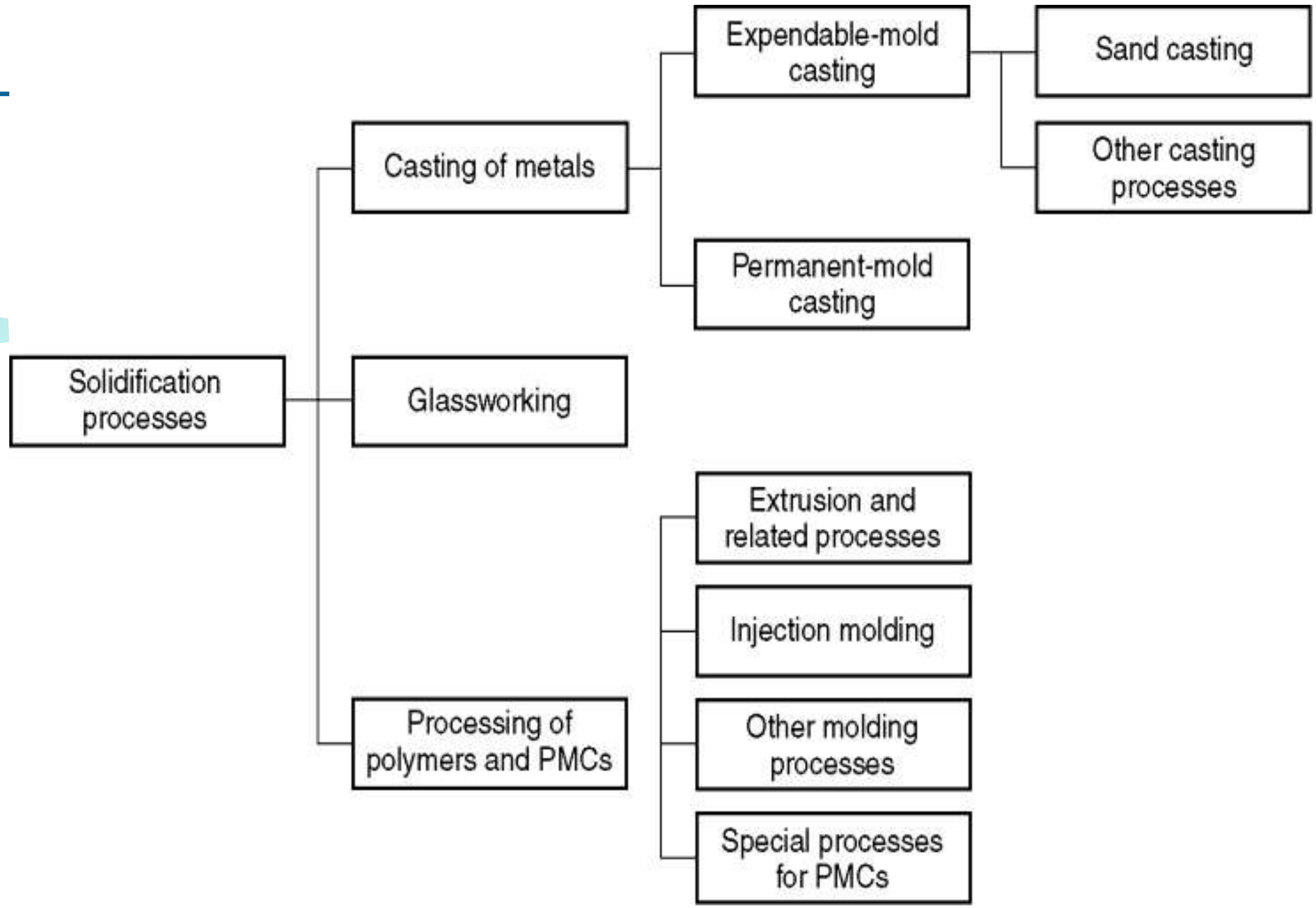
FUNDAMENTALS OF METAL CASTING

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.

Casting

Process in which molten metal flows by gravity or other force into a mold where it solidifies in the shape of the mold cavity

- The term *casting* also applies to the part made in the process
- Steps in casting seem simple:
  1. Melt the metal
  2. Pour it into a mold
  3. Let it freeze

Capabilities and Advantages of Casting

- Can create complex part geometries
- Can create both external and internal shapes
- Some casting processes are *net shape;* others are *near net shape*
- Can produce very large parts
- Some casting methods are suited to mass production

Disadvantages of Casting

- Different disadvantages for different casting processes:
  - Limitations on mechanical properties
  - Poor dimensional accuracy and surface finish for some processes; e.g., sand casting
  - Safety hazards to workers due to hot molten metals
  - Environmental problems

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

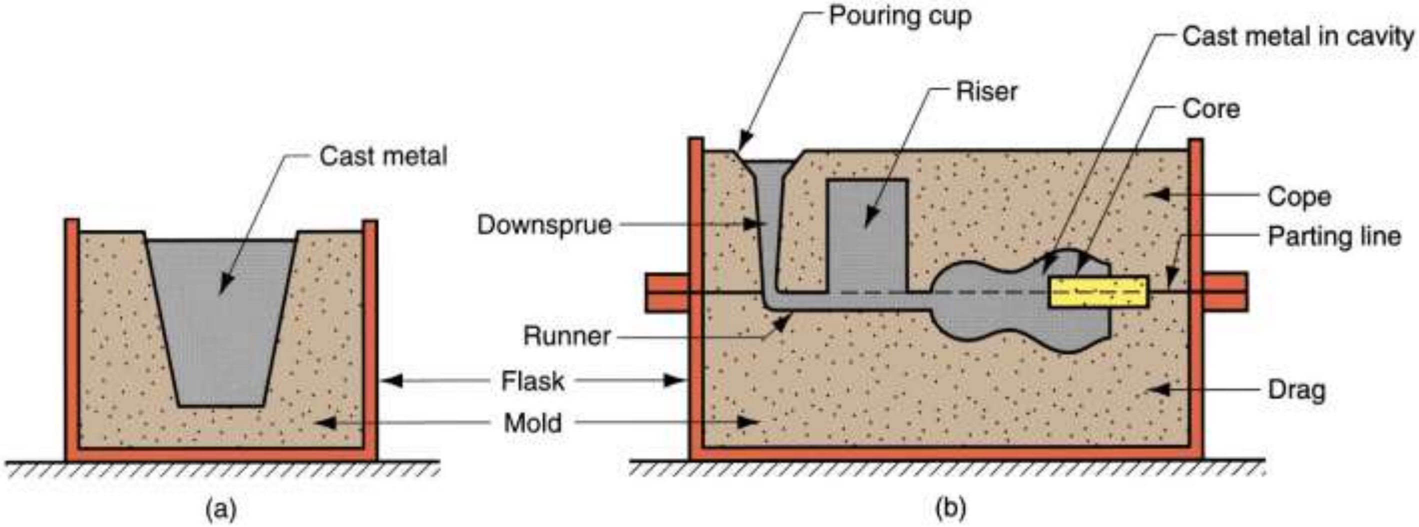
Foundry = factory equipped for making molds, melting and handling molten metal, performing the casting process, and cleaning the finished casting

- 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.

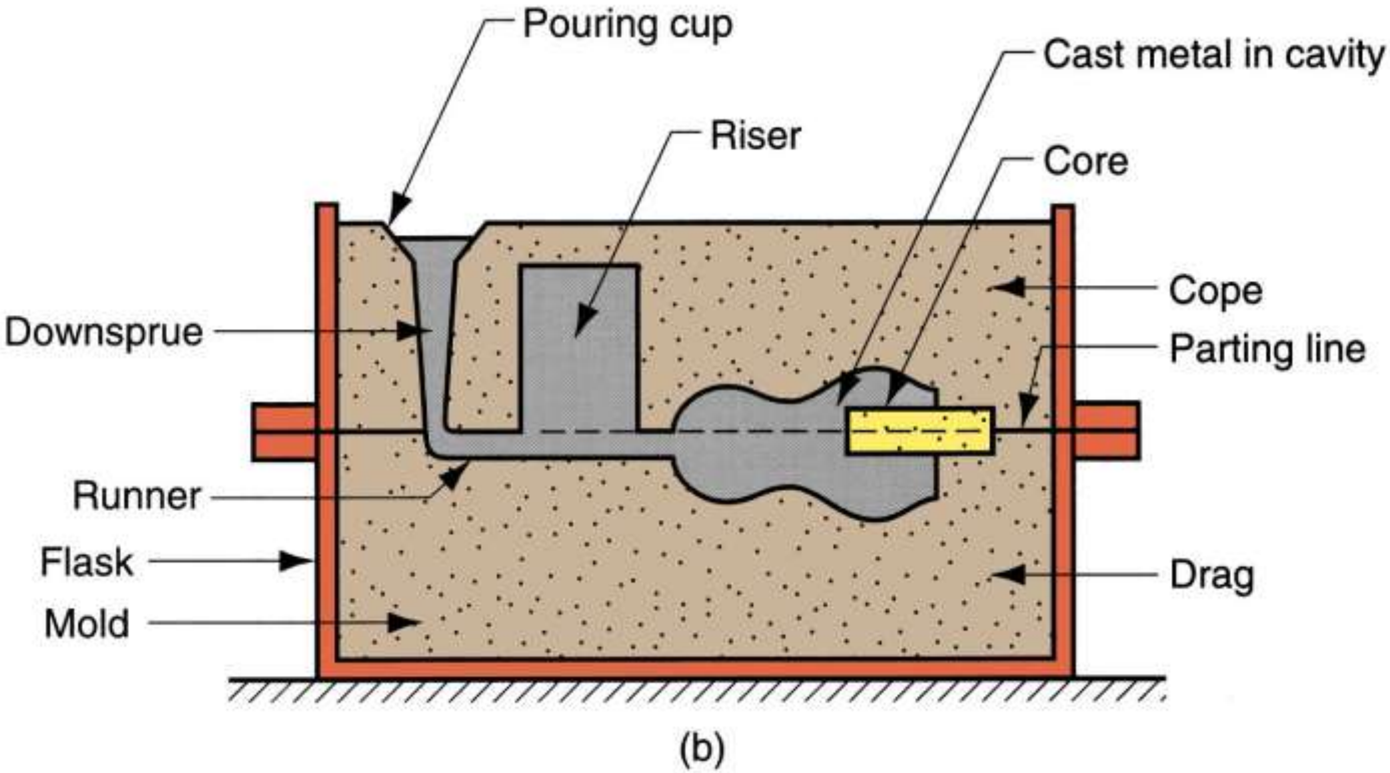
Two Categories of Casting Processes

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

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

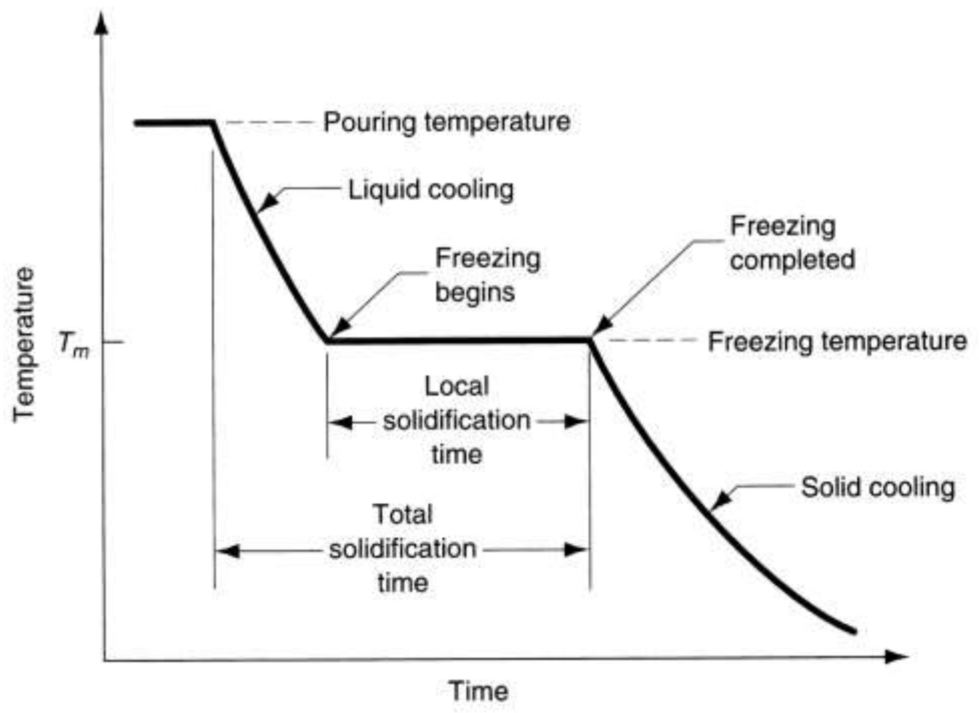
Solidification of Metals

Transformation of molten metal back into solid state

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

Cooling Curve for a Pure Metal

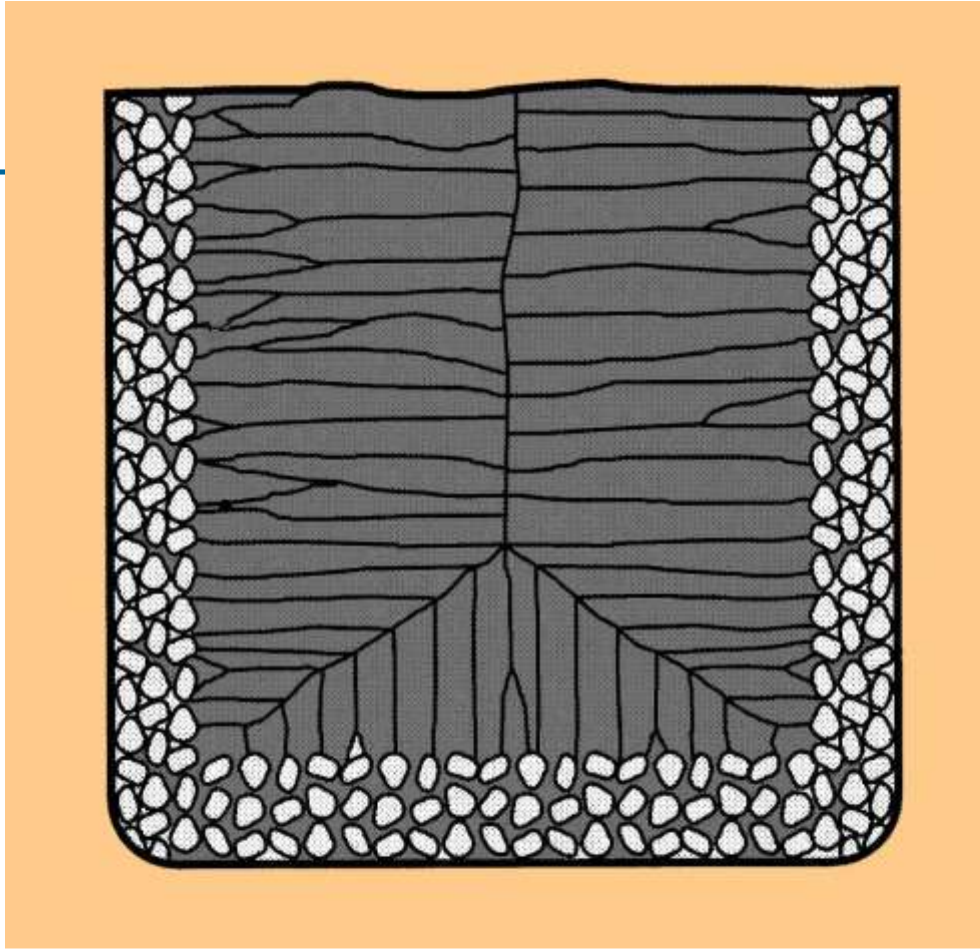
- A pure metal solidifies at a constant temperature equal to its freezing point (same as melting point)



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

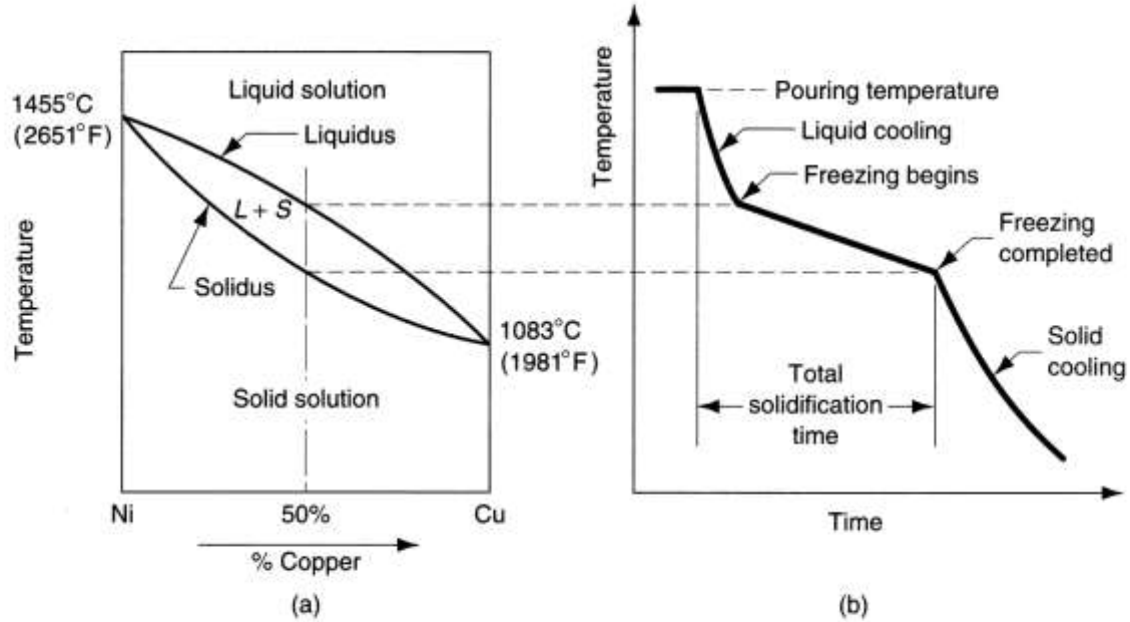


Figure 10.6 (a) Phase diagram for a copper-nickel alloy system and (b) associated cooling curve for a 50%Ni-50%Cu composition during casting.

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

Solidification Time

- Total solidification time T_{TS} = time required for casting to solidify after pouring
- T_{TS} depends on size and shape of casting by relationship known as *Chvorinov's Rule*

$$TST = C_m \left(\frac{V}{A} \right)^n$$

where TST = total solidification time; V = volume of the casting; A = surface area of casting; n = exponent with typical value = 2; and C_m is *mold constant.*

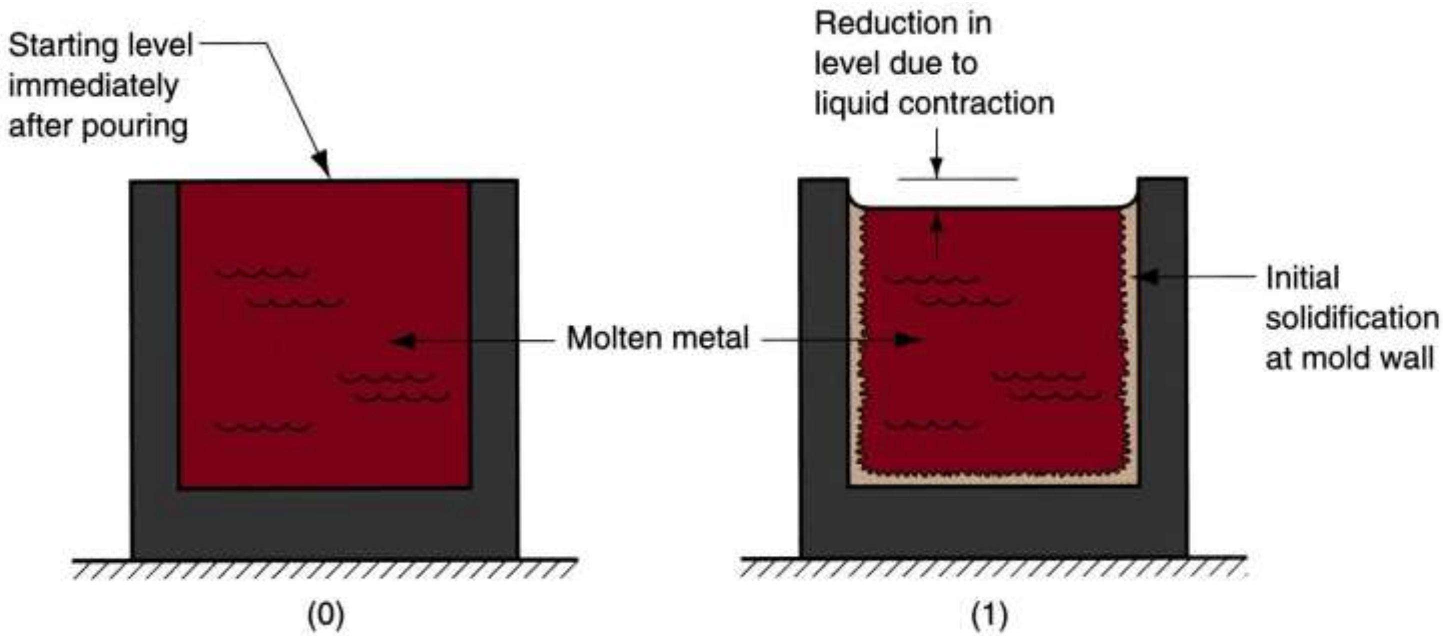
Mold Constant in Chvorinov's Rule

- Mold constant C_m depends on:
  - Mold material
  - Thermal properties of casting metal
  - Pouring temperature
- Value of C_m for a given casting operation can be based on experimental data from previous operations carried out using same mold material, metal, and pouring temperature, even though the shape of the part may be quite different

What Chvorinov's Rule Tells Us

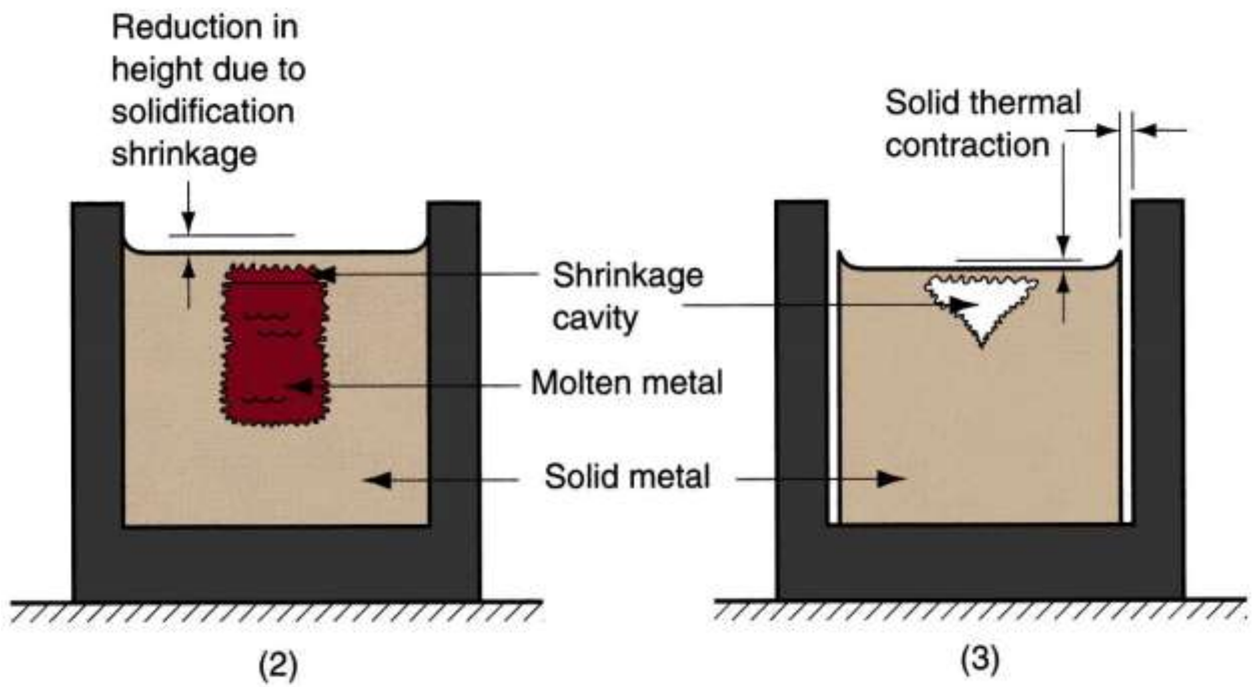
- A casting with a higher volume-to-surface area ratio cools and solidifies more slowly than one with a lower ratio
  - To feed molten metal to main cavity, *TST* for riser must greater than *TST* for main casting
- Since mold constants of riser and casting will be equal, design the riser to have a larger volume-to-area ratio so that the main casting solidifies first
  - This minimizes the effects of shrinkage

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).

