MANUFACTURING TECHNOLOGY – I

Unit 1-Metal Castings

Pattern Making

Pattern

- ❖ The pattern is the principal tool during the casting process.
- ❖ It is the replica of the object to be made by the casting process, with some modifications.
- ❖ The main modifications are the addition of pattern allowances, and the provision of core prints.
- ❖ If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product.
- ❖ The quality of the casting produced depends upon the material of the pattern, its design, and construction.
- ❖ The costs of the pattern and the related equipment are reflected in the cost of the casting.
- ❖ The use of an expensive pattern is justified when the quantity of castings required is substantial.

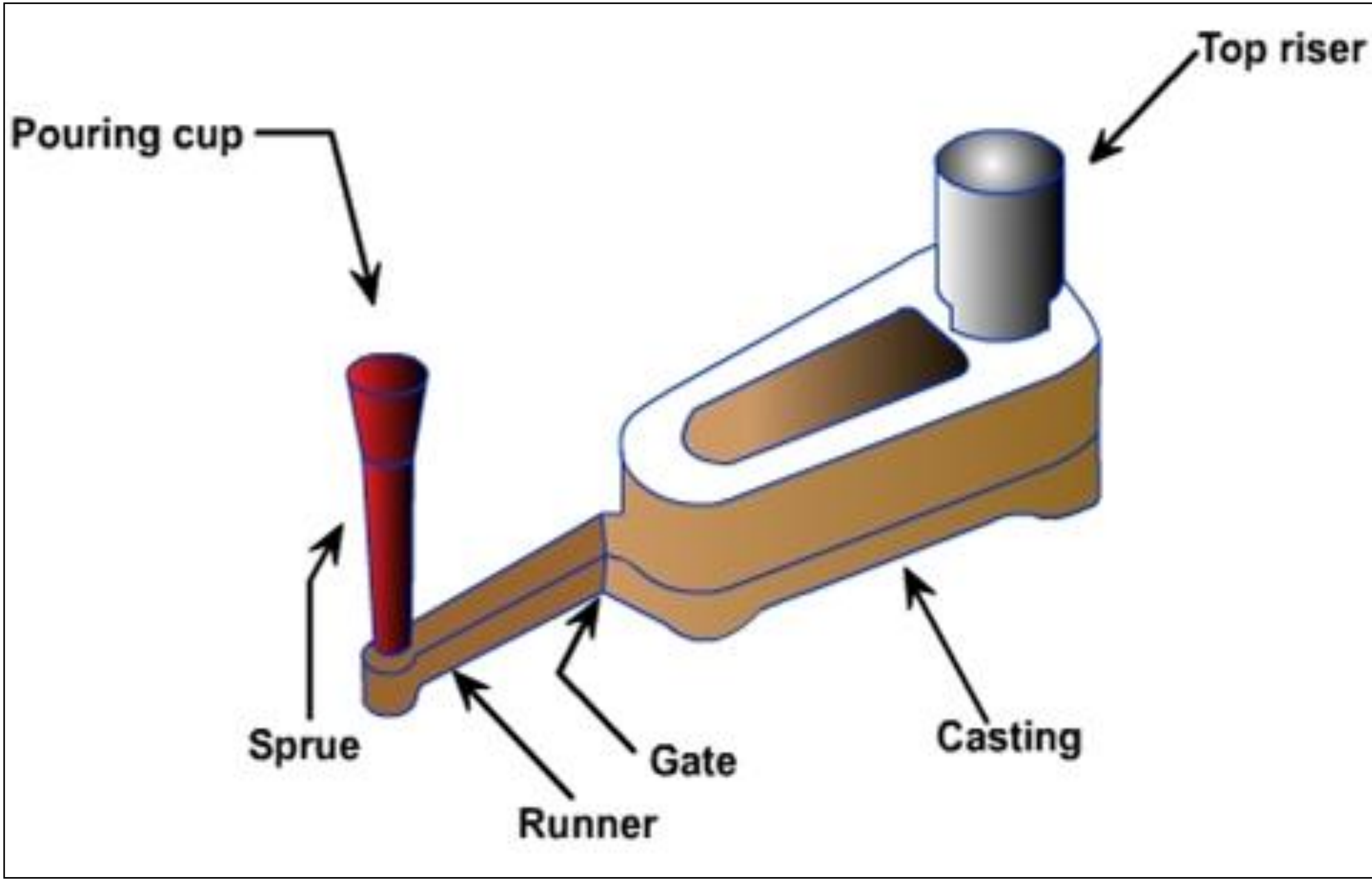


Fig: A typical pattern attached with gating and risering system

Functions of the Pattern

1. A pattern prepares a mould cavity for the purpose of making a casting.
2. A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.
3. Runner, gates, and risers used for feeding molten metal in the mould cavity may form a part of the pattern.
4. Patterns properly made with finished and smooth surfaces reduce casting defects.
5. A properly constructed pattern minimizes the overall cost of the castings.

Pattern Material

Patterns may be constructed from: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins. Each material has its own advantages, limitations, and field of application.

To be suitable for use, 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 Material

- The usual pattern materials are wood, metal, and plastics.
- The most commonly used pattern material is wood, since it is readily available and of low weight.
- Also, it can be easily shaped and is relatively cheap.
- The main disadvantage of wood is its absorption of moisture, which can cause distortion and dimensional changes.
- Hence, proper seasoning and upkeep of wood is almost a pre-requisite for large-scale use of wood as a pattern material.

Materials for making patterns

- Wood
