined
3. Black on core prints for unmachined openings
4. Yellow stripes on black on core prints for machined openings
5. Green on seats of and for loose pieces and loose core prints
6. Diagonal black strips with clear varnish on to strengthen the weak patterns or to shorten a casting.

Core Box

- Cores are compact mass of core sand that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting. The environment in which the core is placed is much different from that of the mold.
- In fact the core has to withstand the severe action of hot metal which completely surrounds it. Cores are classified according to shape and position in the mold. There are various types of cores such as horizontal core, vertical core, balanced core, drop coreand hanging core.

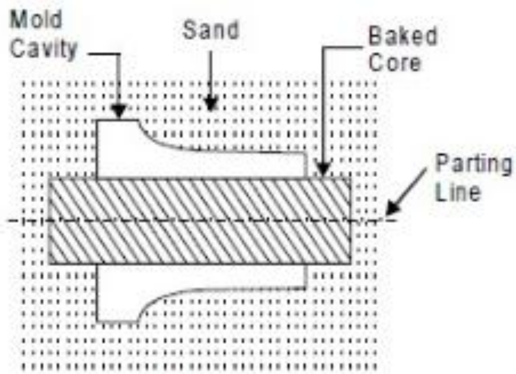


Fig. 10.12 Horizontal core

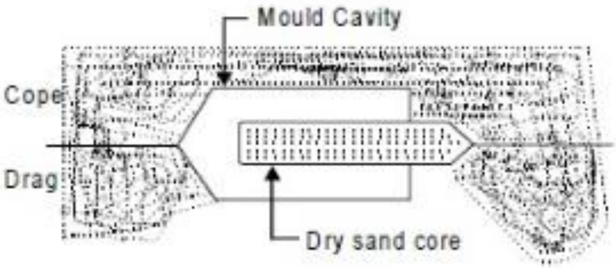


Fig. 10.13 Vertical core

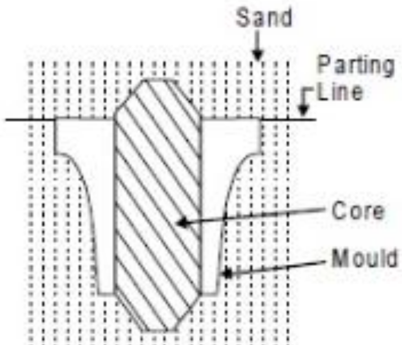


Fig. 10.14 Balanced core

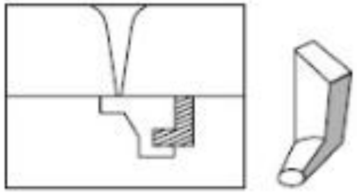


Fig. 10.15 Drop core

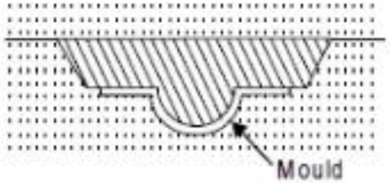


Fig. 10.16 Hanging core

There are various functions of cores which are given below

- 1. Core is used to produce hollowness in castings in form of internal cavities.
- 2. It may form a part of green sand mold
- 3. It may be deployed to improve mold surface.
- 4. It may provide external under cut features in casting.
- 5. It may be used to strengthen the mold.
- 6. It may be used to form gating system of large size mold
- 7. It may be inserted to achieve deep recesses in the casting