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

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

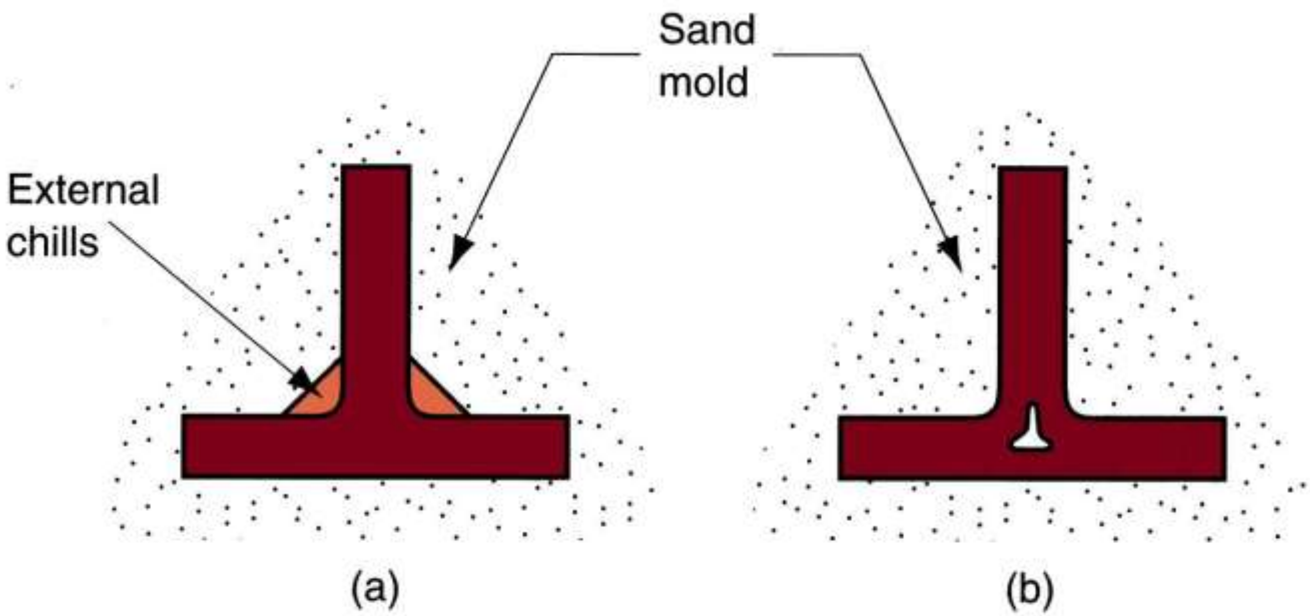
Directional Solidification

- 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

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.

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

PATTERN

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.

<u>*Advantages*</u>:

- 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:

i. The shape and size of casting
ii. No. of castings required
iii. Method of moulding employed
iv. 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.

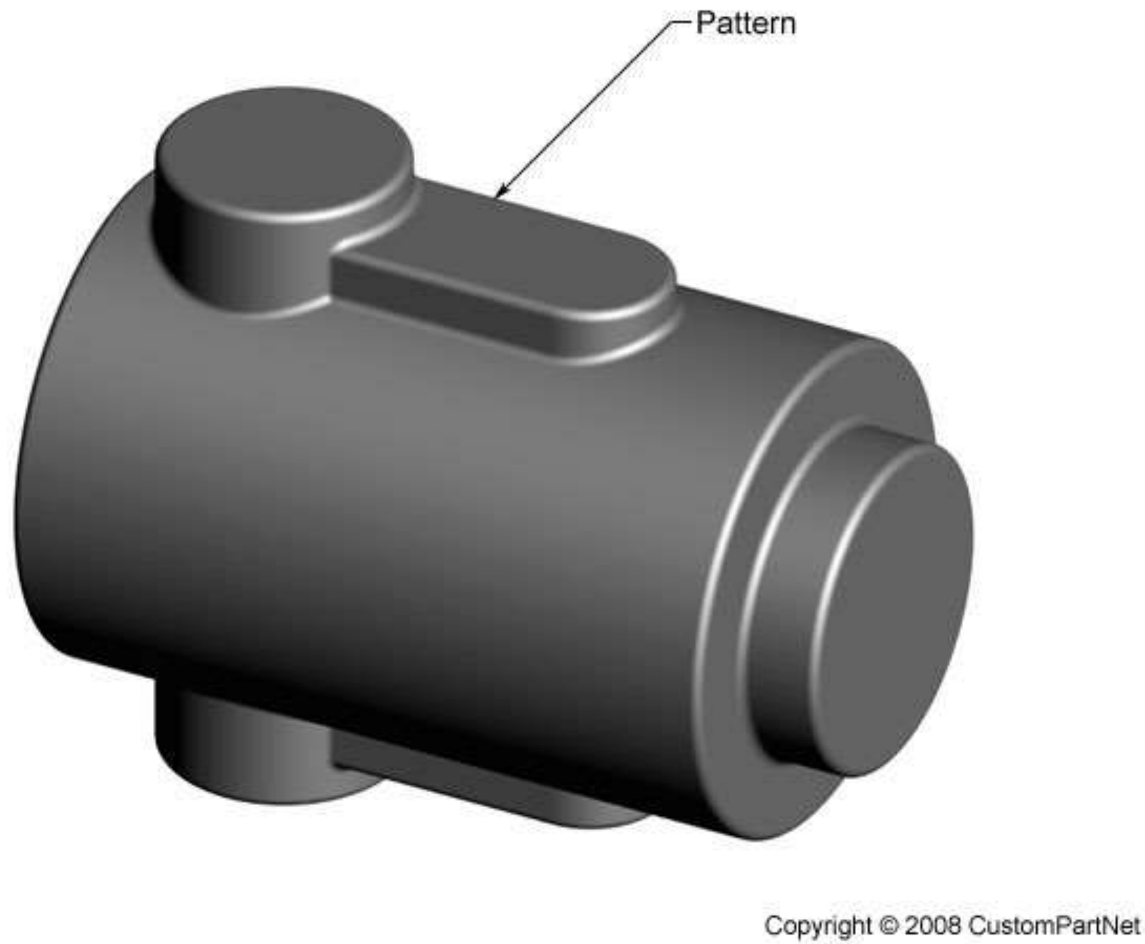
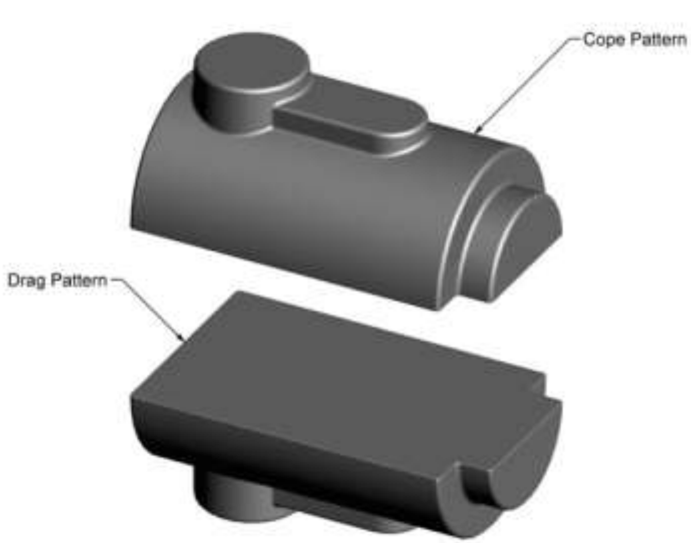


Fig: Single piece pattern

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.,



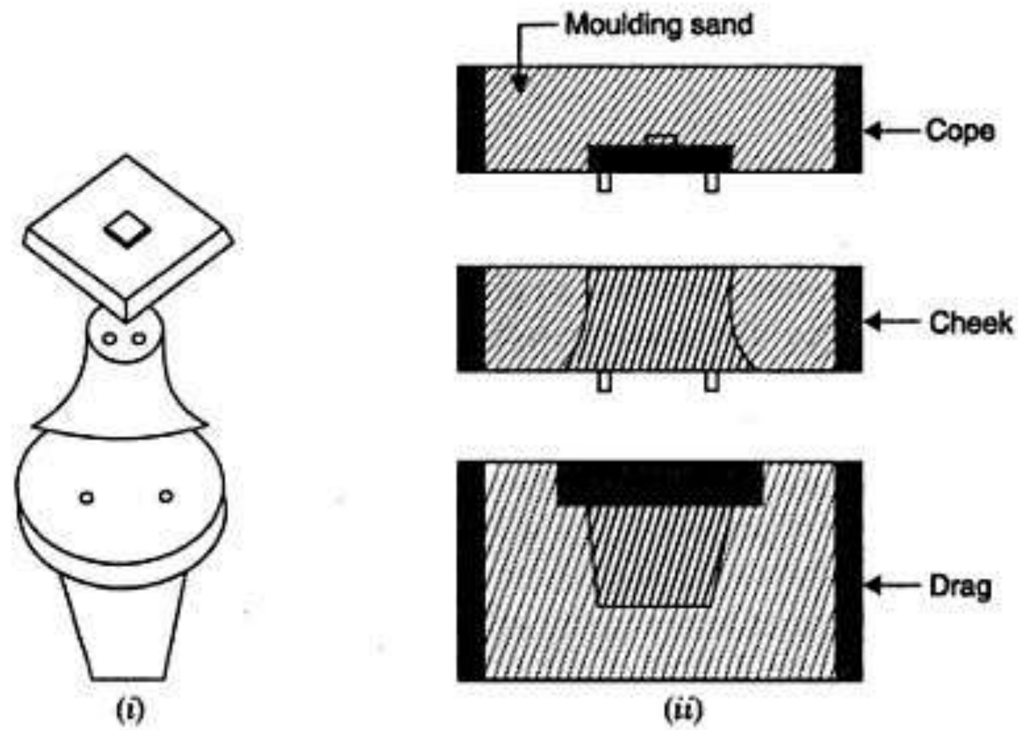
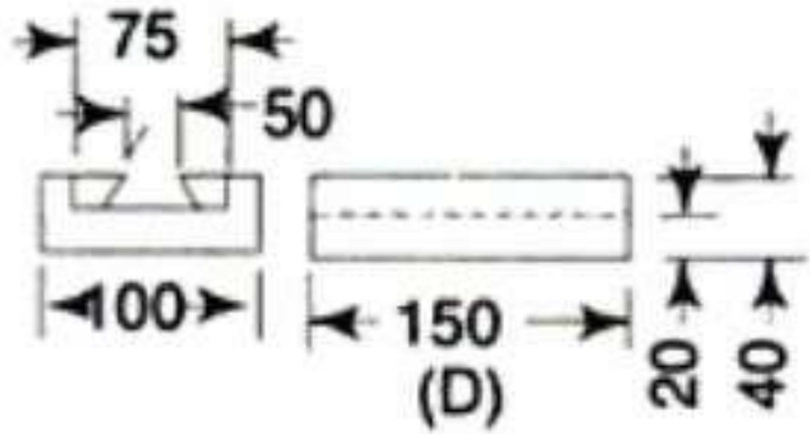
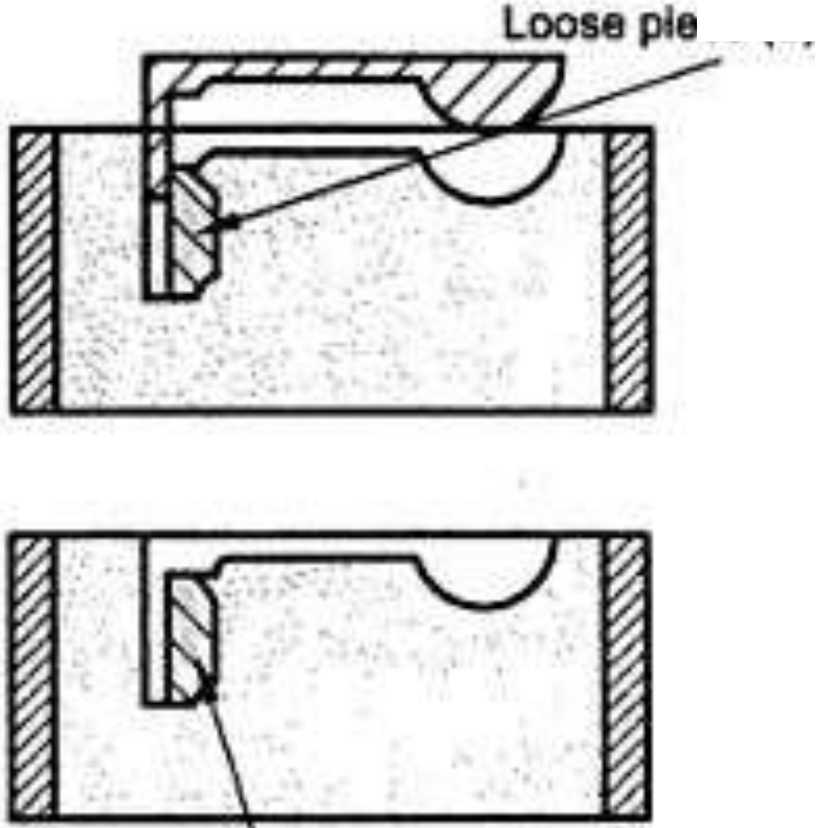


Fig. 2.3. Multipiece pattern.

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)

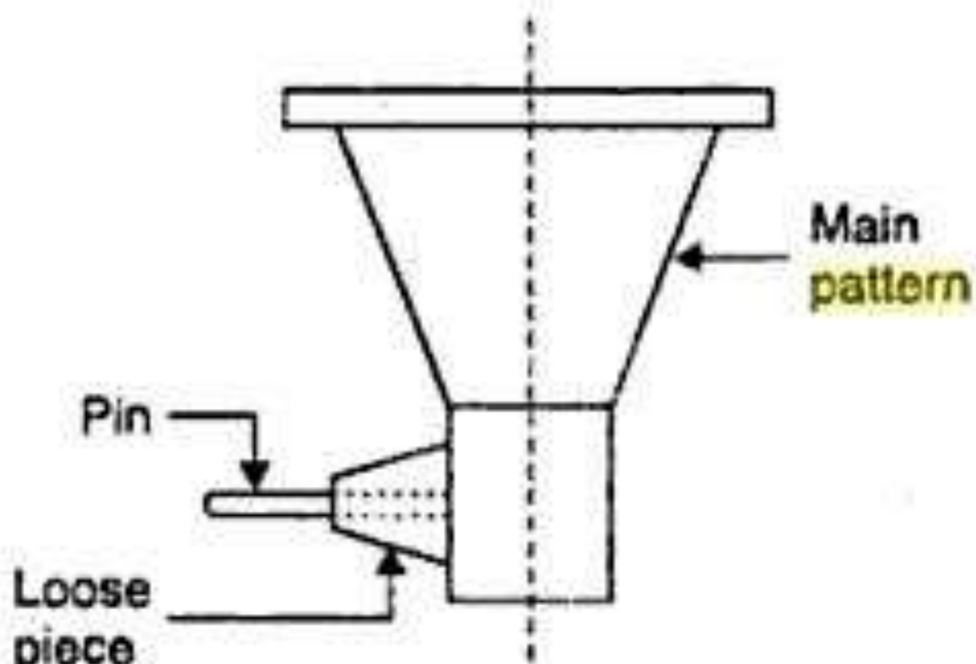


Fig. 1.75. Loose piece pattern.

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.

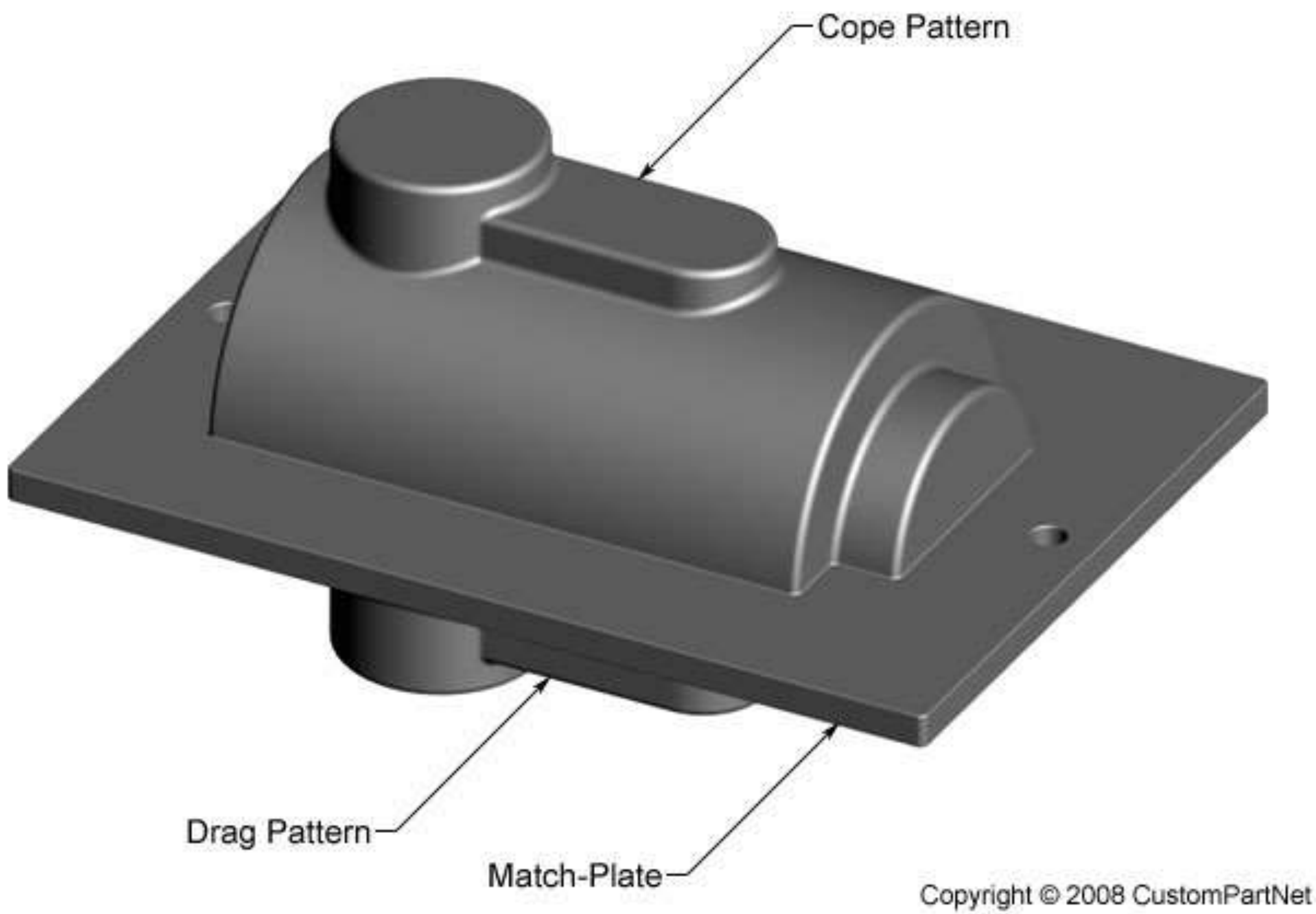


Fig: Match plate pattern

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.

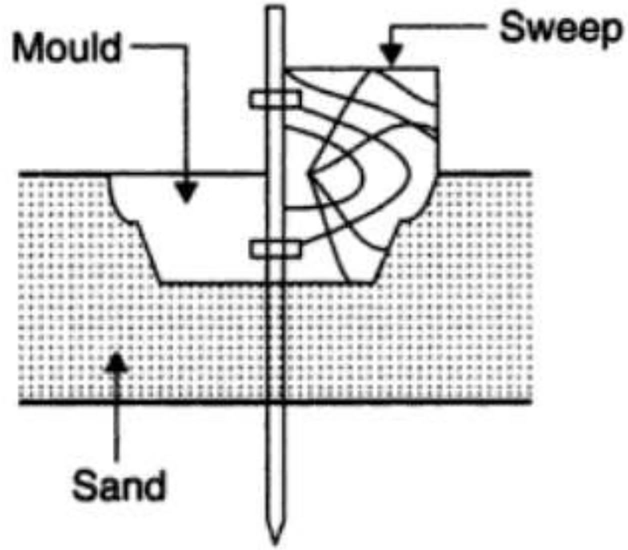


Fig. 2.8. Sweep pattern.

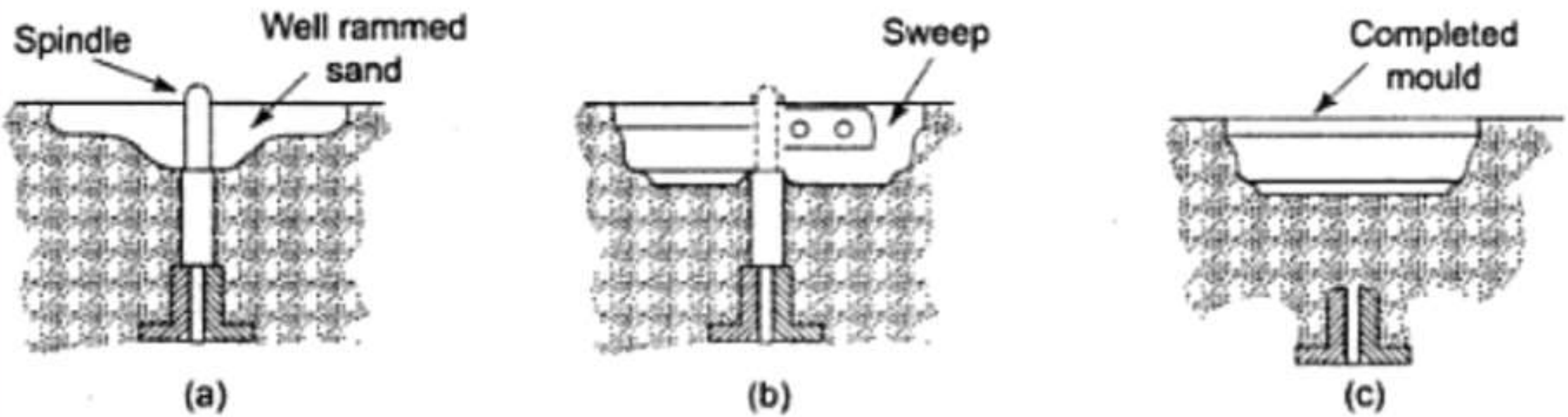


Fig. 3.15 *Sweep pattern*

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.