- Metal
- Plastic
- Plaster
- Wax
- polyterene

Wood:-

Advantages:-

- Inexpensive
- Easily available
- Easy to machine
- Easy to join large patterns
- Light weight
- Good surface finish
- Easy to repaire

Limitations:-

- Susceptible to shrinkage and swelling
- Poor wear resistance
- They absorb moisture
- Cannot withstand rough handling
- Week compared to metals

White pine, mahagony, teak,maple,kail,deodar etc

Metal

Aluminium , steel, cat iron, brass etc

- They do not absorb moisture
- More stronger
- Accurate
- With stand rough handling
- Do not wrap
- Good resistance to abrasion
- Good dimensional accuracy
- Stable
- Wear resistant good weight to strength ratio

Limitations

- Expevsive
- Not easy to repair
- Rusting problem
- Heavier than wood
- Not easy to machine

Plastic

Adanantages

- Durable
- Smooth surface finish
- Moisture resistant
- No swelling or wrap problem
- Light weight
- Good strength
- Wear&corrosion resistant
- Easy to make
- abrasion strength
- Resistant to chemical attack

Limitations

- Fragile & need reinforcement
- Cant withstand mechanical impact

Pattern Allowances

- ❖ Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting.
- ❖ Thus, when the pattern is produced, certain allowances must be given on the sizes specified in the finished component drawing so that a casting with the particular specification can be made.
- ❖ The selection of correct allowances greatly helps to reduce machining costs and avoid rejections.
- ❖ The allowances usually considered on patterns and core boxes are as follows:

1. Shrinkage or contraction allowance
2. Draft or taper allowance
3. Machining or finish allowance
4. Distortion or camber allowance
5. Rapping allowance

Shrinkage or Contraction Allowance

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

1. **Liquid Shrinkage**: it refers to the reduction in volume when the metal changes from liquid state to solid state. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mould.

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.