Core Boxes

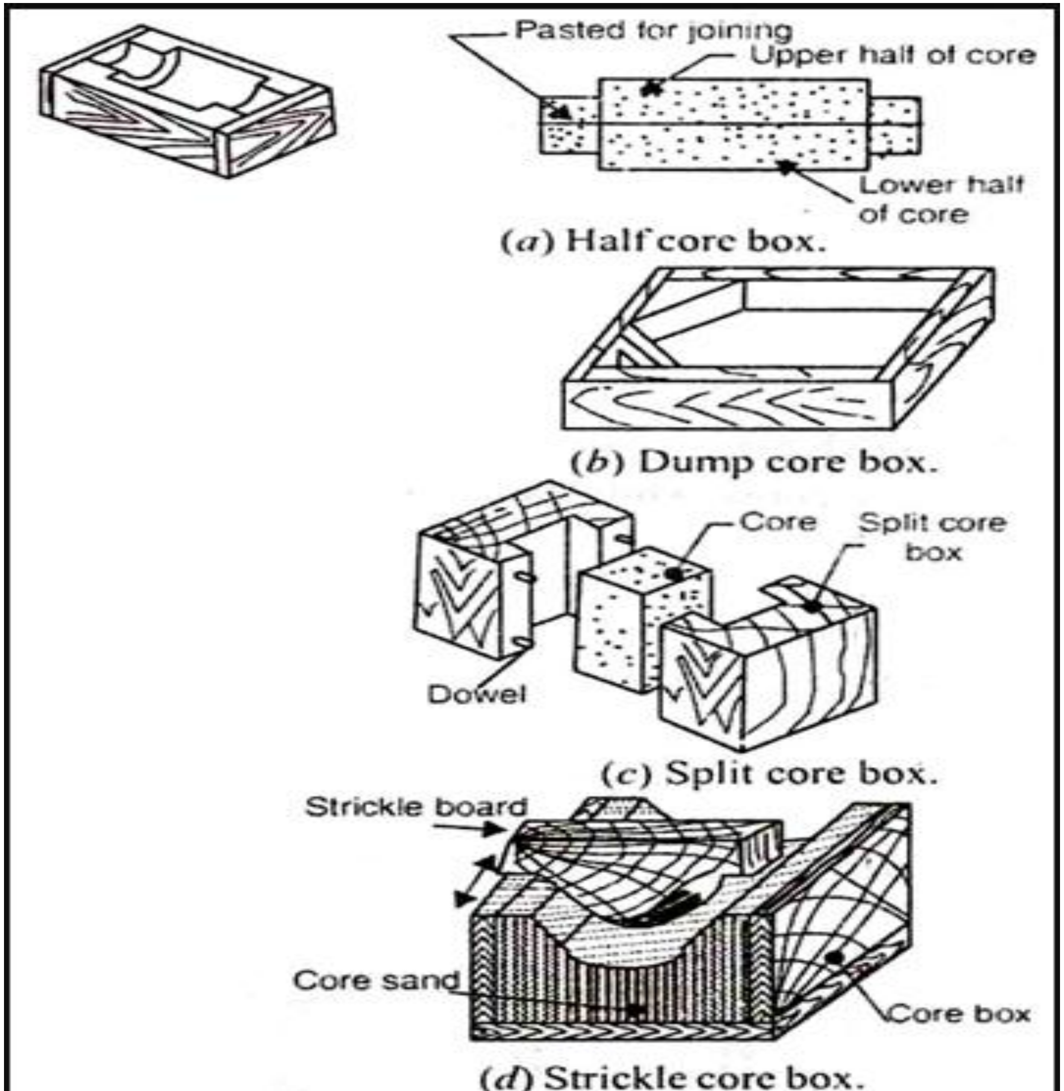
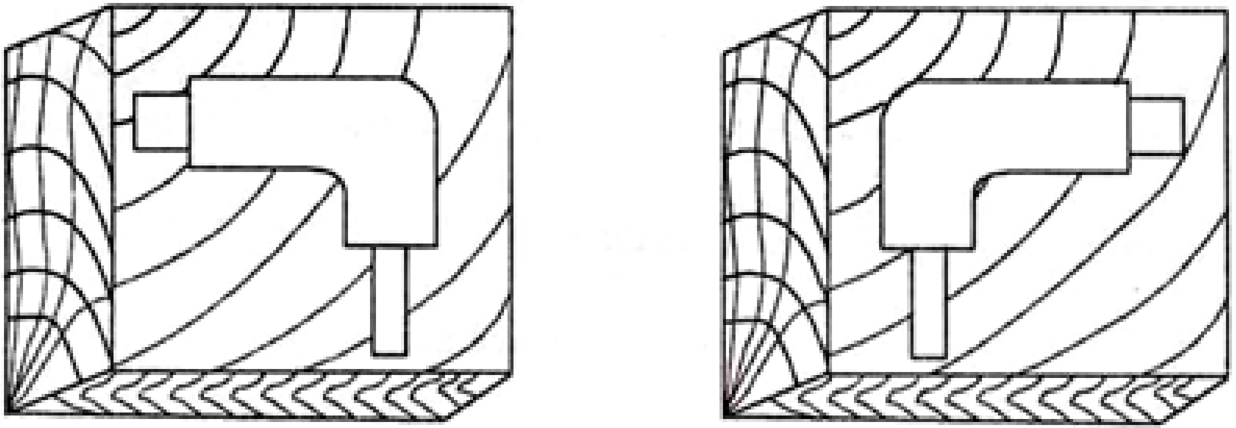
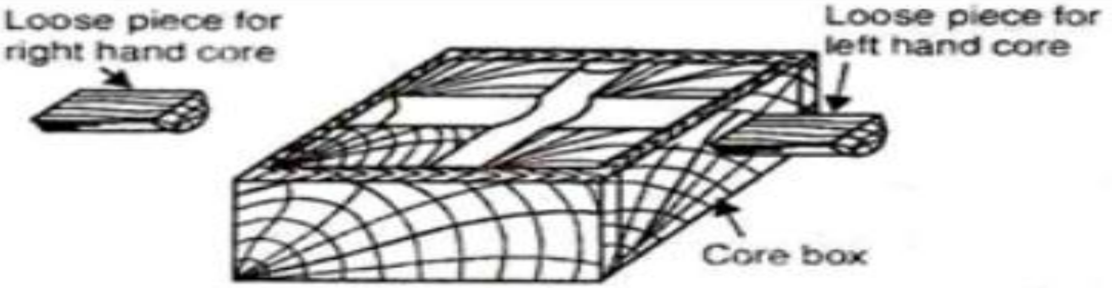