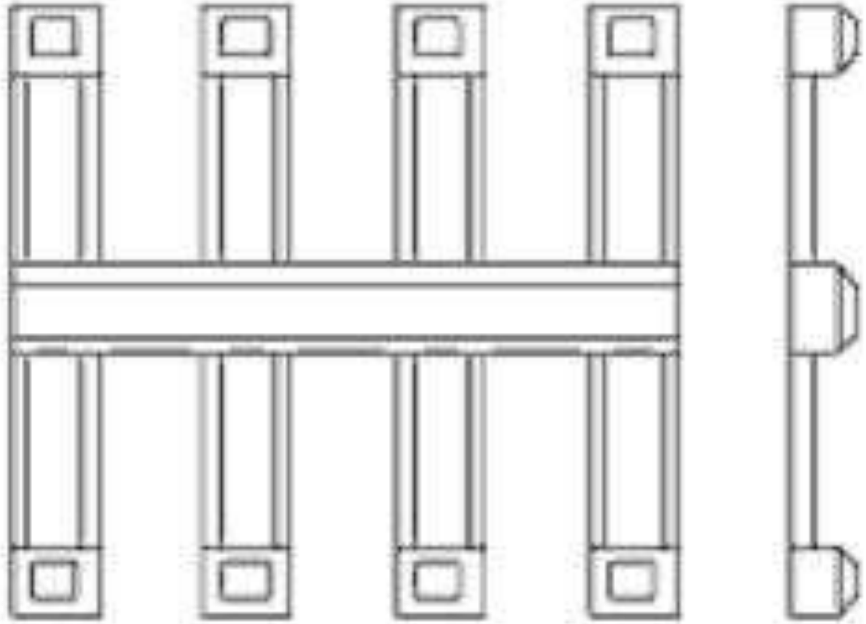
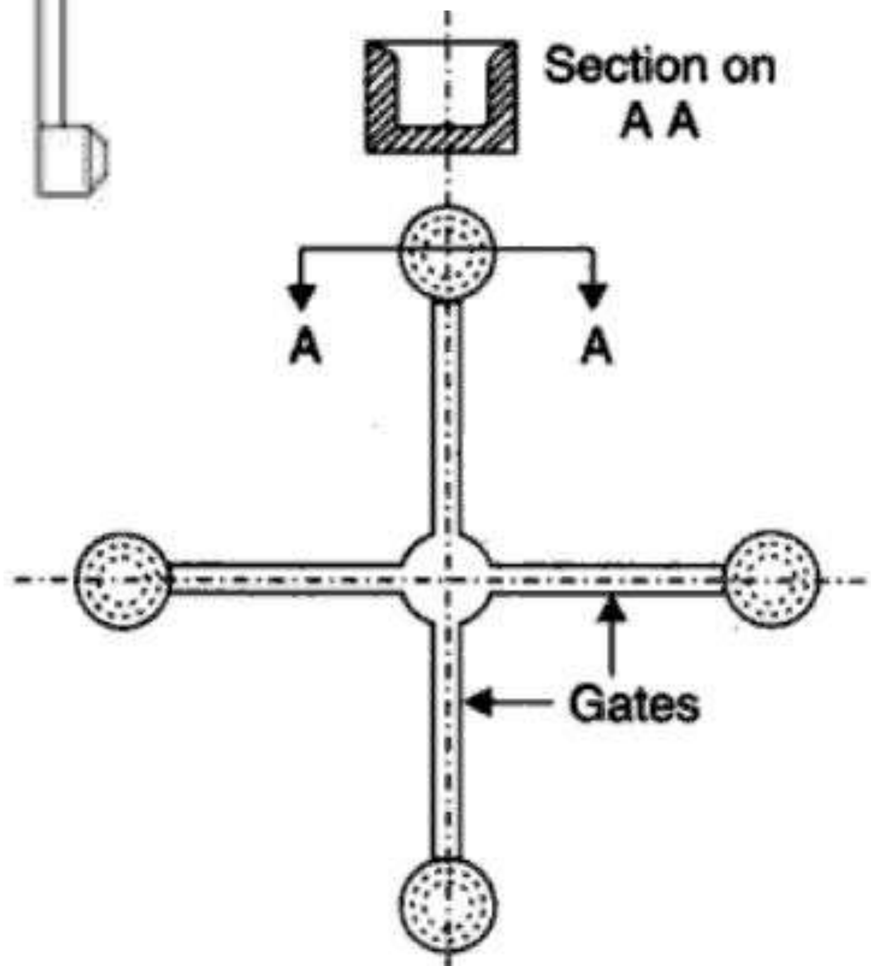


Fig. 1.10 Gated pattern



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.

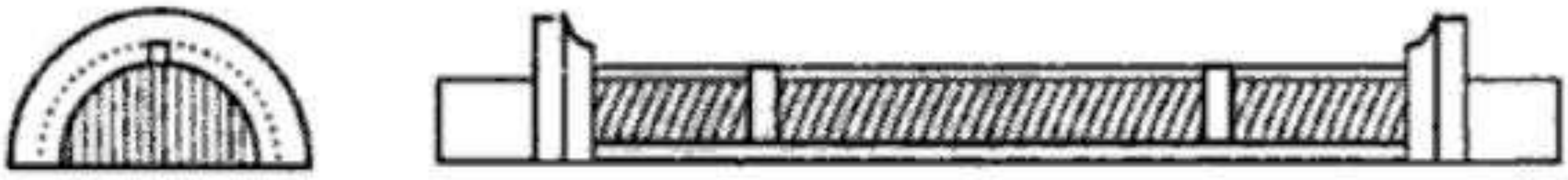


Fig. 1.78. A skeleton pattern for a flanged pipe.

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.

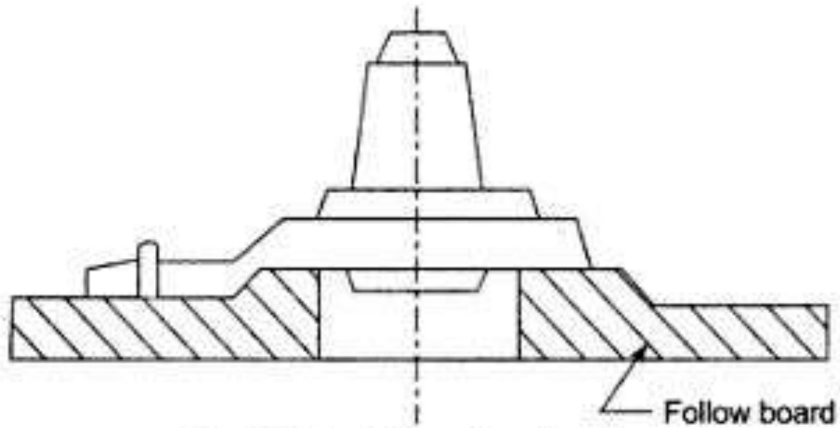


Fig. 3.14 *Follow board pattern*

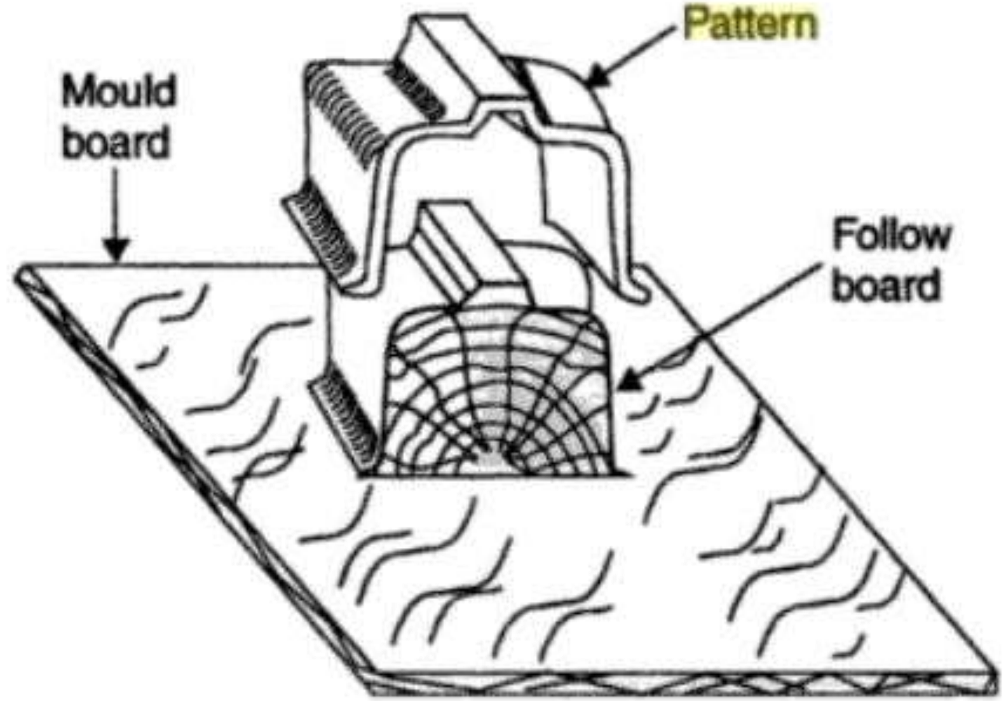


Fig. 1.80. A follow board pattern.

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.

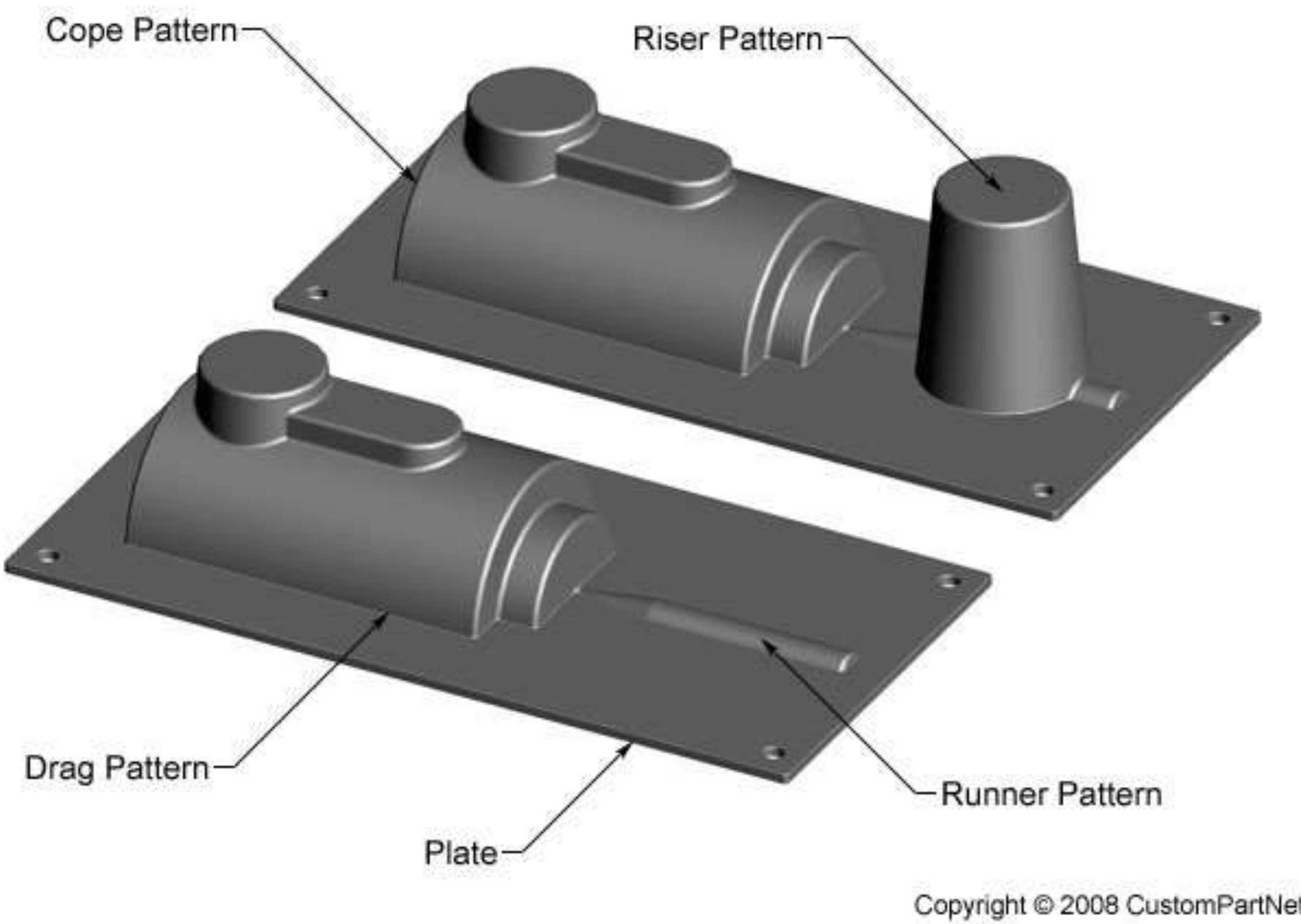
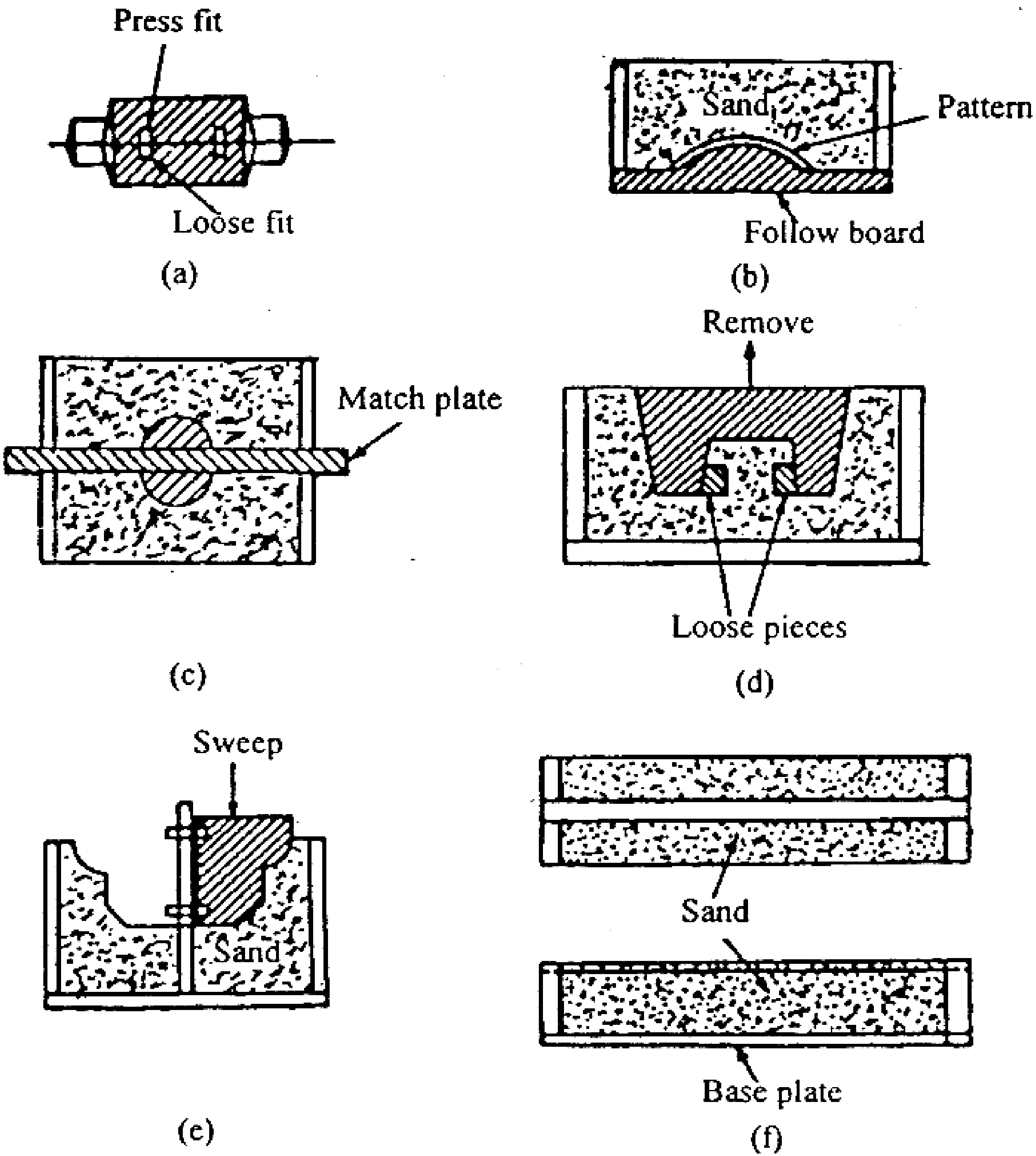
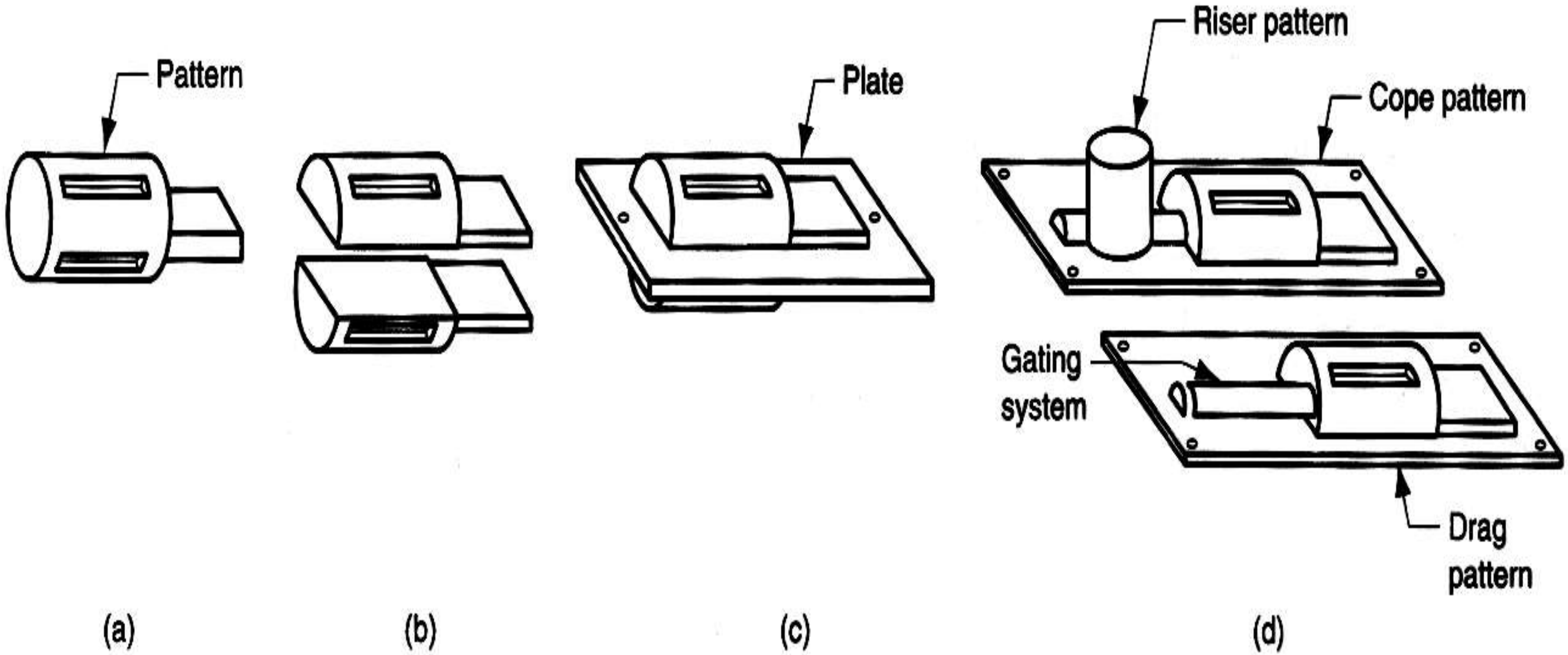


Fig: Cope and drag pattern



(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	2.5
	300 to 600	4.0
Aluminium	Up to 300	1.5
	300 to 600	3.0
Cast Steel	Up to 300	3.0
	300 to 600	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.