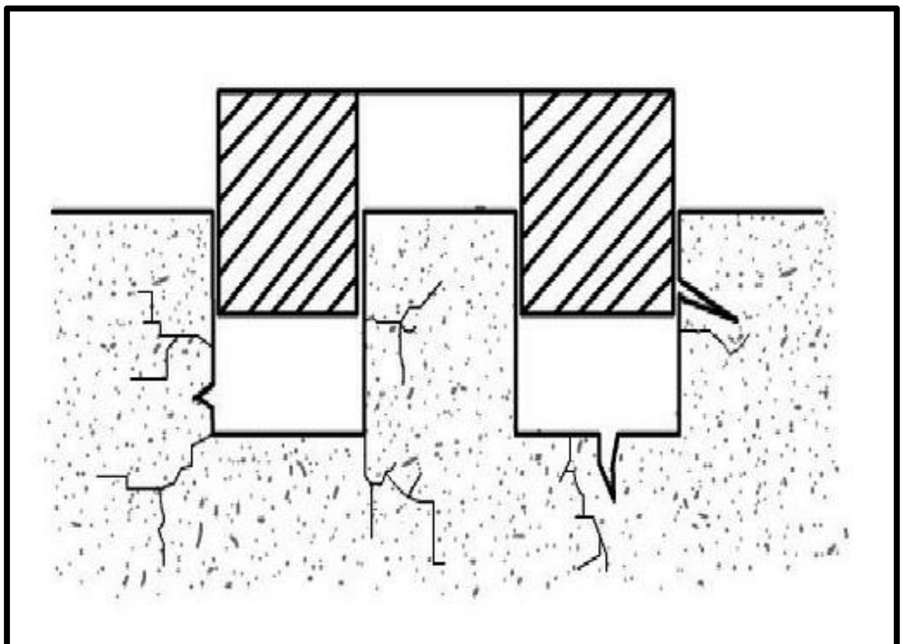
❖ The rate of contraction with temperature is dependent on the material.

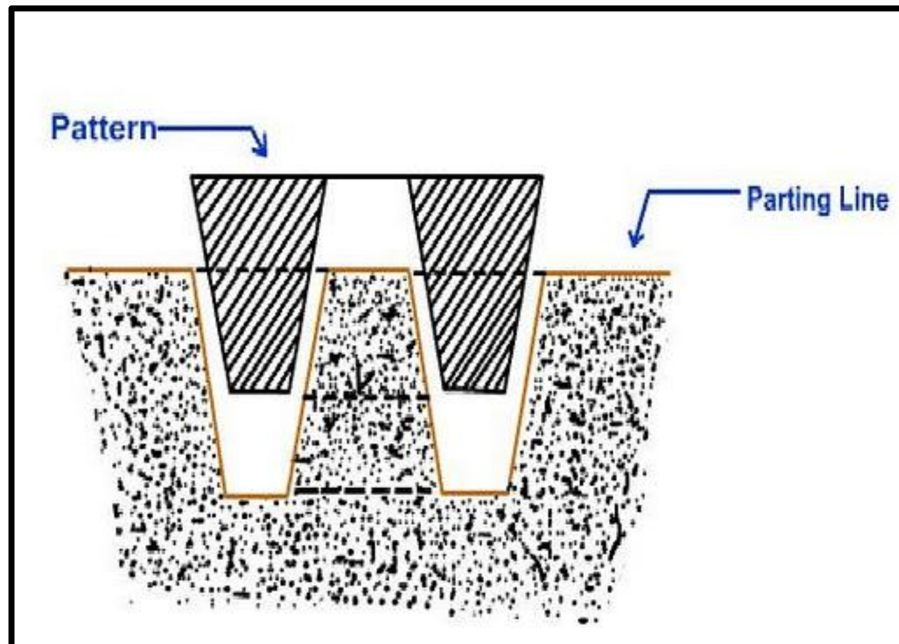
❖ For example steel contracts to a higher degree compared to aluminium.

❖ To compensate the solid shrinkage, a shrink rule must be used in laying out the measurements for the pattern.

Draft or Taper Allowance

- By draft is meant 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 mould and without excessive rapping by the moulder.





Draft or Taper Allowance

❖ Figure (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 mould, thus tending to break it.