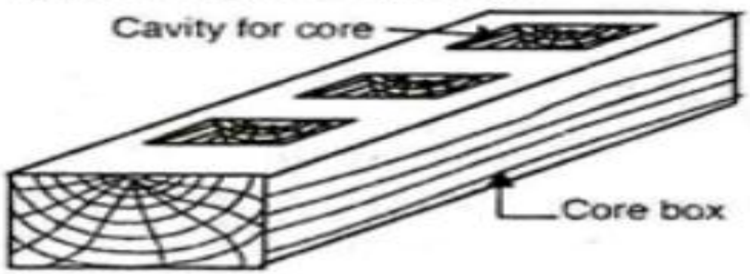
Fig. 3.13. Core boxes.



(e) Left and Right hand core box.



(f) Loose piece core box.



(g) Gang core box.

- The following are the various types of core boxes commonly used in core making:
  - 1. Half Core Box
  - 2. Dump Core Box
  - 3. Split Core Box
  - 4. Strickle Core Box
  - 5. Left and Right Hand Core Box
  - 6. Loose Piece Core Box
  - 7. Gang core Box.

- **Type # 1. Half Core Box:**
  - A half core box is most common type of core box. It is used for making the two identical halves of a symmetrical core. These two half portions are pasted together after backing, thus makes a complete core. The half core box is shown in Fig. 3.13. (a)
- **Type # 2. Dump Core Box:**
  - A dump core box is similar to half core box in construction but produces a full core at a time. This box is commonly used for making rectangular, square, slab, triangular and trapezoidal cores. Dump core box sometimes is also known as slab core box and is shown in Fig. 3.13. (b).

- **Type # 3. Split Core Box:**
  - A split core box consists of two parts, joined together with the help of dowel pins and holes. A complete core is produced in single operation.
  - In its operation, the two boxes are properly aligned and the core sand is rammed from one side. After ramming, the surplus sand is strickled off. The clamps are opened and the core-boxes are withdrawn carefully leaving the core. The split-core box is shown in Fig. 3.13. (c).
- **Type # 4. Strickle Core Box:**
  - A strickle core box is used when the core is required to have an irregular shape. It consists of a strickle wooden board and a core box. The sand is dumped in a core box and rammed. The top surface of the core in the core box is given the desired shape with the help of strickle board. The strickle board is made to a desired shape and moved over top of the rammed sand. The strickle core box is shown in Fig. 3.13 (d).

- **Type # 5. Left and Right Hand Core Box:**
    - The left and right hand core boxes are used when the cores are symmetrical about left and right of a centre line. The core is made in two half's. The left and right hand core is shown in Fig. 3.13. (e).
- **Type # 6. Loose Piece Core Box:**
    - A loose piece core box is used for making cores when provision for bosses, hubs etc., is needed. Both halves of the left and right core can be made from a single core box with the help of loose pieces.
    - Different shapes may be obtained by inserting loose wooden pieces in the core box thus changing the symmetry of core box. A loose piece core box is shown in Fig. 3.13 (f).

- **Type # 7. Gang Core Box:**
  - A gang core box is employed when a large number of small sized cores are required in a single operation. The gang core box is shown in Fig. 3.13 (g).