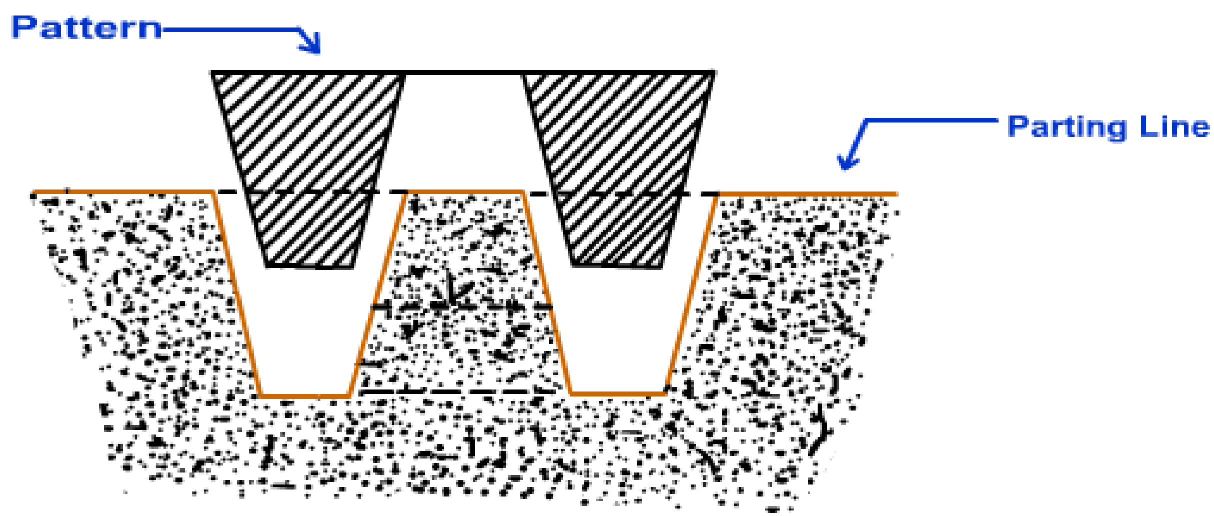


Figure 3 (b) Pattern Having Draft on Vertical Edges

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

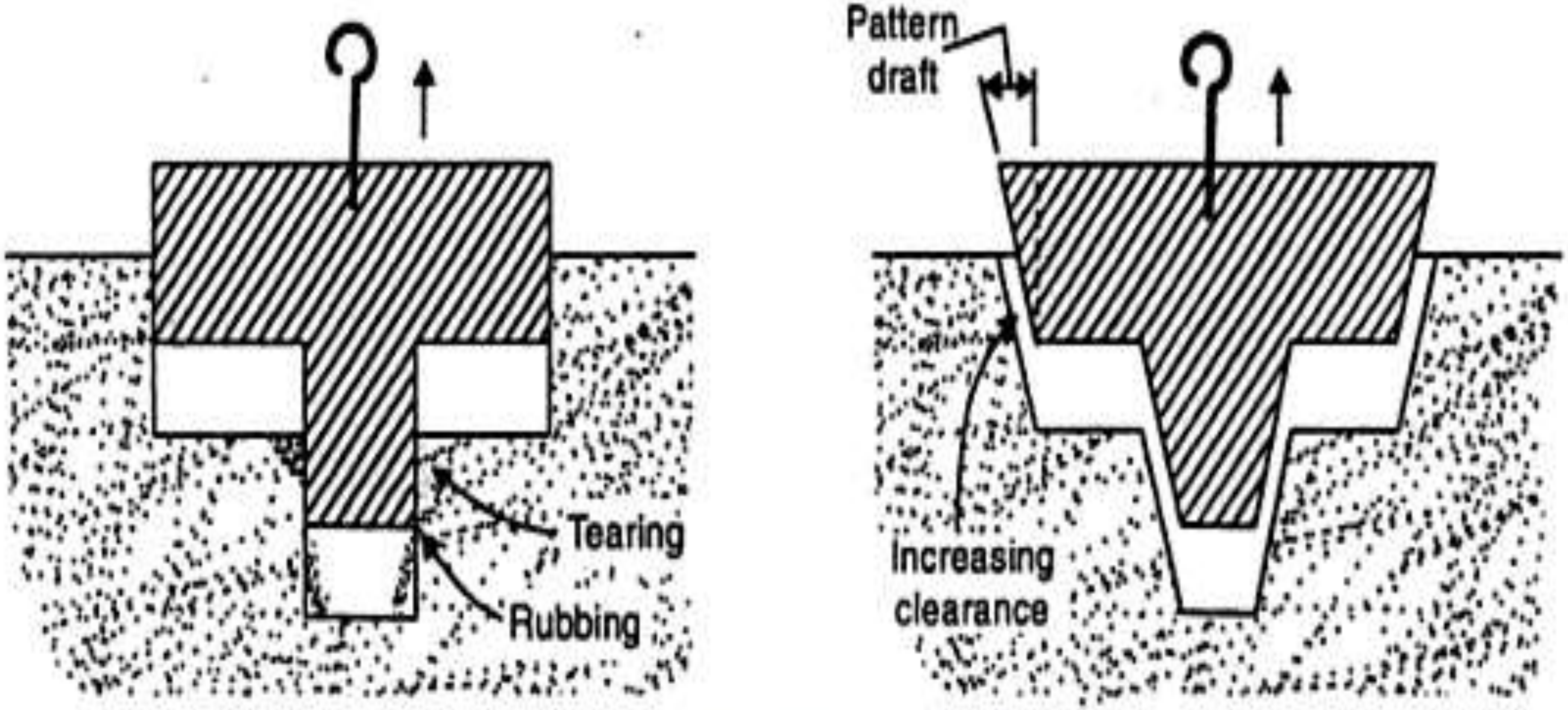


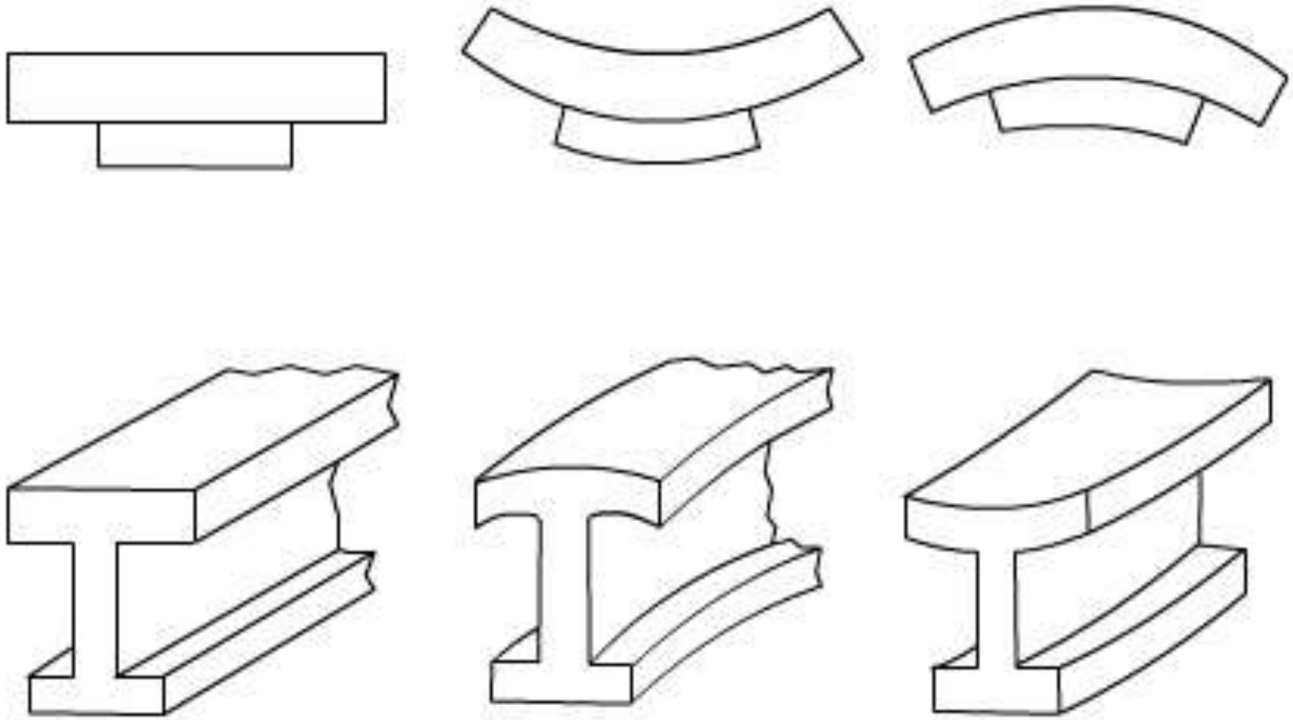
Fig. 2.9 *Draft Allowance.*

Fig: taper in design

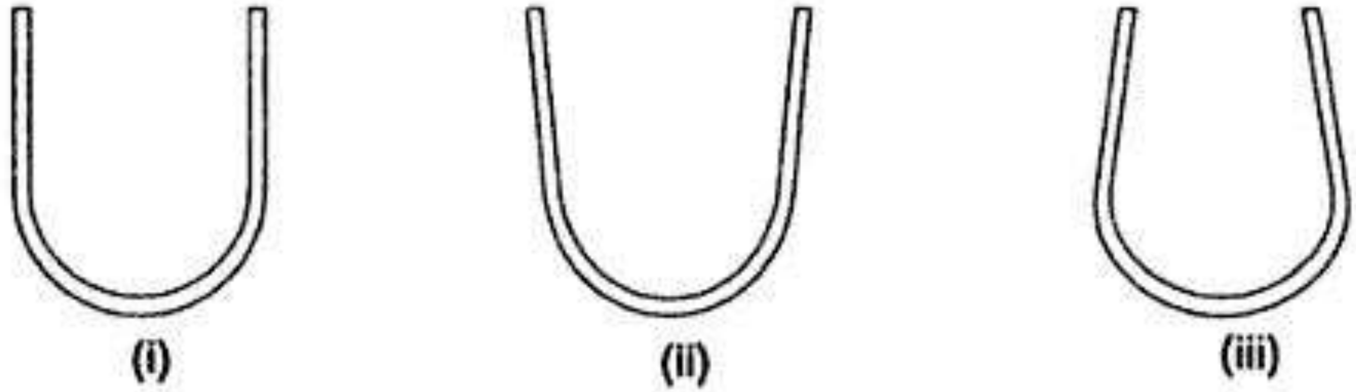
4. Distortion or cambered allowance:

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.

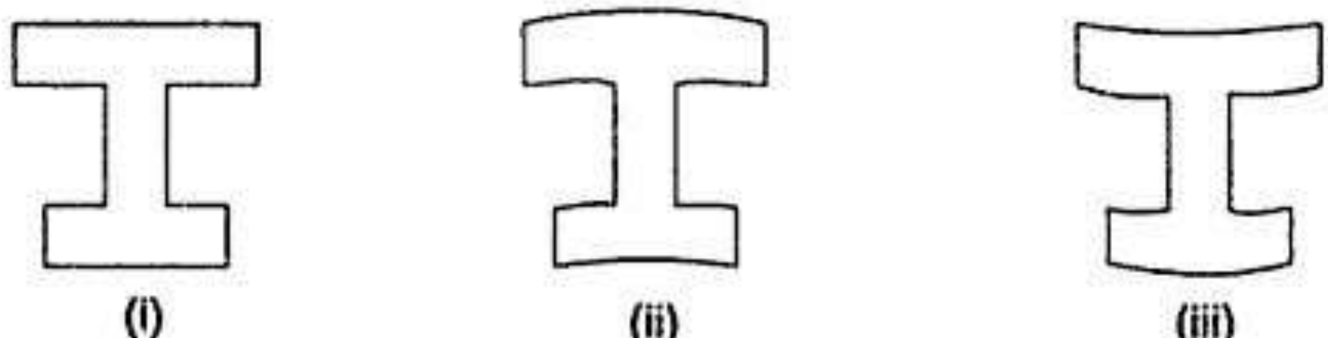


Required Shape of Casting | **Distorted Casting** | **Cambered Pattern**



(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.

Moulding Materials

Major part of Moulding material in sand casting are

1. 70-85% silica sand (SiO_2)
2. 10-12% bonding material e.g., clay cereal etc.
3. 3-6% water

Requirements of molding sand are:

(a) Refractoriness

(b) Cohesiveness

(c) Permeability

(d) Collapsibility

(e) Green Strength

(f) Dry Strength and few other factors

Molding Material and Properties:

A large variety of molding materials is used in foundries for manufacturing molds and cores. They include molding sand, system sand or backing sand, facing sand, parting sand, and core sand. The choice of molding materials is based on their processing properties. The properties that are generally required in molding materials are:

1. Refractoriness:

It is the ability of the molding material to with stand high temperatures (experienced during pouring) with out

1. Fusion,
2. Cracking, buckling or scabbing,
3. Experiencing any major physical change.

- Silica sand has a high refractoriness.

2. Permeability:

- During pouring and subsequent solidification of a casting, a large amount of gases and steam is generated.
- These gases are those that have been absorbed by the metal during melting, air absorbed from the atmosphere and the steam generated by the molding and core sand.
- If these gases are not allowed to escape from the mold, they would be entrapped inside the casting and cause casting defects.
- To overcome this problem the molding material must be porous.
- Proper venting of the mold also helps in escaping the gases that are generated inside the mold cavity.

3. Green Strength:

- The molding sand that contains moisture is termed as green sand.
- The green sand particles must have the ability to cling to each other to impart sufficient strength to the mold.
- The green sand must have enough strength so that the constructed mold retains its shape.
- Green strength helps in making and handling the moulds.

4. Dry Strength:

- A mould may either intentionally be dried, or a green sand mould may lose its moisture and get dried while waiting for getting poured or when it comes in contact with molten metal being poured.
- The sand thus dried must have dry strength to
  1. Withstand erosive forces due to molten metal,
  2. Withstand pressure of molten metal,
  3. Retain its exact shape, and
  4. Withstand the metallostatic pressure of the liquid material.

5. Hot Strength:

- As soon as the moisture is eliminated, the sand would reach at a high temperature when the metal in the mold is still in liquid state.
- The strength of the sand that is required to hold the shape of the cavity is called hot strength.
- In the absence of adequate hot strength, the mold may
  1. enlarge
  2. Break
  3. get cracked.
  4. erode

6. Collapsibility:

- Collapsibility determines the readiness with which the molding sand,
  1. Automatically gets collapsed after the casting solidifies, and
  2. Breaks down in knock out and cleaning operations.
- If the mould or core does not collapse, it may restrict free contraction of solidifying metal and cause the same to tear or crack.

7. Flowability:

- It is the ability of the molding sand to get compacted to a uniform density.
- Flowability assists molding sand to flow and pack all-around the pattern and take up the required shape.
- Flowability increases as clay and water contents increase.

8. Adhesiveness:

It is the property of molding sand owing to which, it

1. Sticks with the walls of molding boxes,
2. Thus makes it possible to mold cope and drag.

9. Fineness:

- Finer sand mould resist metal penetration and produce smooth casting surfaces.
- Fineness and permeability are in conflict with each other and hence they must be balanced for optimum results.

10. **Chemical inertness**

- The sand must not react with the metal being cast. This is especially important with highly reactive metals, such as magnesium and titanium

11. **Cohesiveness**

- This is the ability of the sand to retain a given shape after the pattern is removed.

12. **Availability/cost**

- The availability and cost of the sand is very important because the amount of sand required is three to six times the weight of the casting. Although sand can be screened and reused, the particles eventually become too fine and require periodic replacement with fresh sand.
- In large castings it is economical to use two different sands, because the majority of the sand will not be in contact with the casting, so it does not need any special properties. The sand that is in contact with the casting is called *facing sand*, and is designed for the casting on hand. This sand will be built up around the pattern to a thickness of 30 to 100 mm (1.2 to 3.9 in). The sand that fills in around the facing sand is called *backing sand*. This sand is simply silica sand with only a small amount of binder and no special additives.

Molding Sand Composition:

The main ingredients of any molding sand are:

- Base sand,
- Binder, and
- Moisture

1. Base Sand:

- Silica sand is most commonly used base sand.
- Other base sands that are also used for making mold are zircon sand, Chromite sand, and olivine sand.
- Silica sand is cheapest among all types of base sand and it is easily available.

2. Binder:

- Binders are of many types such as:
  1. Clay binders,
  2. Organic binders and
  3. Inorganic binders

- Clay binders are most commonly used binding agents mixed with the molding sands to provide the strength.

- The most popular clay types are:
  - Kaolinite or fire clay (Al_2O_3 2 SiO_2 2 H_2O) and Bentonite (Al_2O_3 4 SiO_2 nH_2O)
  - Of the two the Bentonite can absorb more water which increases its bonding power.

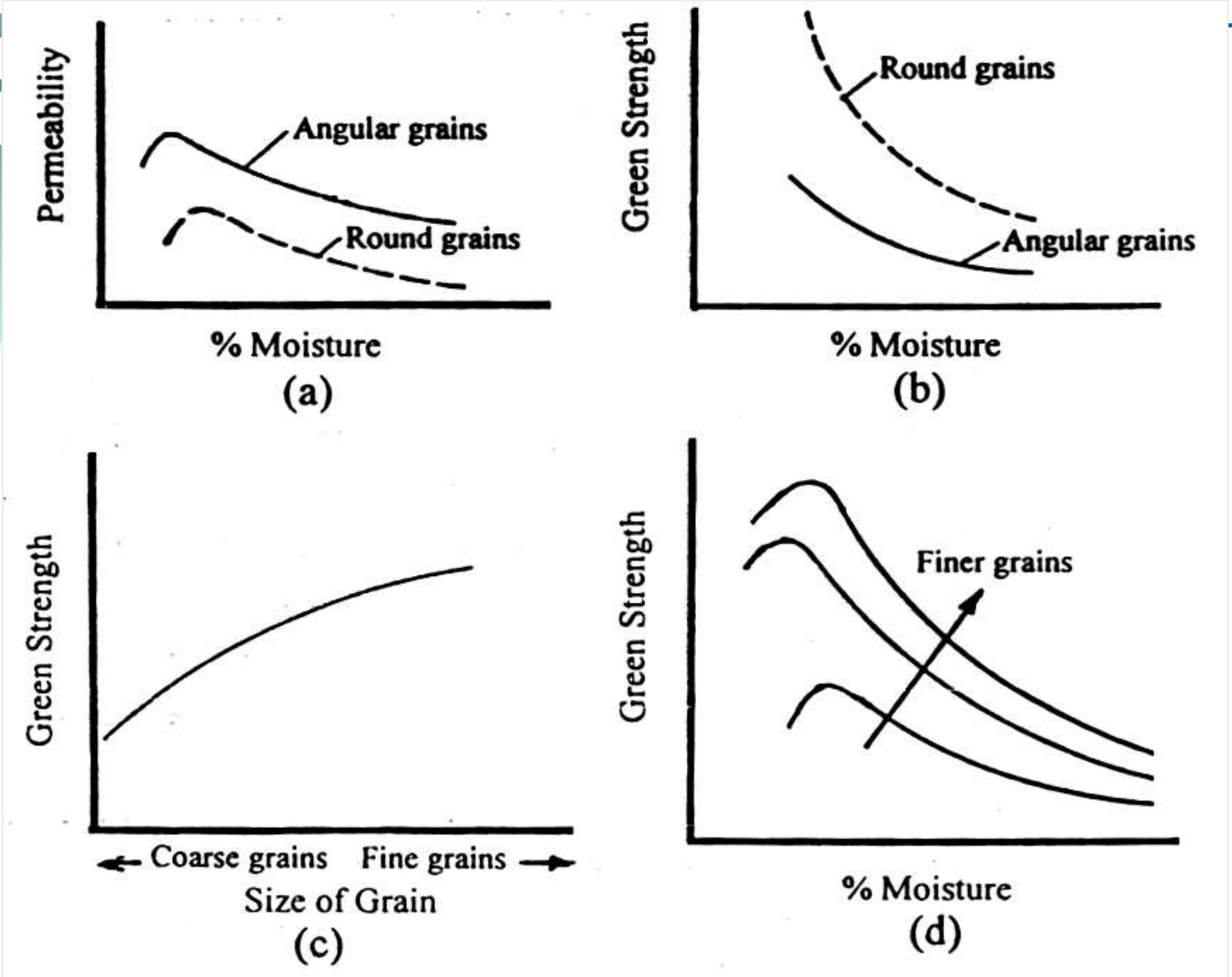
3. Moisture:

- Clay acquires its bonding action only in the presence of the required amount of moisture.
- When water is added to clay, it penetrates the mixture and forms a microfilm, which coats the surface of each flake of the clay.
- The amount of water used should be properly controlled.
- This is because a part of the water, which coats the surface of the clay flakes, helps in bonding, while the remainder helps in improving the plasticity.

A Typical Composition of Molding Sand:

Molding Sand Constituent	Weight Percent
Silica sand	92
Clay (Sodium Bentonite)	8
Water	4

Effect of moisture, grain size and shape on mould quality



Classification of casting Processes:

1.Green Sand Molding:

Green sand is the most diversified molding method used in metal casting operations. The process utilizes a mold made of compressed or compacted moist sand. The term "green" denotes the presence of moisture in the molding sand. The mold material consists of silica sand mixed with a suitable bonding agent (usually clay) and moisture.

Advantages:

- Most metals can be cast by this method.
- Pattern costs and material costs are relatively low.
- No Limitation with respect to size of casting and type of metal or alloy used.

2.Dry Sand Molding:

When it is desired that the gas forming materials are lowered in the molds, air-dried molds are sometimes preferred to green sand molds. Two types of drying of molds are often required.

- Skin drying and
- Complete mold drying.

Complete Dry-Sand Molds

Dry-Sand molds are baked in an oven, (at 300F - 650F for 8-48 hours), prior to the casting operation, in order to dry the mold. This drying strengthens the mold, and hardens its internal surfaces. Dry-Sand molds are manufactured using organic binders rather than clay.

Manufacturing Considerations and Properties of Dry-Sand Molds:

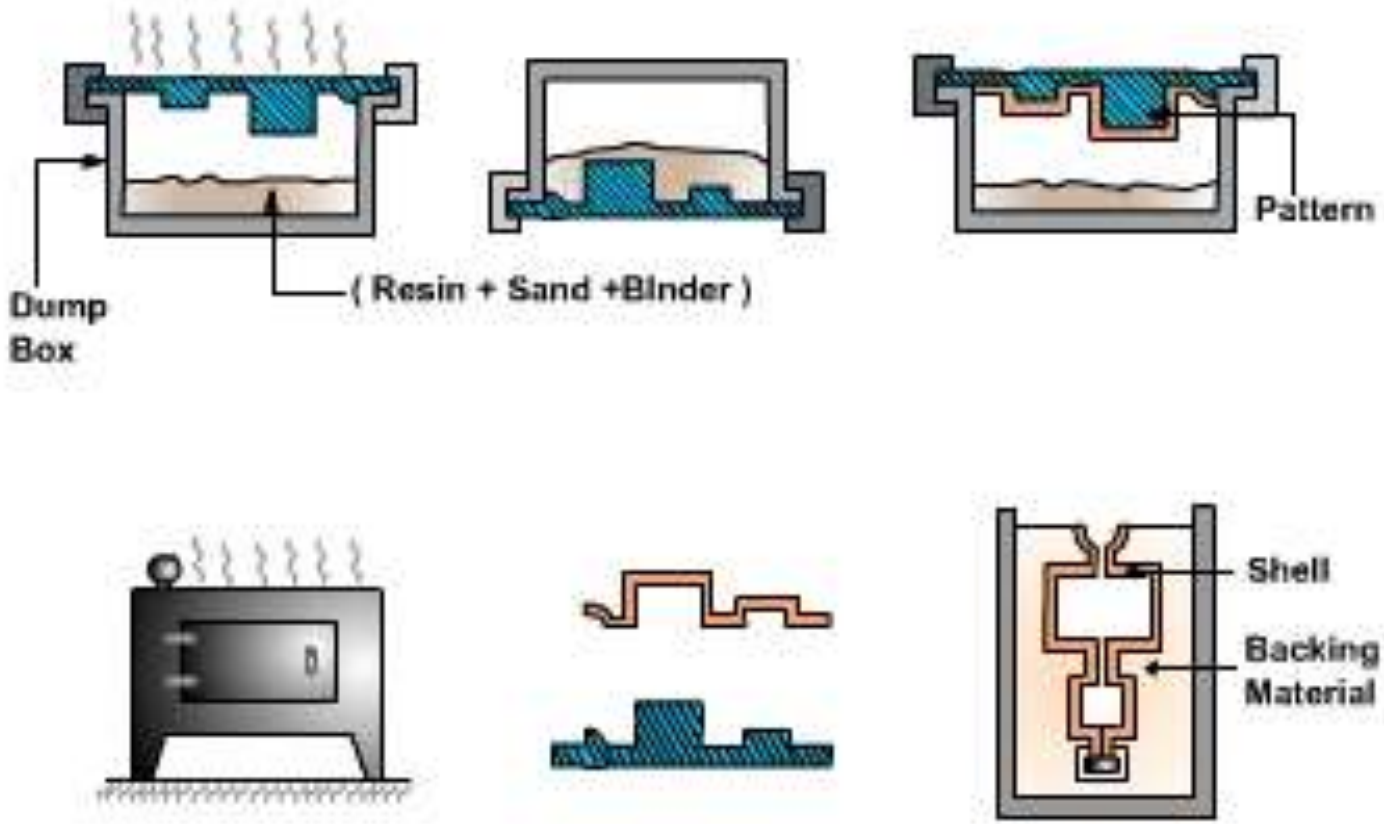
- Better dimensional accuracy of cast part than green-sand molds
- Better surface finish of cast part than green-sand molds
- More expensive manufacturing process than green-sand production
- Manufacturing production rate of castings are reduced due to drying time
- Mold might get distorted
- The metal casting is more susceptible to hot tearing because of the lower collapsibility of the mold
- Dry-Sand casting is generally limited to the manufacture of medium and large castings.

Skin-Dried Molds

- In skin drying a firm mold face is produced. It is done in order to get the partial advantages of dry sand mould, the green sand mould surfaces surrounding the cavity are dried to a depth of 10 to 25mm. Skin drying of the mold can be accomplished with the aid of torches, directed at the mold surface.

3.Shell Molding Process:

- It is a process in which, the sand mixed with a thermosetting resin is allowed to come in contact with a heated pattern plate (200 ^{o}C), this causes a skin (Shell) of about 3.5 mm of sand/plastic mixture to adhere to the pattern..
- Then the shell is removed from the pattern. The cope and drag shells are kept in a flask with necessary backup material and the molten metal is poured into the mold.
- This process can produce complex parts with good surface finish and dimensional tolerance of 0.5 %.
- A good surface finish and good size tolerance reduce the need for machining. The process overall is quite cost effective due to reduced machining and cleanup costs.
- The materials that can be used with this process are cast irons, and aluminum and copper alloys.


Dump
Box
(Resin + Sand +Binder)
Pattern
Shell
Backing
Material

Properties and Considerations of Manufacturing by Shell Mold Casting

- The internal surface of the shell mold is very smooth and rigid. This allows for an easy flow of the liquid metal through the mold cavity during the pouring of the casting, giving castings very good surface finish. Shell Mold Casting enables the manufacture of complex parts with thin sections and smaller projections than green sand molds.
- Manufacturing with the shell mold casting process also imparts high dimensional accuracy. Tolerances of .010 inches (.25mm) are possible. Further machining is usually unnecessary when casting by this process.
- Shell sand molds are less permeable than green sand molds and binder may produce a large volume of gas as it contacts the molten metal being poured for the casting. For these reasons shell molds should be well ventilated.
- The expense of shell mold casting is increased by the cost of the thermosetting resin binder, but decreased by the fact that only a small percentage of sand is used compared to other sand casting processes.
- Shell mold casting processes are easily automated
- The special metal patterns needed for shell mold casting are expensive, making it a less desirable process for short runs. However manufacturing by shell casting may be economical for large batch production.

4.Sodium Silicate Molding Process

- In this process, the refractory material is coated with a sodium silicate-based binder. For molds, the sand mixture can be compacted manually, jolted or squeezed around the pattern in the flask.
- After compaction, CO_2 gas is passed through the core or mold. The CO_2 chemically reacts with the sodium silicate to cure, or harden, the binder. This cured binder then holds the refractory in place around the pattern. After curing, the pattern is withdrawn from the mold.
- The sodium silicate process is one of the most environmentally acceptable of the chemical processes available.

The major disadvantage of the process is that the binder is very hygroscopic and readily absorbs water, which causes a porosity in the castings.. Also, because the binder creates such a hard, rigid mold wall, shakeout and collapsibility characteristics can slow down production.