Draft or Taper Allowance Video (Click Here)

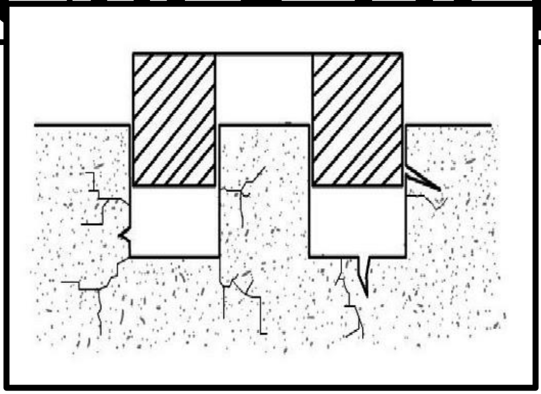


Fig (a): Pattern Having No Draft on Vertical Edges

Draft or Taper Allowance

- Figure (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 mould cavity.

Draft or Taper Allowance Video (Click Here)

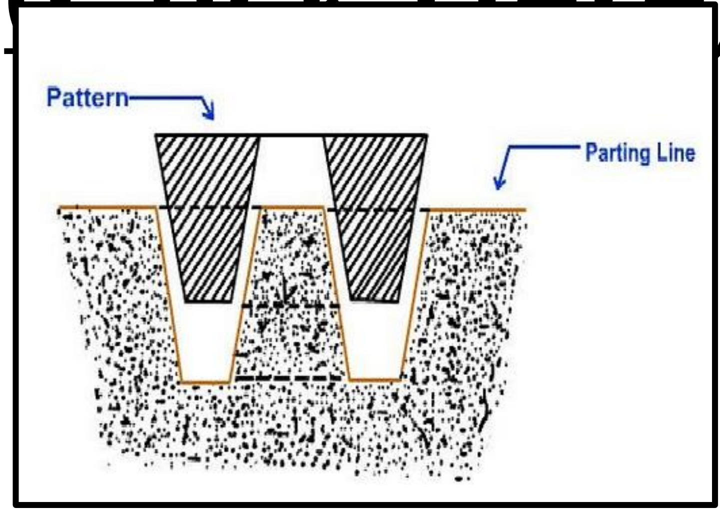


Fig (b): Pattern Having Draft on Vertical Edges

Draft or Taper Allowance

- ❖ Draft allowance varies with the complexity of the sand job.
- ❖ But in general inner details of the pattern require higher draft than outer surfaces.
- ❖ The amount of draft depends upon
  - ✓ The length of the vertical side of the pattern to be extracted;
  - ✓ The intricacy of the pattern;
  - ✓ The method of moulding; and
  - ✓ Pattern material.

Machining or Finish Allowance

- The finish and accuracy achieved in sand casting are generally poor and therefore when the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining.
- Machining or finish allowances are therefore added in the pattern dimension.
- The amount of machining allowance to be provided for is affected by the method of moulding and casting used viz.
  - ✓ Hand moulding or machine moulding,
  - ✓ Sand casting or metal mould casting.
- The amount of machining allowance is also affected by
  - ✓ The size and shape of the casting;
  - ✓ The casting orientation;
  - ✓ The metal; and
  - ✓ The degree of accuracy and finish required.

Distortion or Camber Allowance

- ❖ Sometimes castings get distorted, during solidification, due to their typical shape.
- ❖ For example, if the casting has the form of the letter U, V, T, or L etc. it will tend to contract at the closed end causing the vertical legs to look slightly inclined.
- ❖ This can be prevented by making the legs of the U, V, T, or L shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical.
- ❖ The distortion in casting may occur due to internal stresses.
- ❖ These internal stresses are caused on account of unequal cooling of different section of the casting and hindered contraction.