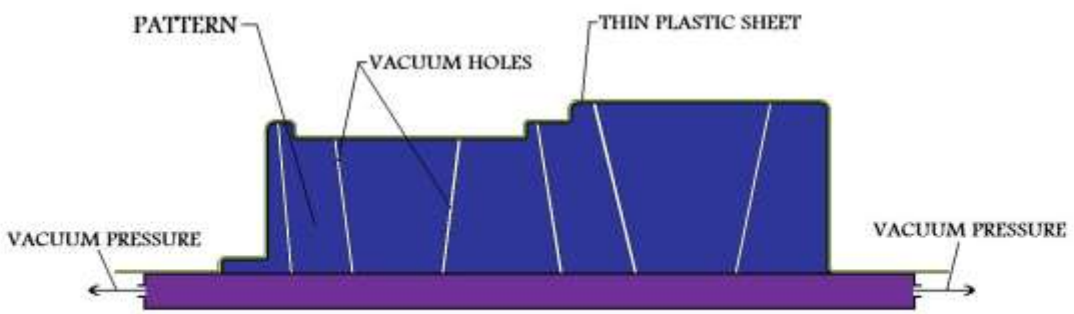
- Some of the advantages of the process are:
  - A hard, rigid core and mold are typical of the process, which gives the casting good dimensional tolerances;
  - good casting surface finishes are readily obtainable;

Vacuum Mold Casting

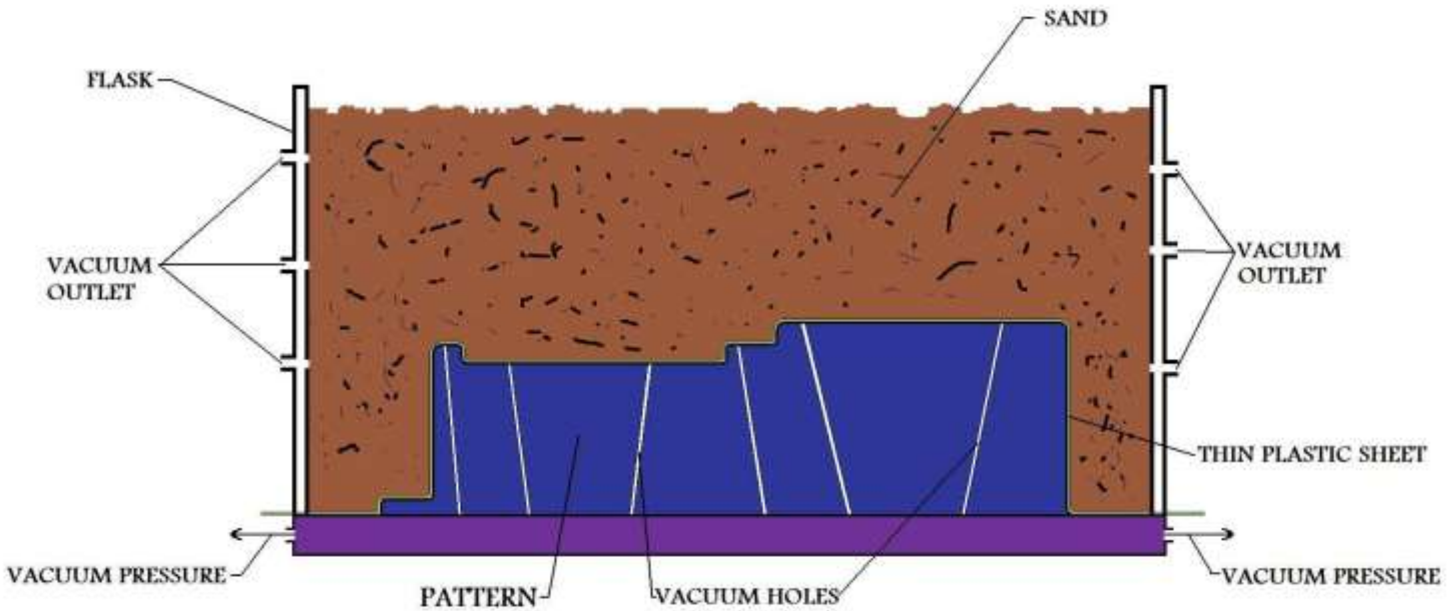
- Vacuum Mold Casting, also known in manufacturing industry as the V-process, employs a sand mold that contains no moisture or binders. The internal cavity of the mold holds the shape of the casting due to forces exerted by the pressure of a vacuum.

The process:

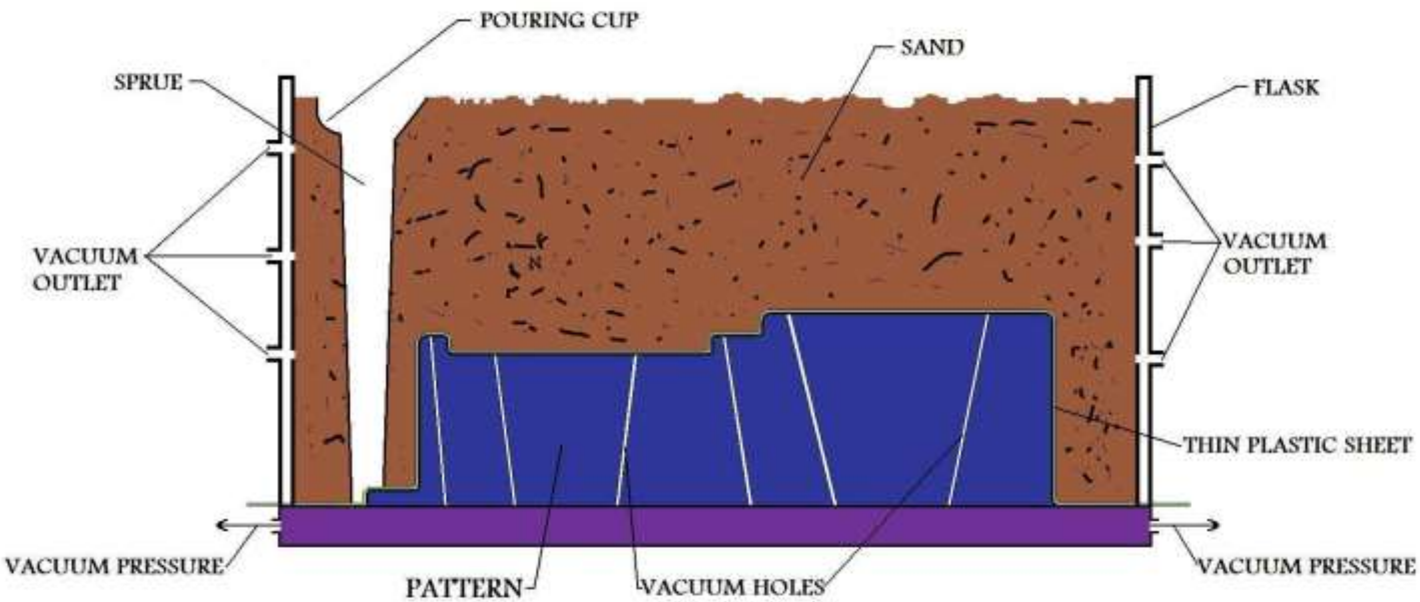
- A special pattern is used for the vacuum mold casting process. It is either a match-plate or a cope and drag pattern with tiny holes to enable a vacuum suction. A thin plastic sheet is placed over the casting pattern and the vacuum pressure is turned on causing the sheet to adhere to the surface of the pattern.



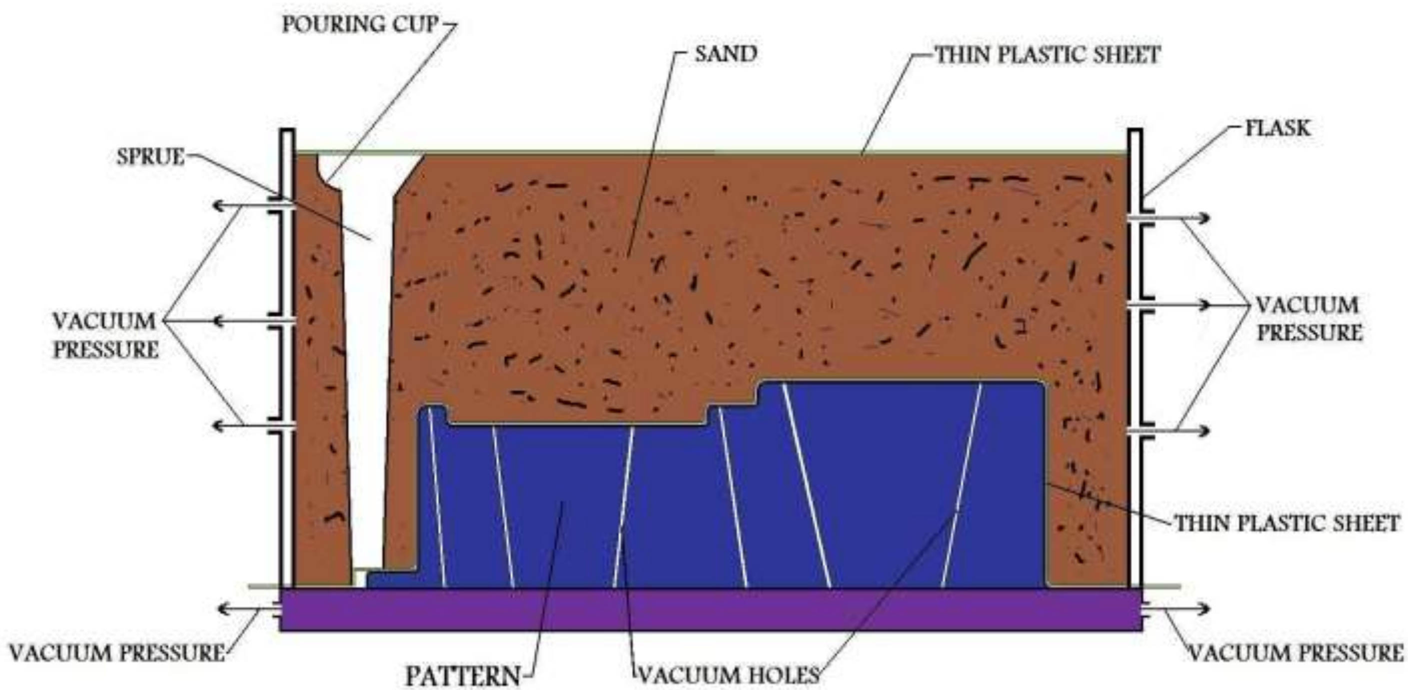
- A special flask is used for this manufacturing process. The flask has holes to utilize vacuum pressure. This flask is placed over the casting pattern and filled with sand



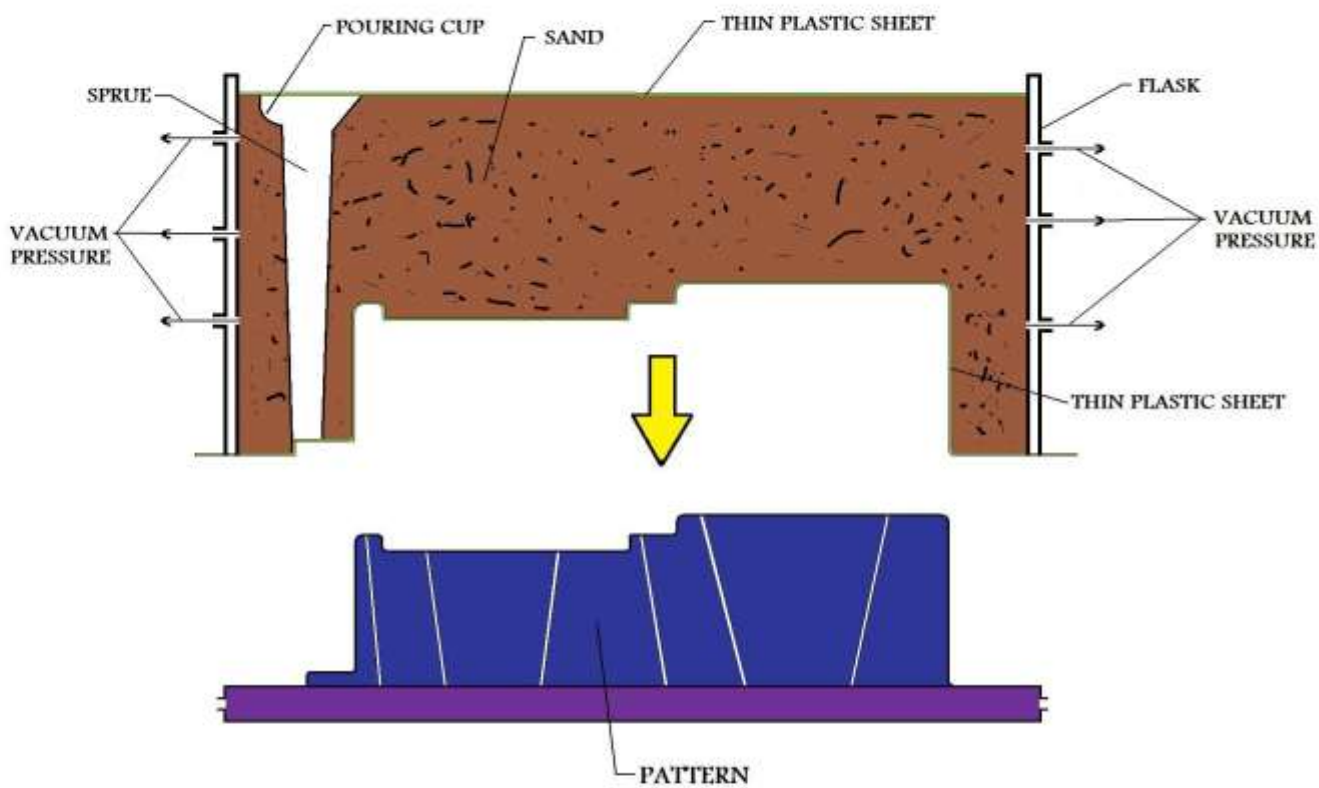
A pouring cup and sprue are cut into the mold for the pouring of the metal casting.



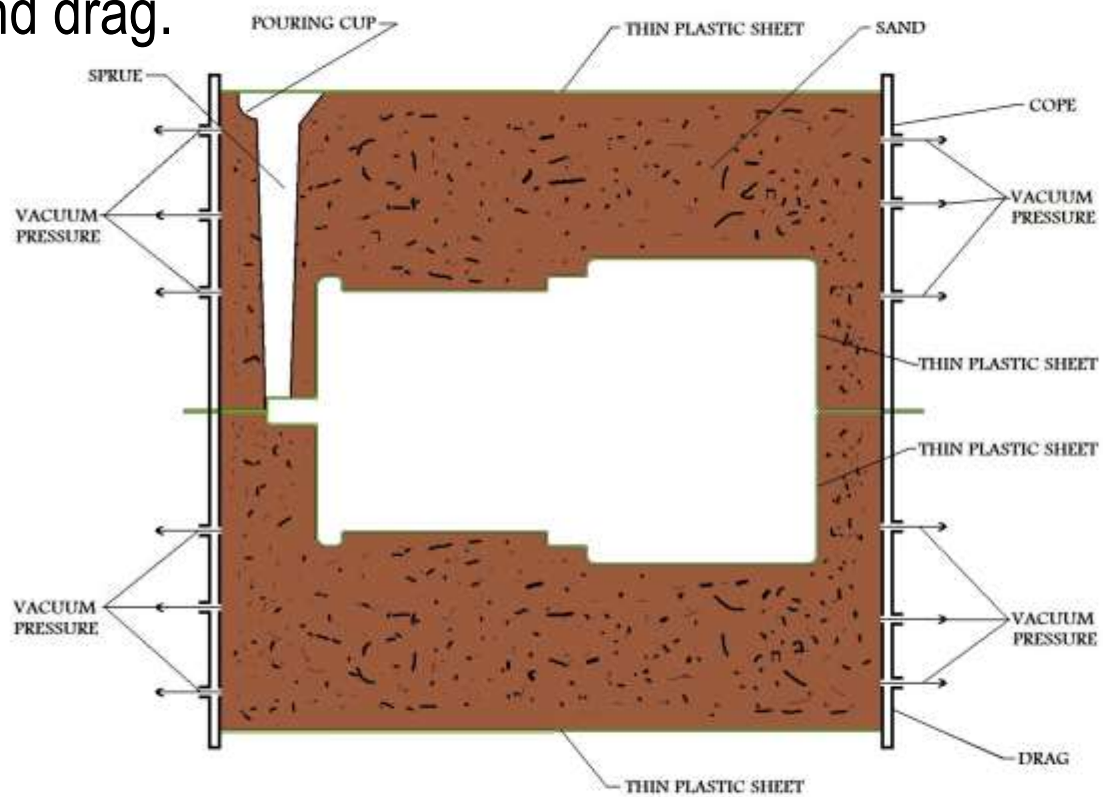
Next another thin plastic sheet is placed over the top of the mold. The vacuum pressure acting through the flask is turned on and the plastic film adheres to the top of the mold.



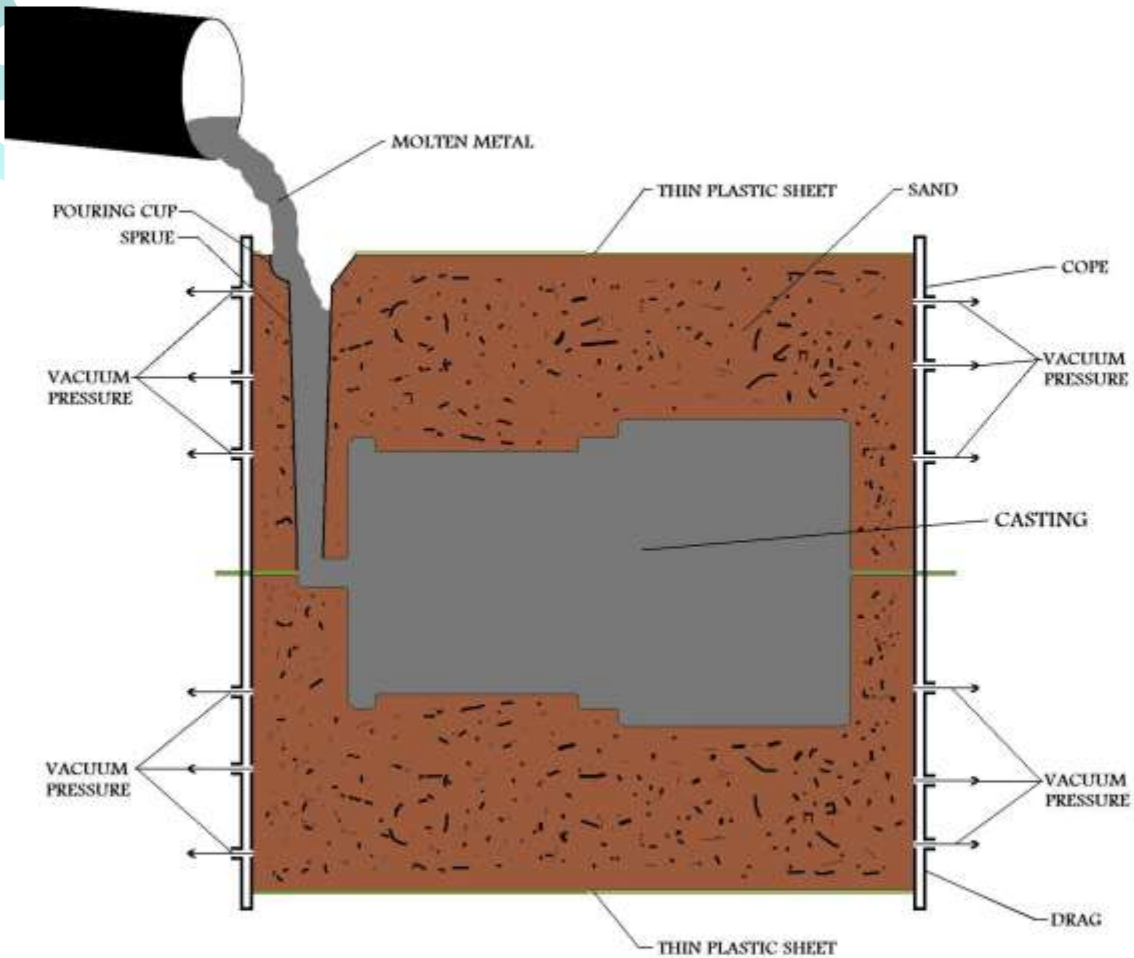
In the next stage of vacuum mold casting manufacture, the vacuum on the special casting pattern is turned off and the pattern is removed. The vacuum pressure from the flask is still on. This causes the plastic film on the top to adhere to the top and the plastic film formerly on the pattern to adhere to the bottom. The film on the bottom is now holding the impression of the casting in the sand with the force of the vacuum suction.



The drag portion of the mold is manufactured in the same fashion. The two halves are then assembled for the pouring of the casting. Note that there are now 4 plastic films in use. One on each half of the internal casting cavity and on each of the outer surfaces of the cope and drag.



During the pouring of the casting the molten metal easily burns away the plastic.

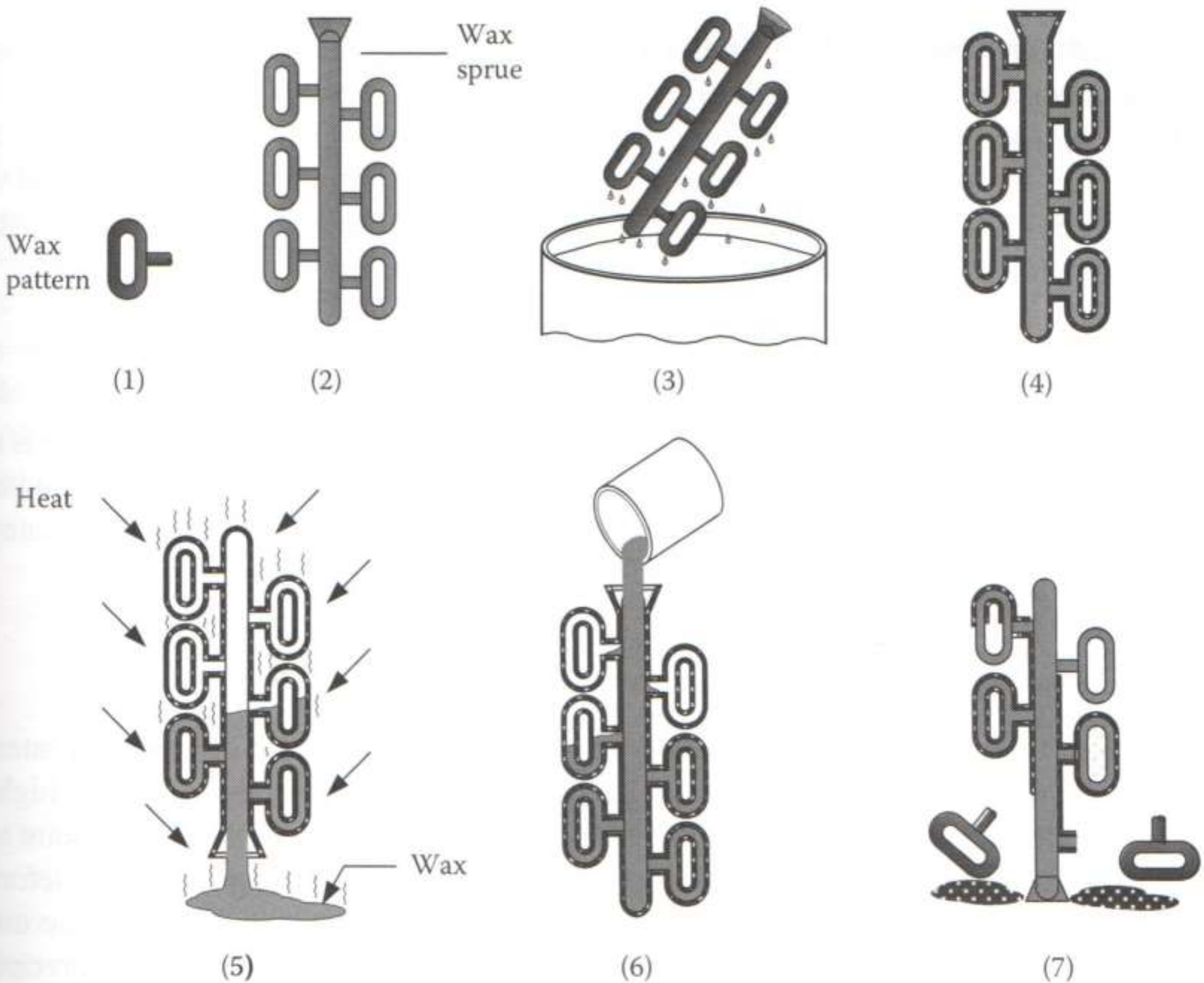


Properties and Considerations of Manufacturing by Vacuum Mold Casting

- In vacuum mold casting manufacture there is no need for special molding sands or binders.
- Sand recovery and reconditioning, a common problem in metal casting industry, is very easy due to the lack of binders and other agents in the sand.
- When manufacturing parts by vacuum mold casting the sand mold contains no water so moisture related metal casting defects are eliminated.
- The size of risers can be significantly reduced for this metal casting process, making it more efficient in the use of material.
- Casting manufacture by vacuum molding is a relatively slow process.
- Vacuum mold casting is not well suited to automation.

Investment Casting

- Investment casting is a manufacturing process in which a wax pattern is coated with a refractory ceramic material. Once the ceramic material is hardened its internal geometry takes the shape of the casting. The wax is melted out and molten metal is poured into the cavity where the wax pattern was. The metal solidifies within the ceramic mold and then the metal casting is broken out. This manufacturing technique is also known as the lost wax process.


Wax pattern
Wax sprue
Heat
Wax
(1)
(2)
(3)
(4)
(5)
(6)
(7)

Properties And Considerations Of Manufacturing By Investment Casting

- Investment Casting is a manufacturing process that allows the casting of extremely complex parts, with good surface finish.
- Very thin sections can be produced with this process. Metal castings with sections as narrow as .015in (.4mm) have been manufactured using investment casting.
- Investment casting also allows for high dimensional accuracy. Tolerances as low as .003in (.076mm) have been claimed with this manufacturing process.
- Practically any metal can be investment cast. Parts manufactured by this process are generally small, but parts weighing up to 75lbs have been found suitable for this technique.
- Parts of the investment process may be automated.
- Investment casting is a complicated process and is relatively expensive.

Plaster Mold Casting

- Plaster of Paris is mixed with water
- Then plaster of Paris and water are then mixed with various additives such as talc and silica flour. The additives serve to control the setting time of the plaster and improve its strength.
- The plaster of Paris mixture is then poured over the casting pattern. The slurry must sit for about 20 minutes before it sets enough to remove the pattern.
- The pattern used for this type of casting manufacture should be made from plastic or metal. Since it will experience prolonged exposure to water from the plaster mix, wood casting patterns have a tendency to warp.
- After stripping the pattern, the mold must be baked for several hours to remove the moisture and become hard enough to pour the casting. The two halves of the mold are then assembled for casting manufacture

Properties and Considerations of Manufacturing by Plaster Mold Casting

- When baking the casting mold just the right amount of water should be left in the mold material. Too much moisture in the mold can cause casting defects, but if the mold is two dehydrated it will lack adequate strength.
- The fluid plaster slurry flows readily over the pattern, making an impression of great detail and surface finish. Also due to the low thermal conductivity of the mold material the casting will solidify slowly creating more uniform grain structure and mitigating casting warping. The qualities of the plaster mold enable the process to manufacture parts with excellent surface finish, thin sections, and produces high geometric accuracy.
- There is a limit to the casting materials that may be used for this type of manufacturing process, due to the fact that a plaster mold will not withstand temperature above 2200F (1200C). Higher melting point materials can not be cast in plaster. This process is typically used in industry to manufacture castings made from aluminum, magnesium, zinc, and copper based alloys.
- Manufacturing production rates for this type of casting process are relatively slow due to the long preparation time for the mold.
- The plaster mold is not permeable which severely limits the escape of gases from the casting

Solving the Permeability Problem

- Permeability can be produced in the mold material by aerating the plaster slurry before forming the mold for the casting. This "foamed plaster" will allow for the much easier escape of gases from the casting. Sometimes in manufacturing industry a special technique called the *Antioch Process* may be used to make a permeable plaster casting mold.

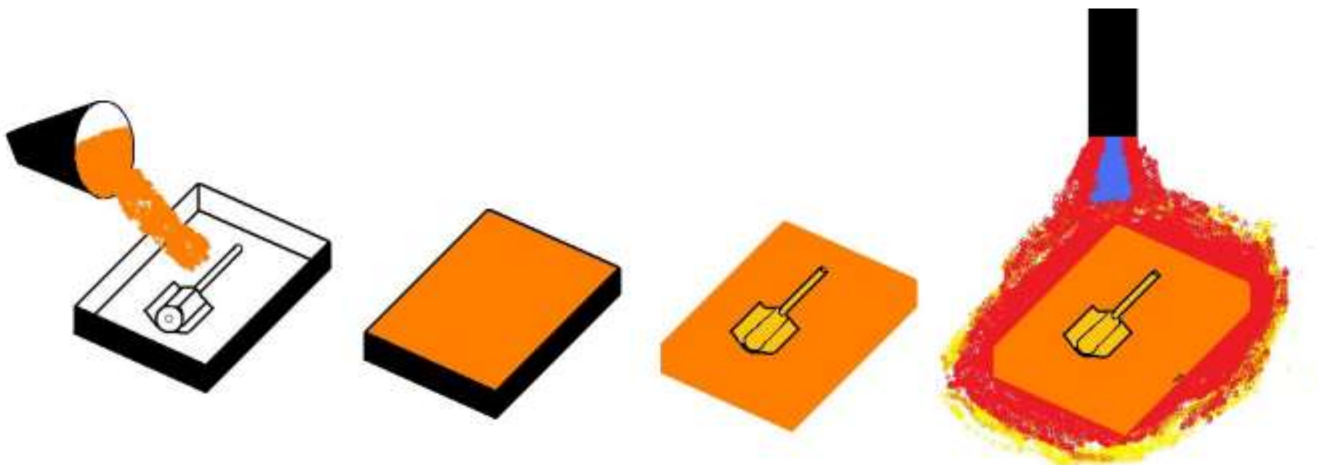
The Antioch Process

- In the Antioch Process 50% plaster of Paris and 50% sand is mixed with water. The mixture is poured over the casting pattern and let set. After the pattern is removed the mold is autoclaved in steam, (placed in an oven that uses hot steam under high pressure), and then let set in air. The resulting mold will easily allow the escape of gases from the casting.

Ceramic Mold Casting

- The manufacturing process of ceramic mold casting is like the process of plaster mold casting but can cast materials at much higher temperatures. Instead of using plaster to create the mold for the metalcasting, ceramic casting uses refractory ceramics for a mold material.

A mixture of fine grain zircon ($ZrSiO_4$), aluminum oxide, fused silica, bonding agents, and water creates a ceramic *slurry* . This slurry is poured over the casting pattern and let set. The pattern is then removed and the mold is left to dry. The mold is then *fired*.



- The firing will burn off any unwanted material and make the mold hardened and rigid. The mold may also need to be baked in a furnace as well. The firing of the mold produces a network of microscopic cracks in the mold material. These cracks give the ceramic mold both good permeability and collapsibility for the casting process.

Properties and Considerations of Manufacturing by Ceramic Mold Casting

- Manufacturing by ceramic mold casting is similar to plaster mold in that it can produce parts with thin sections, excellent surface finish, and high dimensional accuracy. Manufacturing tolerances between .002 and .010 inches are possible with this process.
- To be able to cast parts with high dimensional accuracy eliminates the need for machining, and the scrap that would be produced by machining. Therefore precision metal casting processes like this are efficient to cast precious metals, or materials that would be difficult to machine.
- Unlike the mold material in the plaster metal casting process, the refractory mold material in ceramic casting can withstand extremely elevated temperatures. Due to this heat tolerance the ceramic casting process can be used to manufacture ferrous and other high melting point metalcasting materials. Stainless steels and tool steels can be cast with this process.
- Ceramic mold casting is relatively expensive.
- The long preparation time of the mold makes manufacturing production rates for this process slow
- Unlike in plaster mold casting, the ceramic mold has excellent permeability due to the microcrazing, (production of microscopic cracks), that occurs in the firing of the ceramic mold.

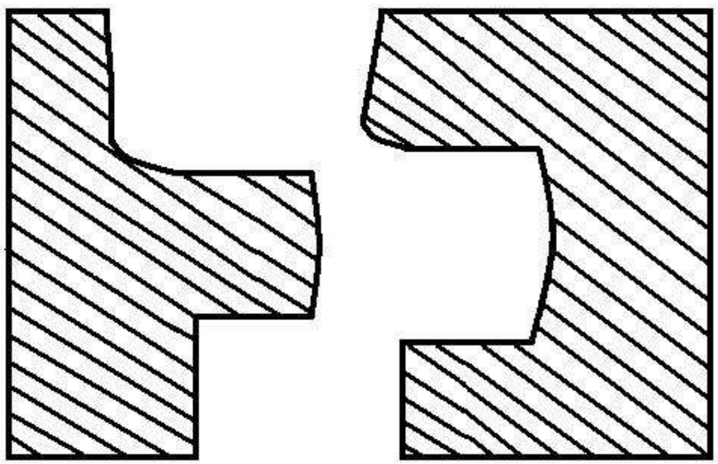
Expanded Polystyrene Casting

- Lost Foam Process

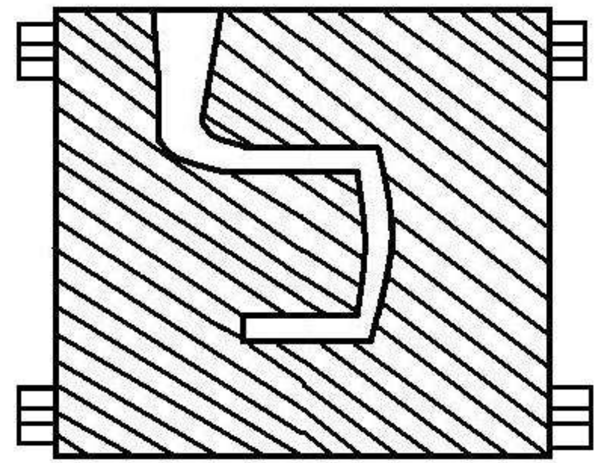
Permanent Mold Casting

- Can be used repeatedly for multiple castings.
- The mold also called a die is commonly made of steel or iron, but other metals or ceramics can be used.
- The sections of the mold are most likely machined from two separate blocks. These parts are manufactured precisely. They are created so that they fit together and may be opened and closed easily and accurately. The gating system as well as the part geometry is machined into the mold.
- A significant amount of resources need to be utilized in the production of the mold, making setup more expensive for permanent mold manufacturing runs. However, once created, a permanent mold may be used tens of thousands of times before its mold life is up.
- Due to the continuous repetition of high forces and temperatures all molds will eventually decay to the point where they can no longer effectively manufacture quality castings. The number of castings produced by that particular mold before it had to be replaced is termed *mold life* . Many factors effect mold life such as the molds operating temperature, mold material and casting metal.

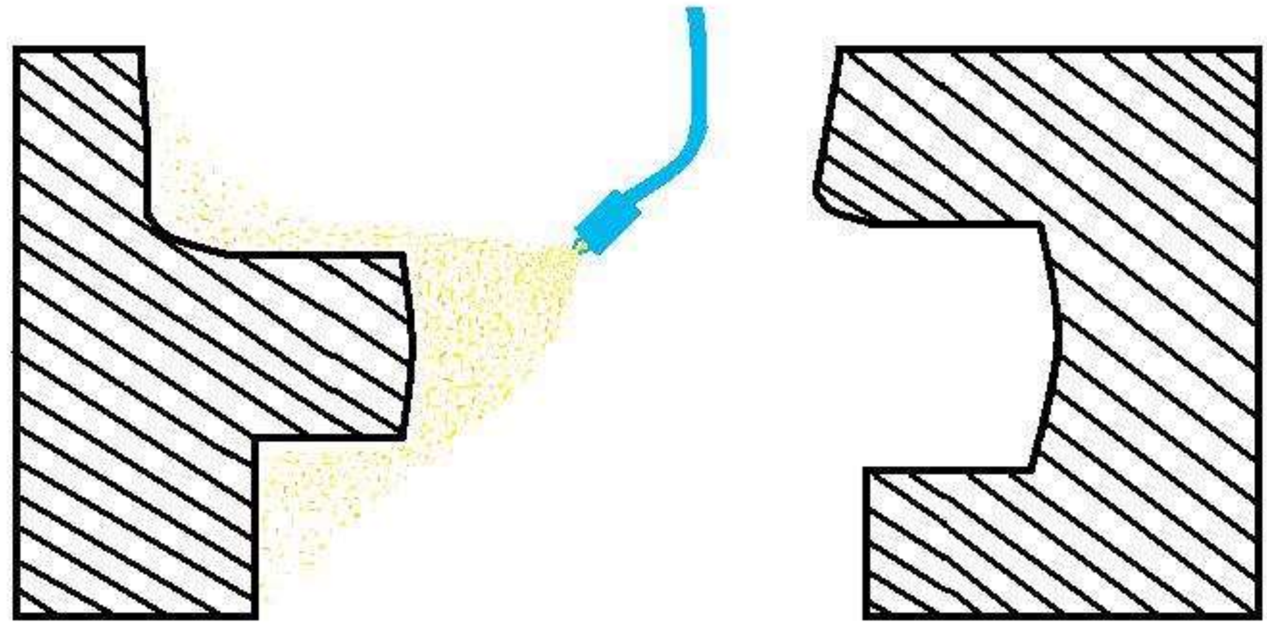
TWO HALVES OF A BASIC PERMANENT MOLD (CROSS-SECTIONAL)



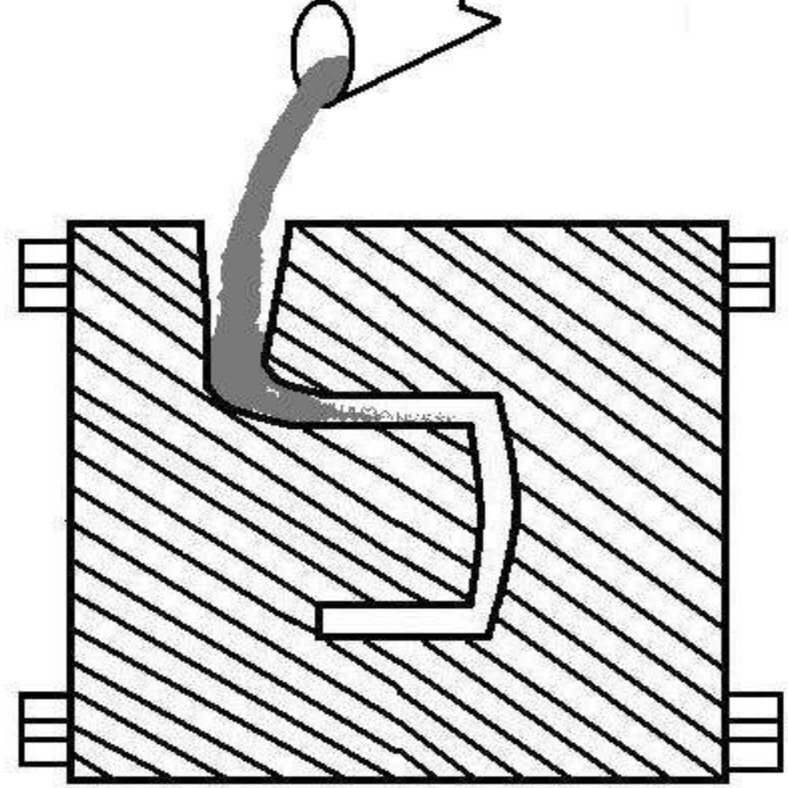
BASIC PERMANENT MOLD ASSEMBLED (CROSS-SECTIONAL)



BASIC PERMANENT MOLD BEING SPRAYED WITH REFRACTORY SLURRY PRIOR TO THE CASTING OPERATION



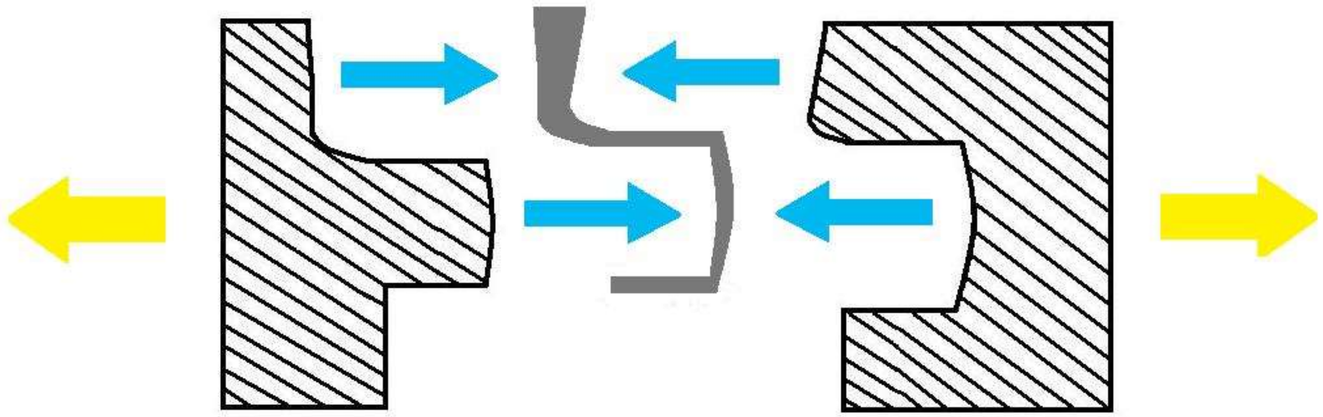
This coating serves as a thermal gradient helping to control the heat flow, and acting as a lubricant for easier removal of the cast part. In addition applying the refractory coat as a regular part of the manufacturing process will increase the mold life.



POURING OF BASIC PERMANENT MOLD
(GRAVITY FED PROCESS)

The mold will be heated prior to the pouring of the metal casting. A possible temperature that a permanent metal casting mold may be heated before pouring could be around 350F (175C). The heating of the mold will facilitate the smoother flow of the liquid metal through the molds gating system and casting cavity. Pouring in a heated mold will also reduce the thermal shock encountered by the mold due to the high temperature gradient between the molten metal and the mold. This will act to increase mold life

BASIC PERMANENT MOLD IS OPENED AND SOLIDIFIED CASTING IS EJECTED



In manufacturing practice the cast part is usually removed before much cooling occurs to prevent the solid metal casting from contracting too much in the mold. This is done to prevent cracking the casting since the permanent mold does not collapse. The removal of the part is accomplished by way of ejector pins built into the mold.

Properties And Considerations Of Manufacturing By Permanent Mold Casting

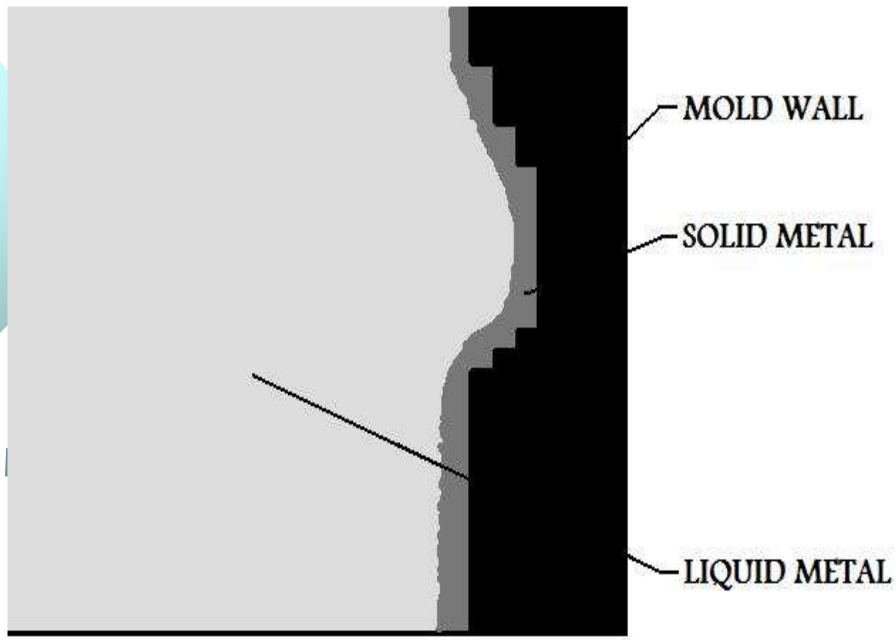
- Generally this manufacturing process is only suited for materials with lower melting temperatures, such as zinc, copper, magnesium, and aluminum alloys.
- Steels may be cast in permanent molds made of graphite or some special refractory material.
- The mold may be cooled by water or heat fins to help the dissipation of heat during the casting process.
- Due to the need to open and close the mold to remove the work piece, part geometry is limited.
- Closer dimensional accuracy as well as excellent surface finish of the part, is another advantage of this manufacturing process.
- In industrial manufacture permanent mold casting results in a lower percentage of rejects than many expendable mold processes.
- There is a limitation on the size of cast parts manufactured by this process.
- The initial setup cost are high making permanent mold casting unsuitable for small production runs.
- This manufacturing process is useful in industry for high volume runs. Where once set up, it can be extremely economical with a high rate of production.

Slush Casting

- Slush casting is a variation of permanent mold casting that is used to produce hollow parts. In this method neither the strength of the part nor its internal geometry can be controlled accurately. This casting process is used primarily to manufacture toys and parts that are ornamental in nature, such as lamp bases and statues.

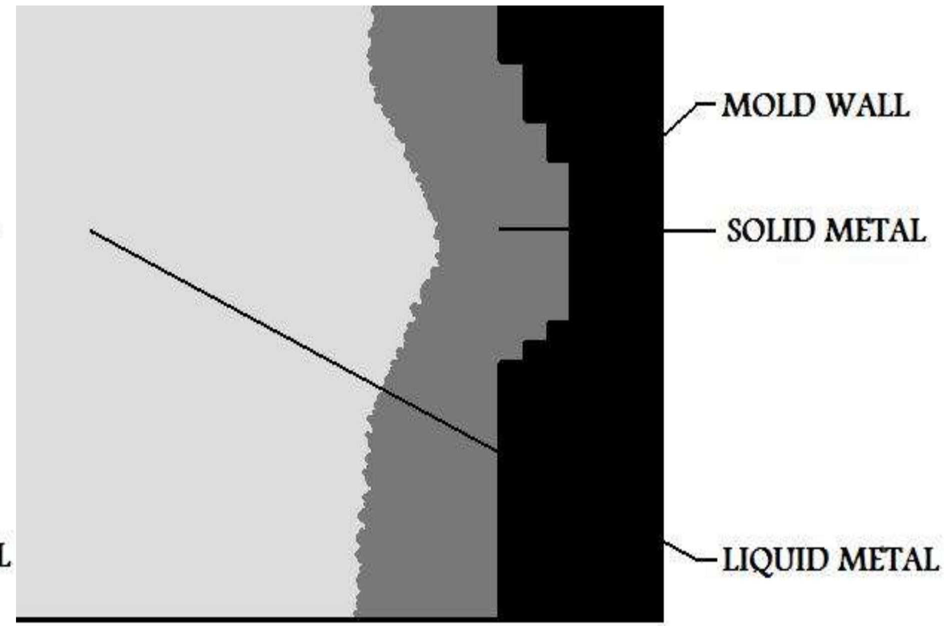
MOLD FOR SLUSH CASTING
IMMEDIATELY AFTER POURING

The main principle of this casting process relies on the fact that when a metal casting hardens in a mold, it will solidify from the mold wall towards the inside of the casting. In other words a metal skin forms first, (as the external geometry of the part). This skin thickens as more of the metal casting's material converts to a solid state.