Distortion or Camber Allowance

Measure taken to prevent the distortion in casting include:

- ❖ Modification of casting design
- ❖ Providing sufficient machining allowance to cover the distortion affect
- ❖ Providing suitable allowance on the pattern, called ***camber*** or distortion allowance (inverse reflection)

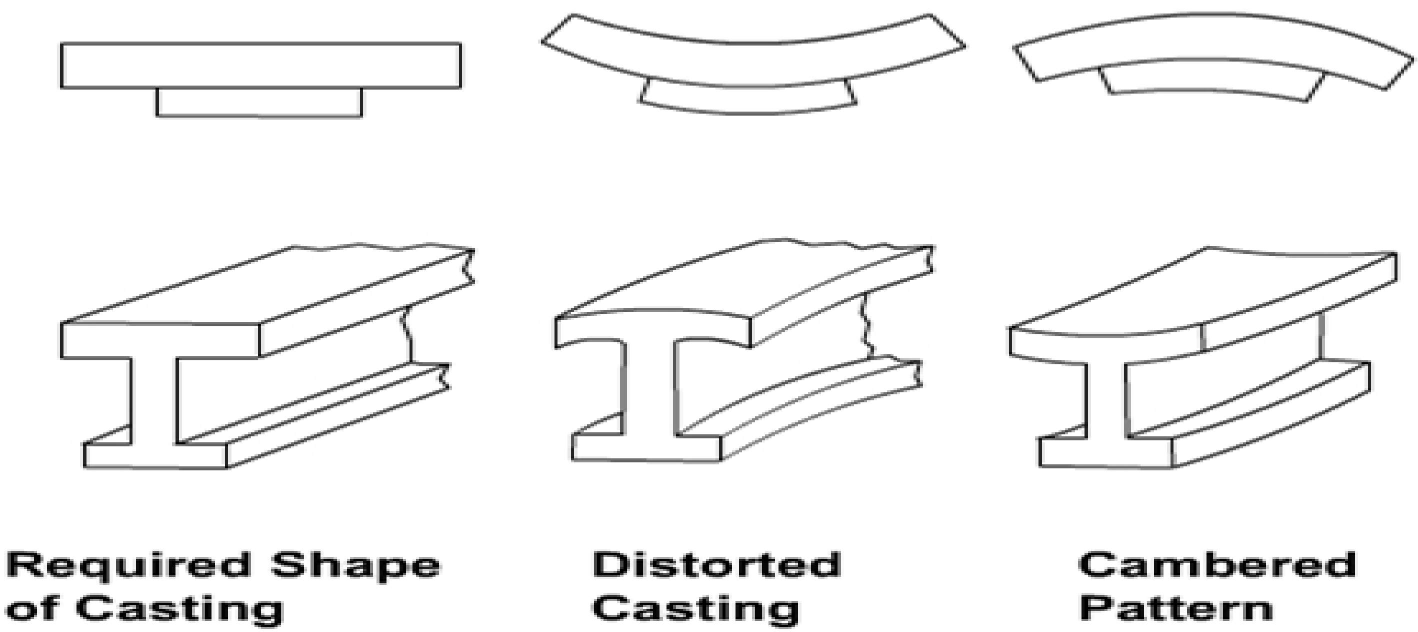


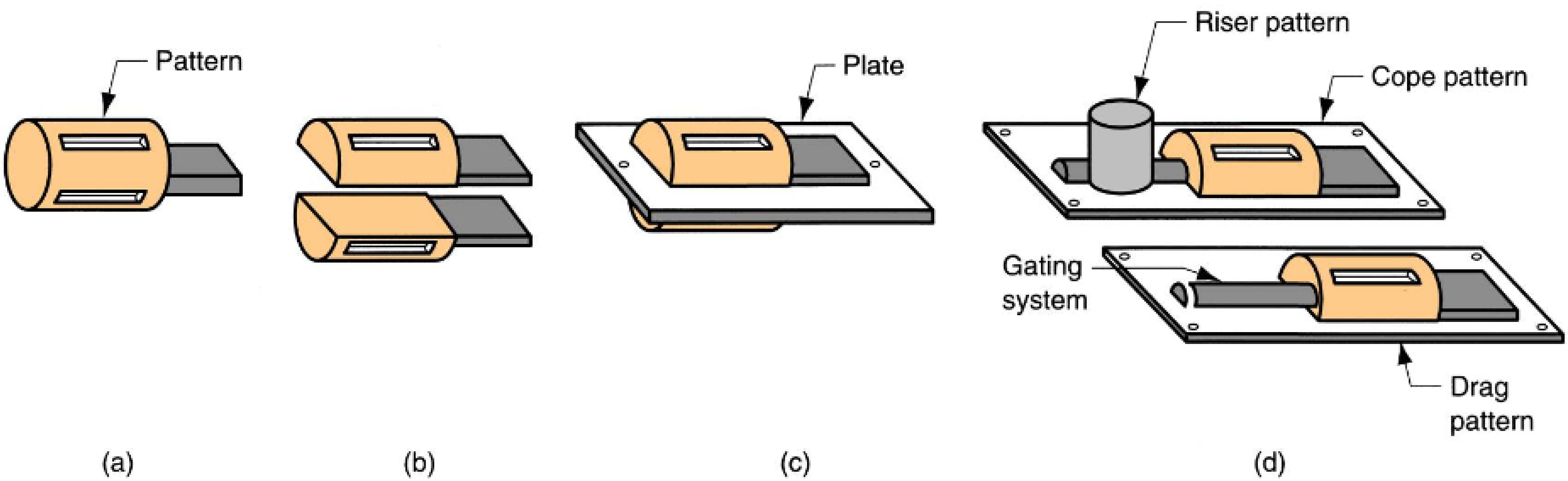
Fig: Distortions in Casting

Rapping Allowance

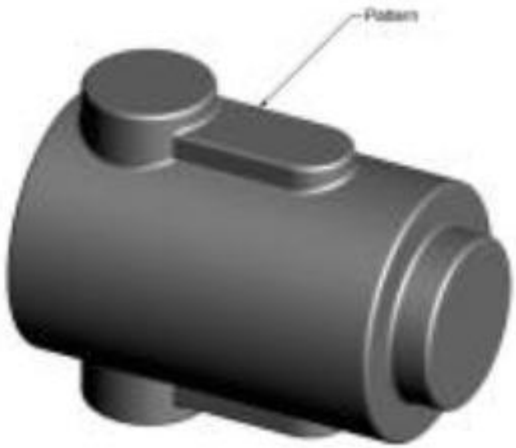
- ❖ Before the withdrawal from the sand mould, the pattern is rapped all around the vertical faces to enlarge the mould cavity slightly, which facilitate its removal.