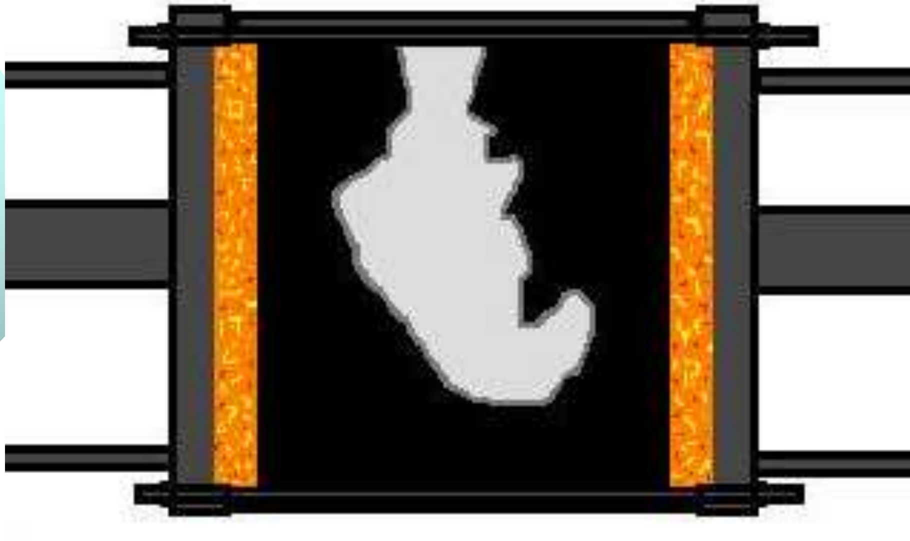
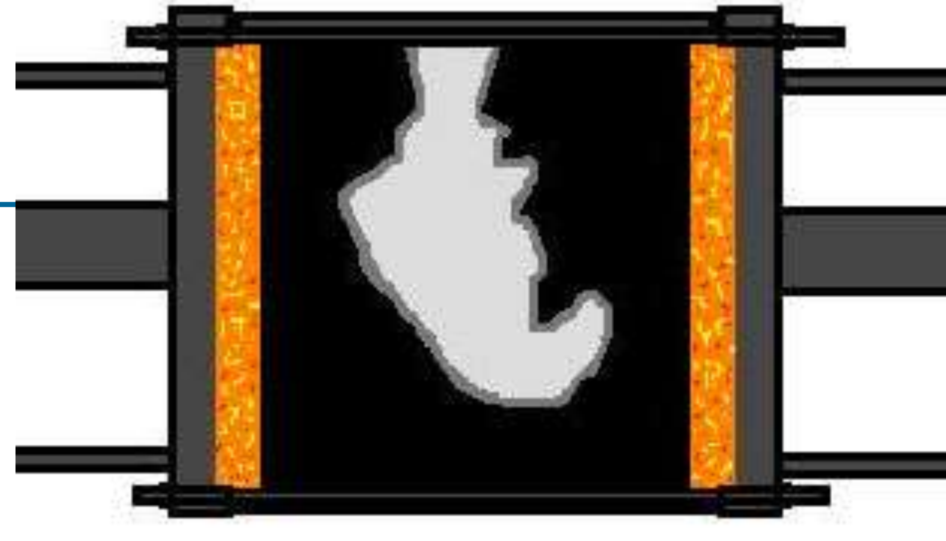
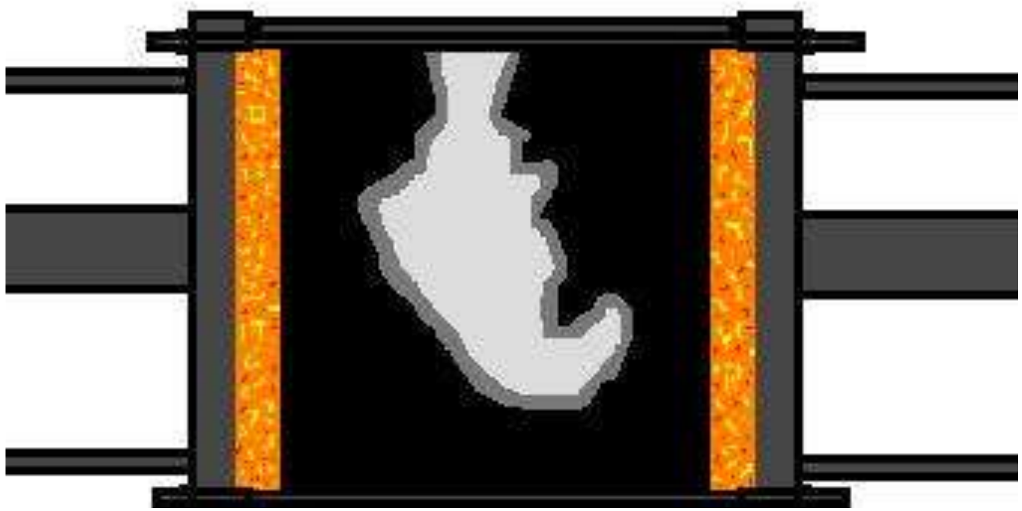
SECTION OF CASTING NEAR MOLD WALL
SHORT TIME AFTER POURING

SOLIDIFICATION CAN BE SEEN TO START AT INTERFACE BETWEEN MOLTEN METAL AND MOLD SURFACES

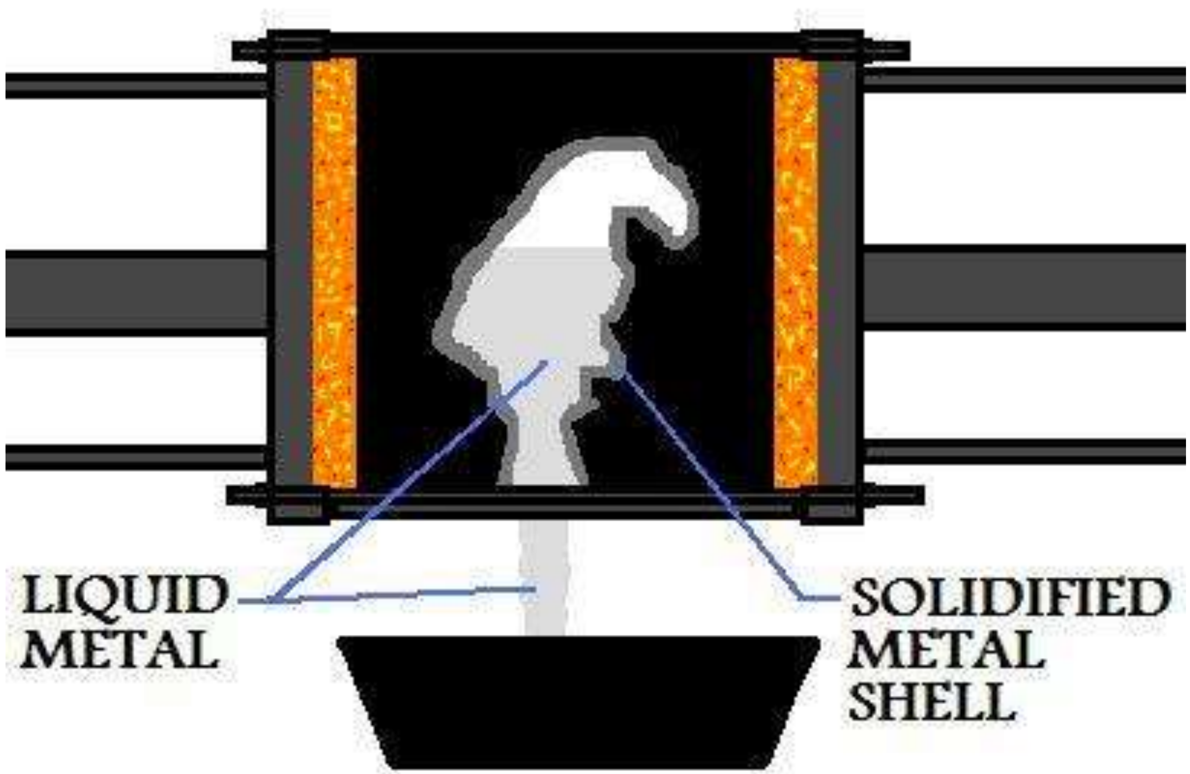


SECTION OF CASTING NEAR MOLD WALL
LONGER TIME AFTER POURING

SOLIDIFICATION PROGRESSES FROM MOLD-CASTING INTERFACE TOWARRDS INNER REGIONS OF THE MATERIAL THICKNESS OF THIS SOLID SECTION INCREASES WITH TIME

THE LIQUID METAL FROM THE INTERIOR OF THE CASTING IS POURED OUT BEFORE THE ENTIRE MASS OF MOLTEN MATERIAL CAN HARDEN. LEAVING ONLY THE SOLIDIFIED OUTER SHELL.



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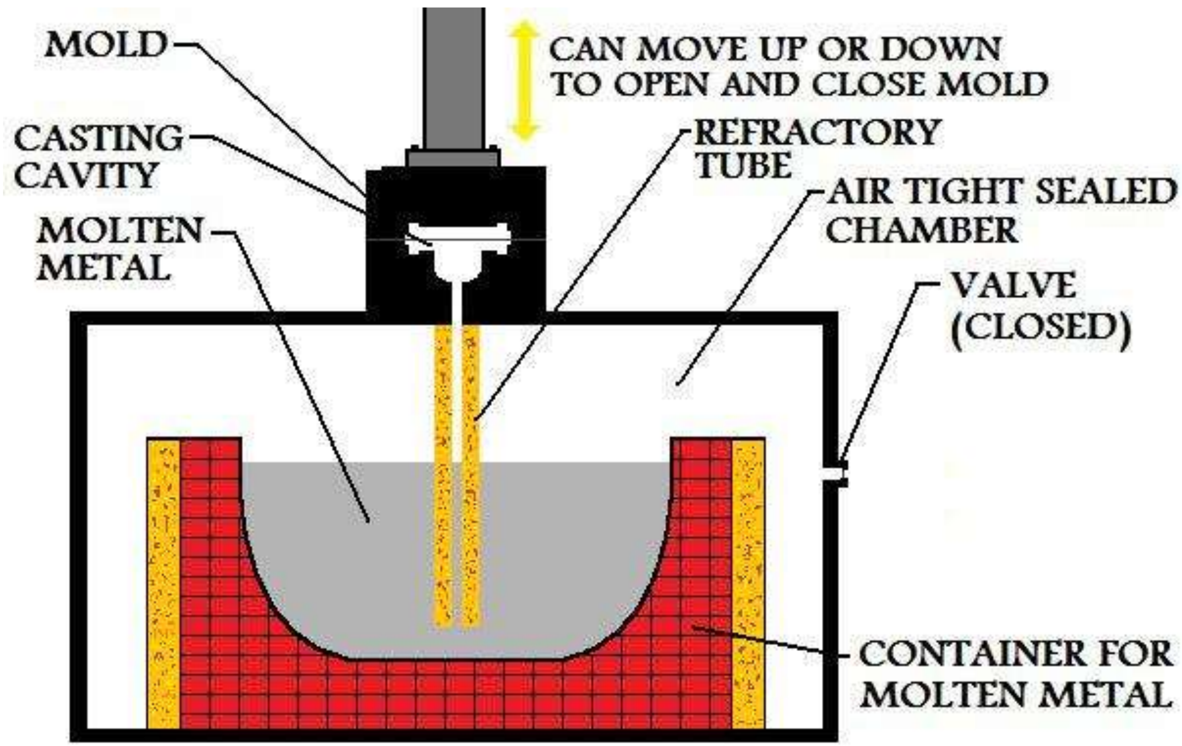
Properties And Considerations Of Manufacturing By Slush Casting

- Slush casting is mainly suited to lower melting point materials, zinc, tin, or aluminum alloys are commonly slush cast in manufacturing industry.
- With this process you need to have a mechanical means of turning over the mold in order to pour out the molten metal from the cast part.
- When manufacturing by slush casting it is difficult to accurately control the casting's strength and other mechanical properties.
- The casting's internal geometry cannot be effectively controlled with this process.
- The hollow castings manufactured by this process are lighter than solid parts, and save on material.

Pressure Casting

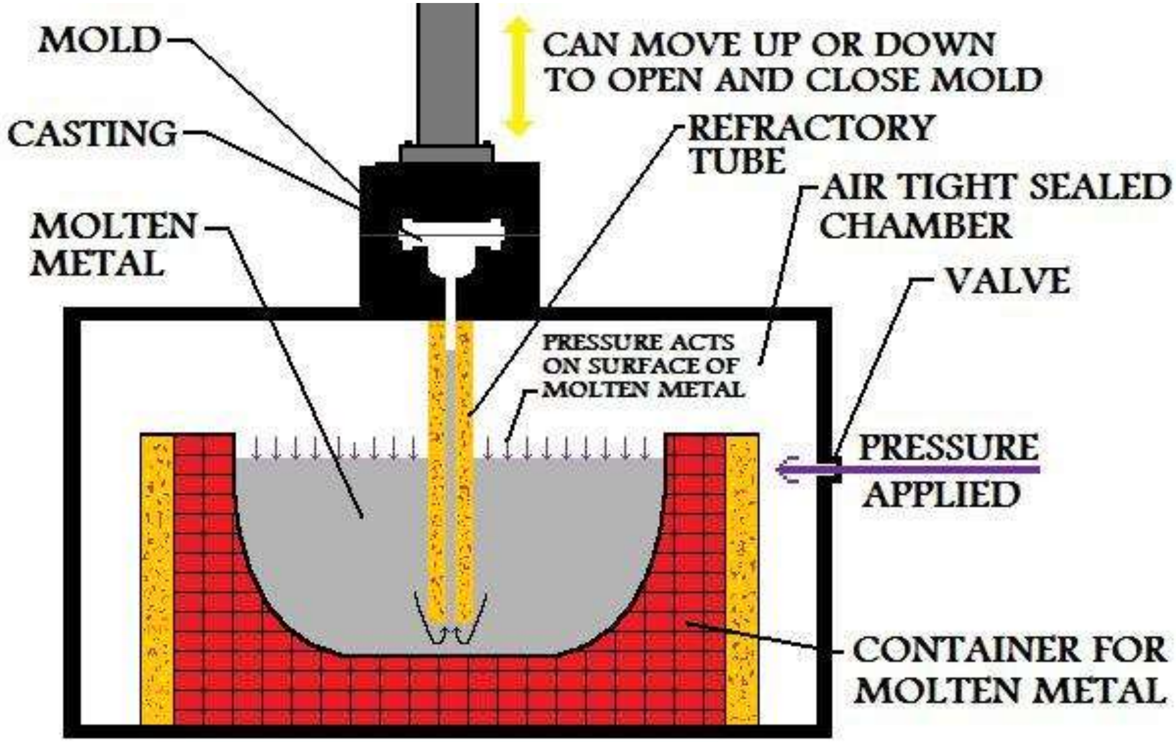
- Instead of pouring the molten metal into the casting and allowing gravity to be the force that distributes the liquid material through the mold, pressure casting uses air pressure to force the metal through the gating system and the casting's cavity

The gating system is set up so that the molten material flows into the mold from the bottom instead of the top, (like in gravity fed processes).The mold is set up above the supply of liquid metal to be used for the casting. A refractory tube goes from the entrance of the gating system down into the molten material.



PRESSURE CASTING

MOLD IS IN PLACE AND OPERATION IS READY TO BEGIN



PRESSURE CASTING

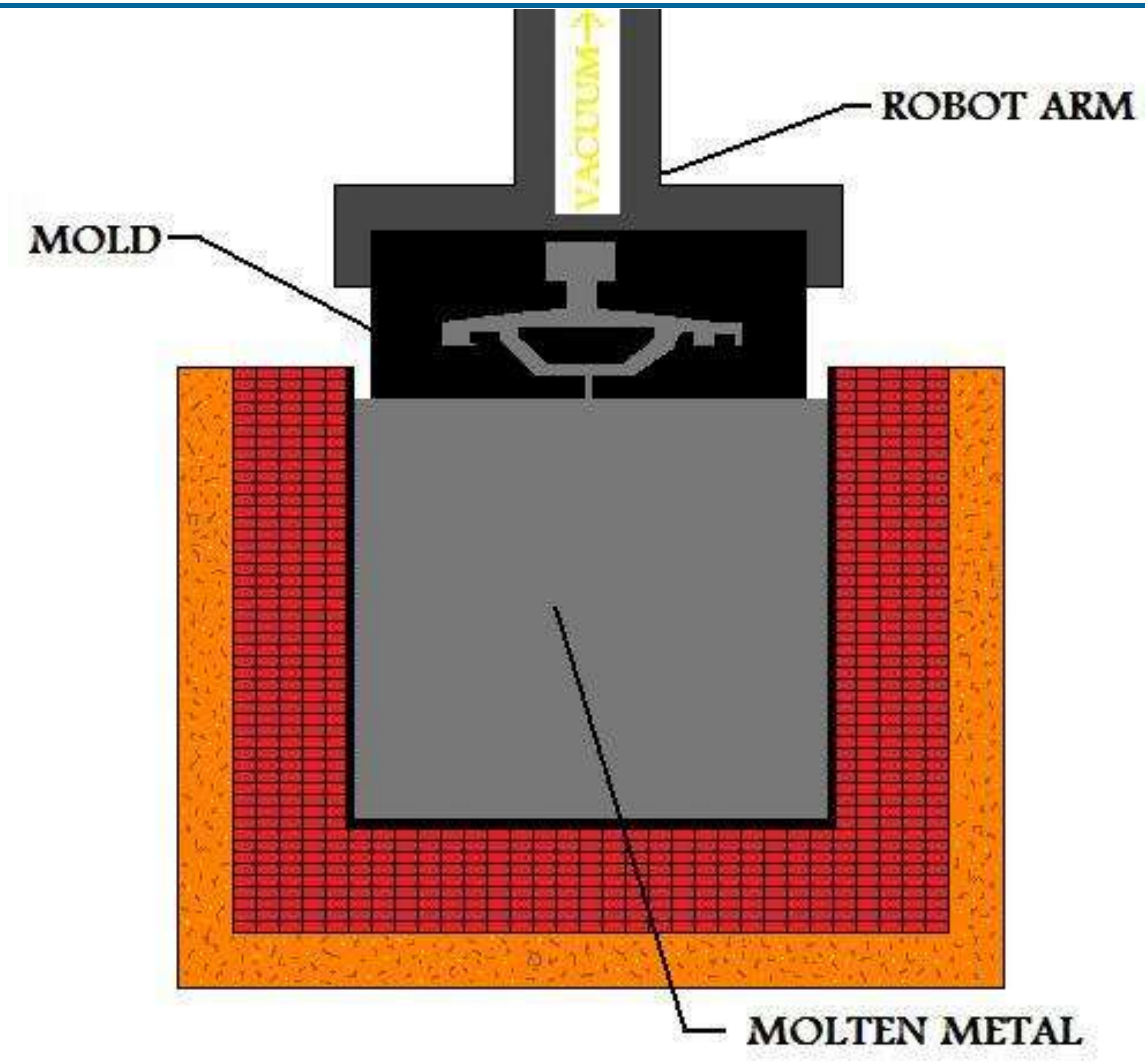
PRESSURE DIFFERENCE BETWEEN CHAMBER AND MOLD FORCES METAL TO FLOW UP THE REFRACTORY TUBE

The air pressure is maintained until the metal casting has hardened within the mold

Properties And Considerations Of Manufacturing By Pressure Casting

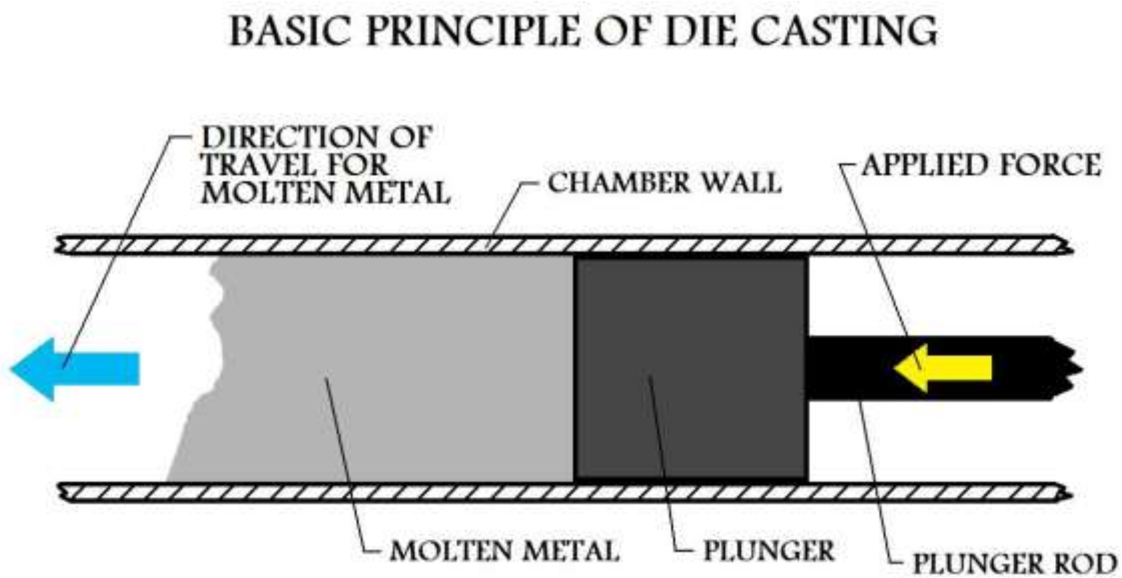
- Pressure casting manufacture can be used to produce castings with superior mechanical properties, good surface finish, and close dimensional accuracy.
- Like in other permanent mold methods the mold needs to be able to open and close for removal of the work piece. Therefore very complicated casting geometry is limited.
- Since the refractory tube is submersed in the molten material, the metal drawn for the casting comes from well below the surface. This metal has had less exposure to the environment than the material at the top. Gas trapped in the metal as well as oxidation effects are greatly reduced.
- The high setup cost makes pressure casting not efficient for small runs, but an excellent productivity rate makes it suitable for large batch manufacture.

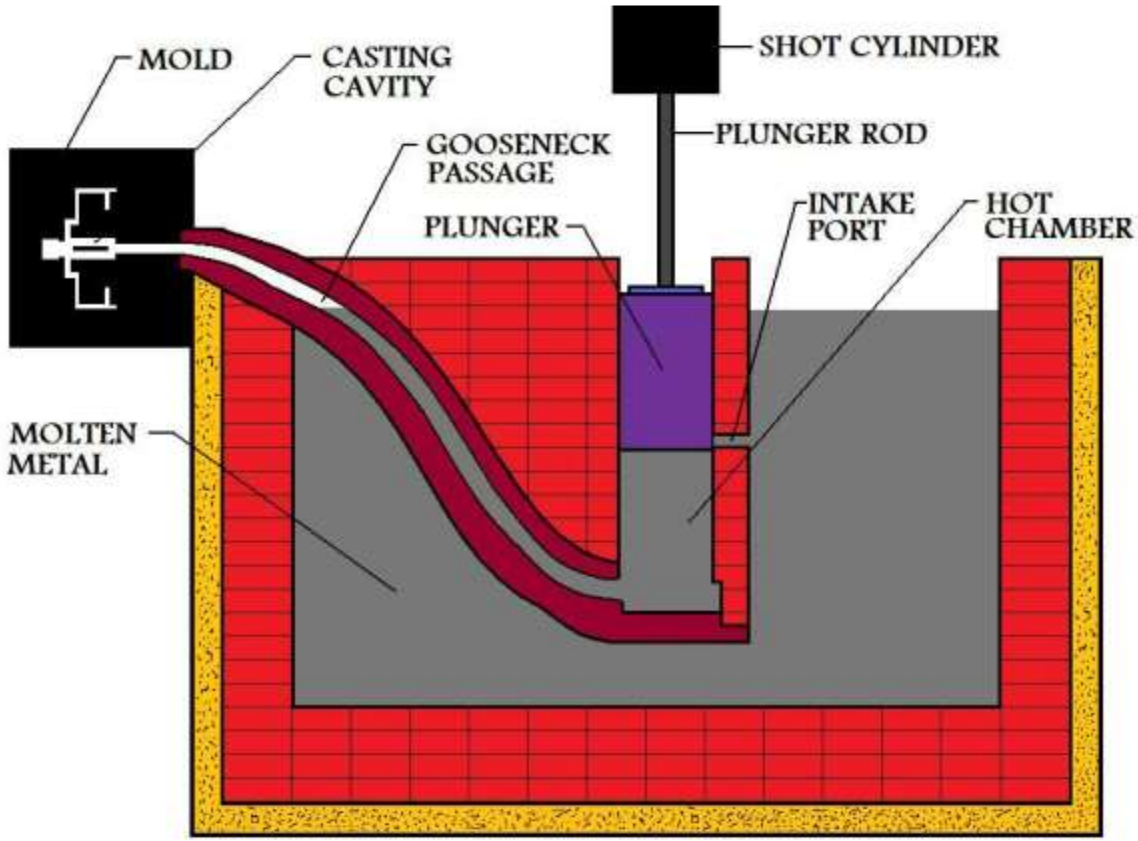
Vacuum Permanent Mold Casting



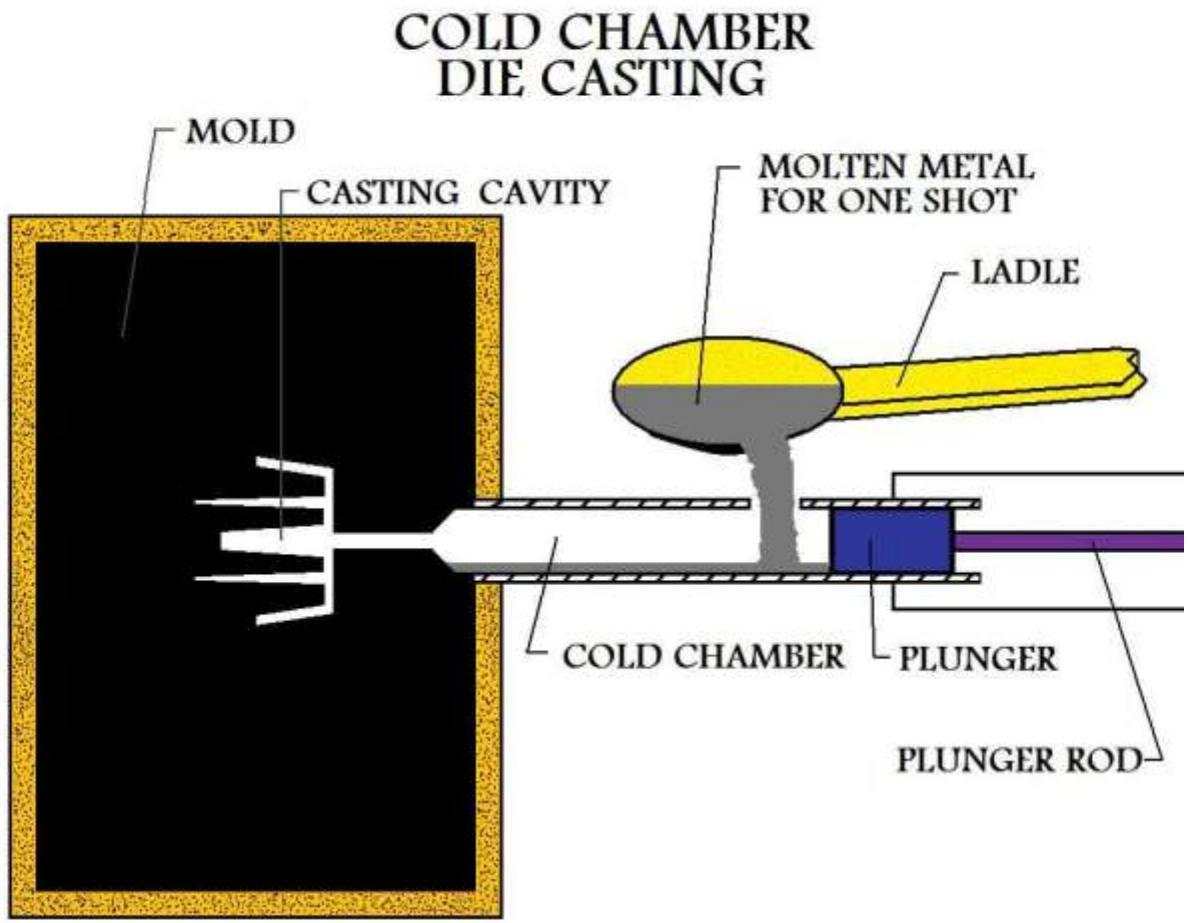
Die Casting Manufacture

- Large amount of pressure is used to ensure the flow of metal through the mold, metal castings with great surface detail, dimensional accuracy, and extremely thin walls can be produced.
- Two types –
  1. Hot Chamber die casting
  2. Cold Chamber die casting

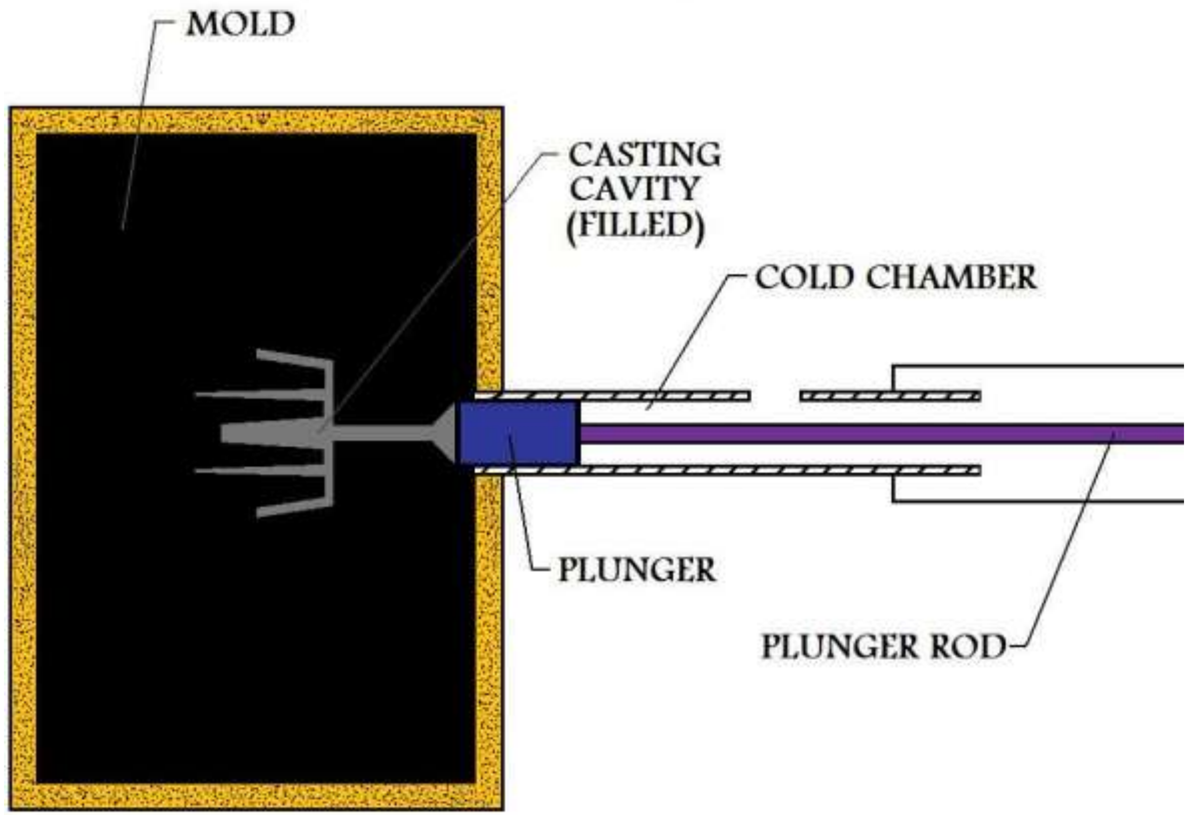

BASIC PRINCIPLE OF DIE CASTING
DIRECTION OF TRAVEL FOR MOLTEN METAL
CHAMBER WALL
APPLIED FORCE
MOLTEN METAL
PLUNGER
PLUNGER ROD



HOT CHAMBER DIE CASTING


COLD CHAMBER
DIE CASTING
MOLD
CASTING CAVITY
MOLTEN METAL
FOR ONE SHOT
LADLE
COLD CHAMBER
PLUNGER
PLUNGER ROD

COLD CHAMBER DIE CASTING



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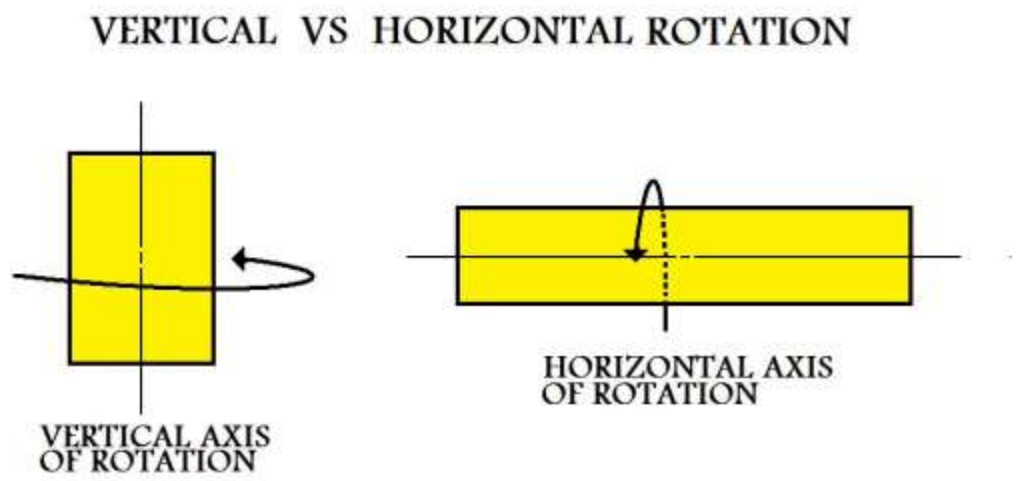
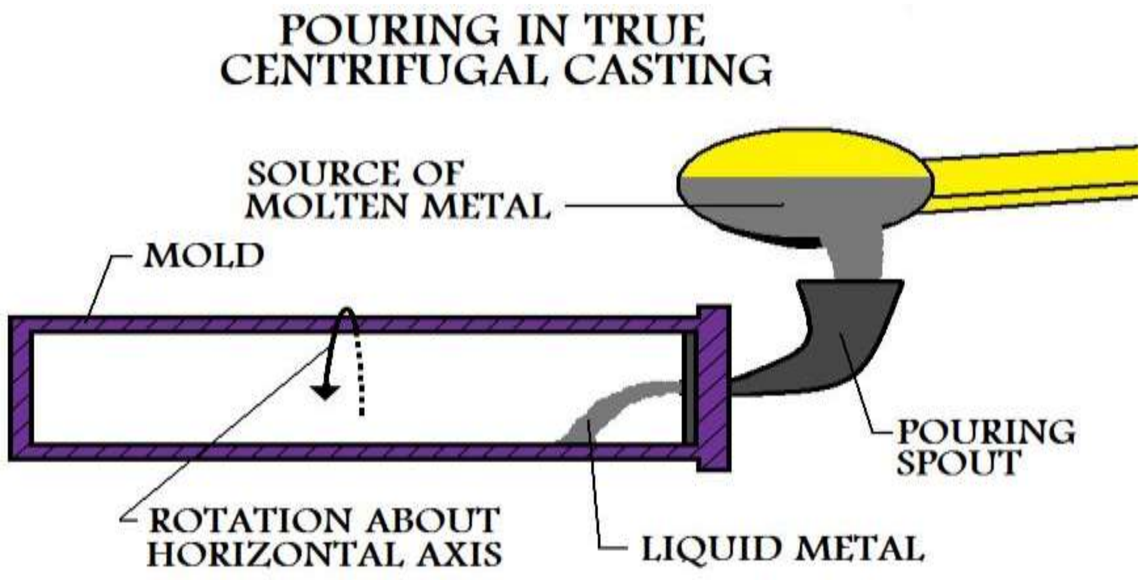
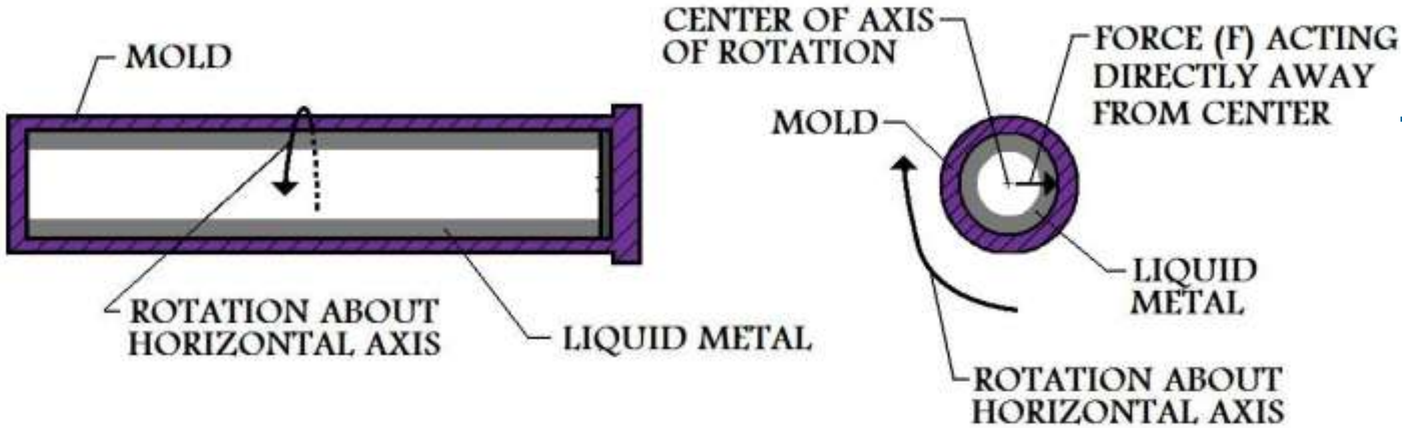
True Centrifugal Casting

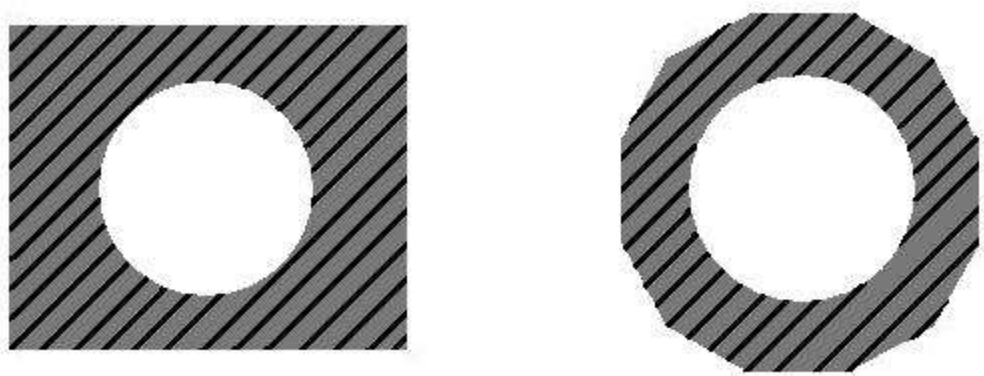




SOLIDIFICATION IN TRUE CENTRIFUGAL CASTING



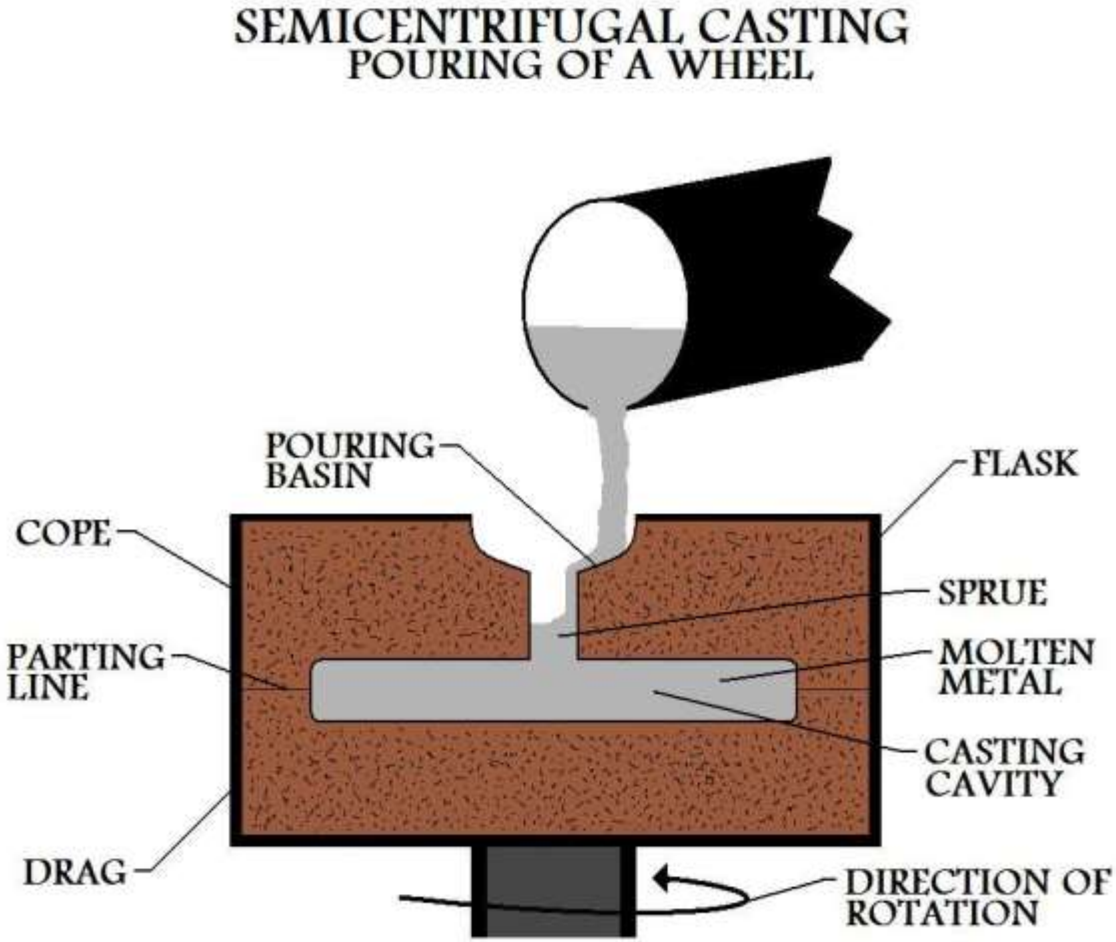
CROSS-SECTION OF PARTS MANUFACTURED BY THE TRUE CENTRIFUGAL CASTING PROCESS



SQUARE

10 SIDED POLYGON

Semicentrifugal Casting



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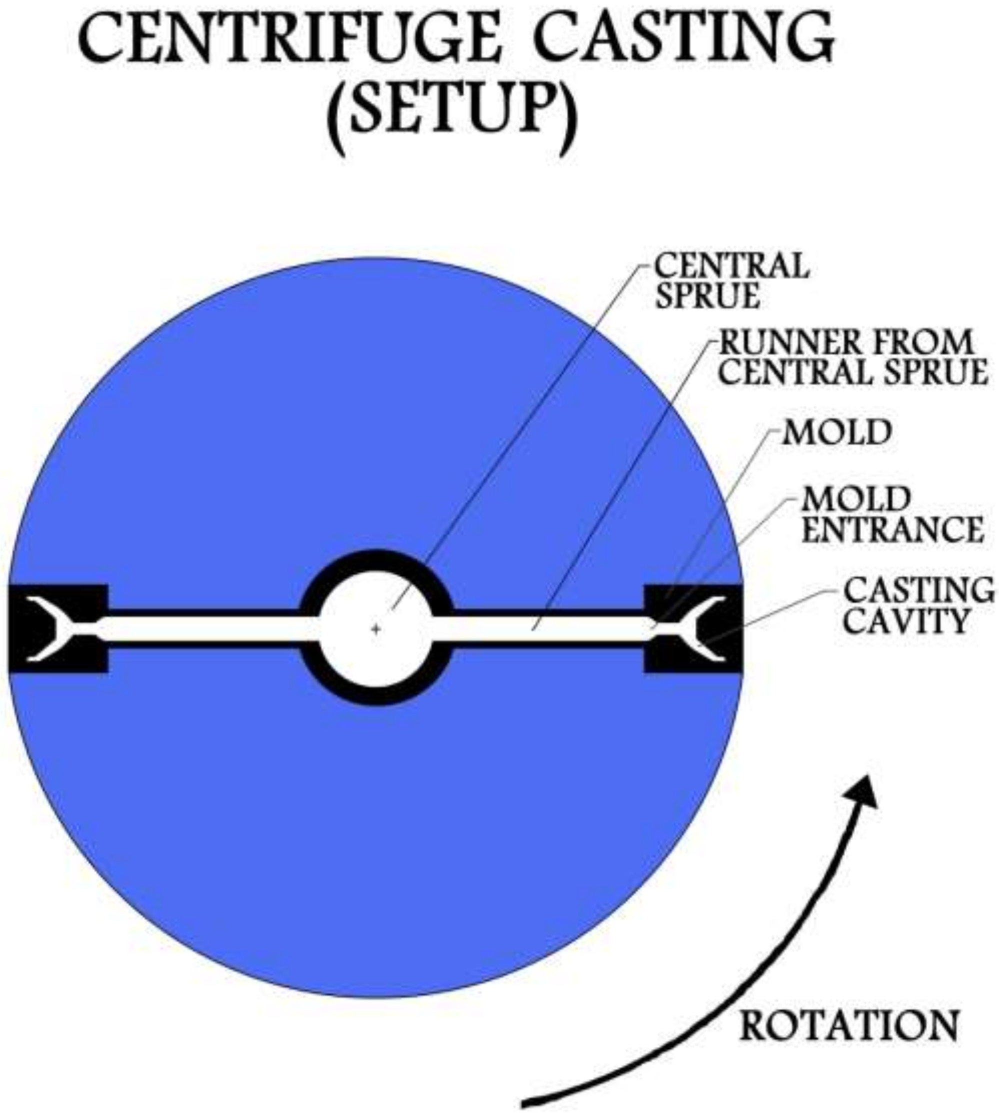
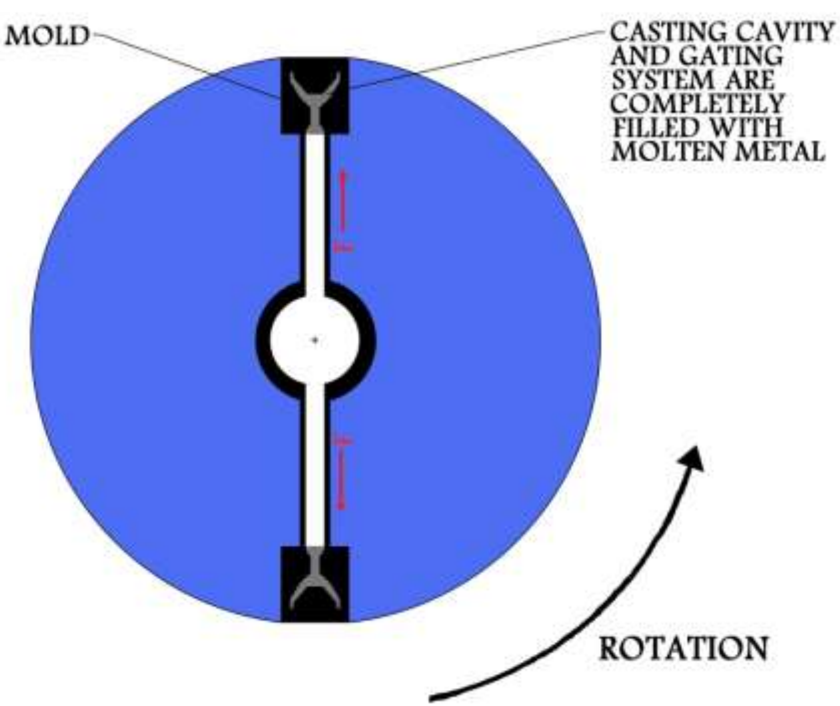
Centrifuge Casting



CENTRIFUGE CASTING (SOLIDIFICATION)



CENTRIFUGE CASTING (POURING)