- ❖ Since it enlarges the final casting made, it is desirable that the original pattern dimension should be reduced to account for this increase.
- ❖ There is no sure way of quantifying this allowance, since it is highly dependent on the foundry personnel practice involved.
- ❖ It is a negative allowance and is to be applied only to those dimensions that are parallel to the parting plane.

Types of Patterns

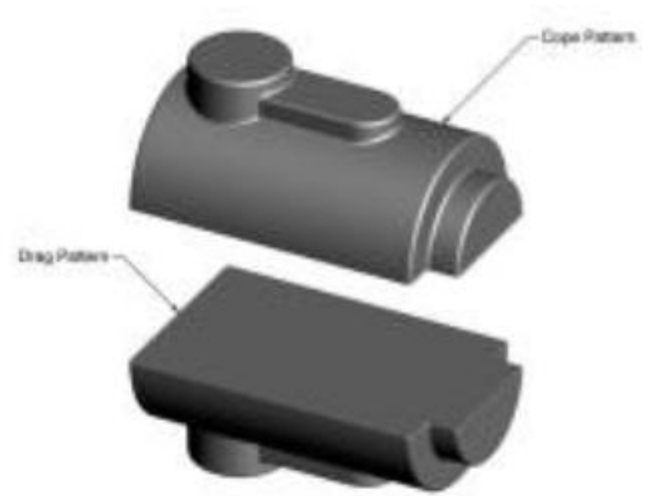
Types of patterns used in sand casting:
(a) solid pattern
(b) split pattern
(c) match-plate pattern
(d) cope and drag pattern



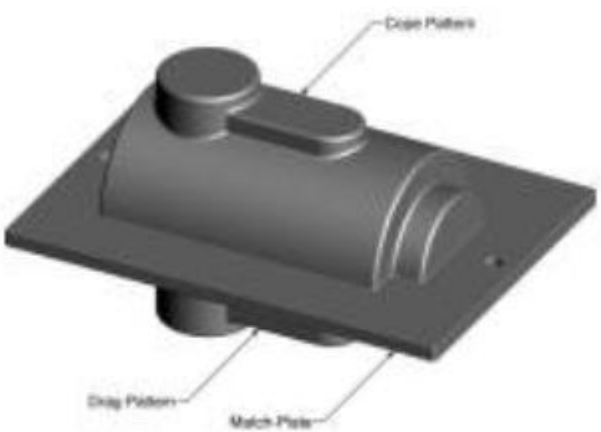
Pattern Making



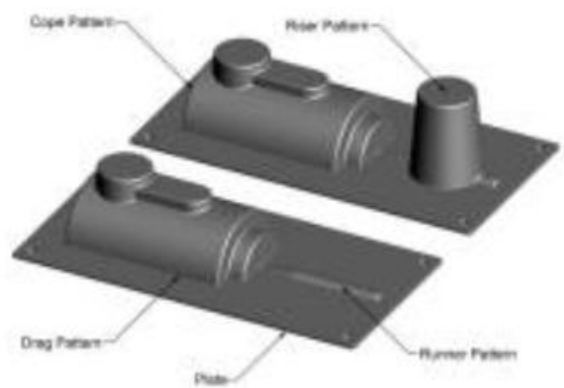
One piece or Solid Pattern



Split Pattern



Match Plate Pattern



Cope & Drag Pattern

Different types of Pattern

The most commonly used patterns in foundry are as follows

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

Different types of Pattern

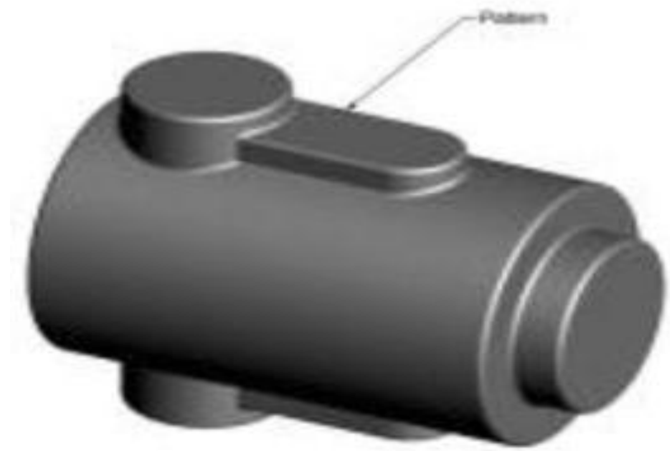
1. Single Piece Pattern

- The one piece or single pattern is the most **inexpensive of all types of patterns.**
- This type of pattern is used only in cases where the job is very simple and does not create any withdrawal problems.
- It is also used for application in very small-scale production or in prototype development.
- This type of pattern is expected to be entirely in the drag and one of the surface is expected to be flat which is used as the parting plane.
- A gating system is made in the mould by cutting sand with the help of sand tools.
- If no such flat surface exists, the moulding becomes complicated.

Different types of Pattern

1. Single piece pattern

- A solid pattern is a model of the part as a single piece.
- It is the easiest to fabricate, but can cause some difficulties in making the mould.
- The parting line and runner system must be determined separately.
- Solid patterns are typically used for geometrically simple parts that are produced in low quantities.



One piece or Solid Pattern

Different types of Pattern

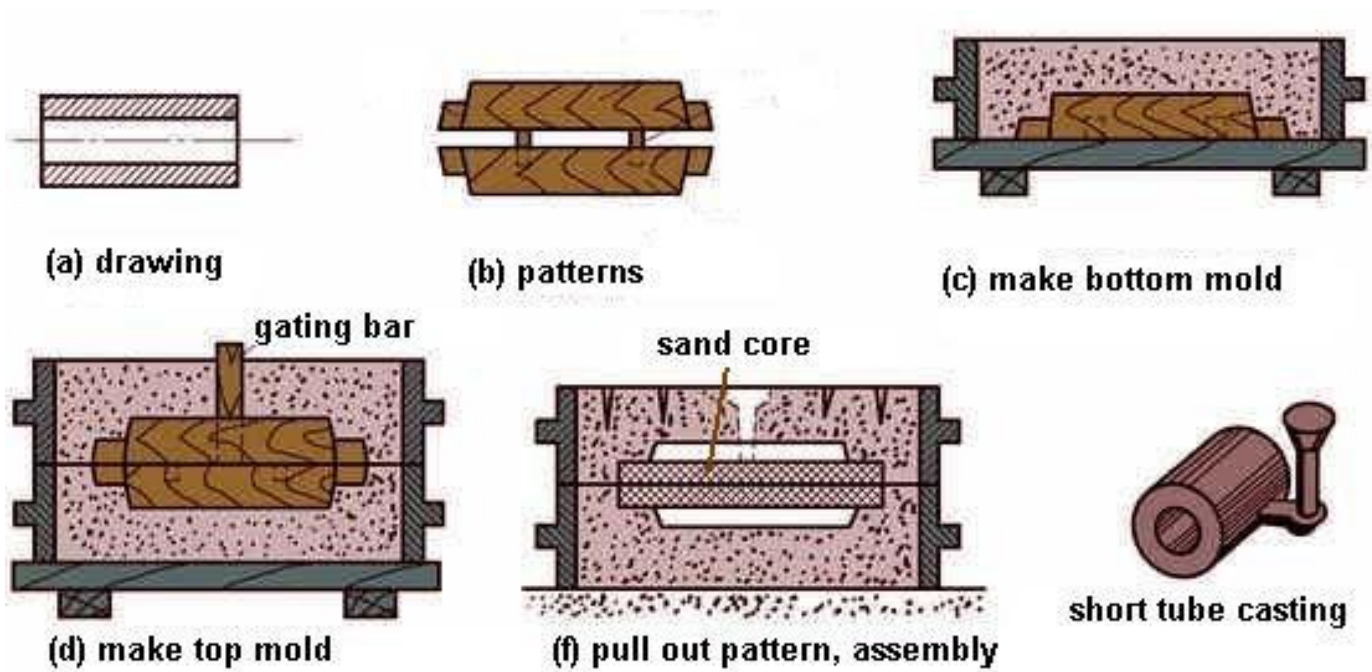
2. Split or Two Piece Pattern

- ❖ Split or two piece pattern is most widely used type of pattern for intricate castings.
- ❖ It is split along the parting surface, the position of which is determined by the shape of the casting.
- ❖ One half of the pattern is moulded in drag and the other half in cope.
- ❖ The two halves of the pattern must be aligned properly by making use of the dowel pins, which are fitted, to the cope half of the pattern.
- ❖ These dowel pins match with the precisely made holes in the drag half of the pattern.

Different types of Pattern

2. Split pattern or two piece pattern

The patterns could be designed as two separated parts, and could be assembled with stop bolts.

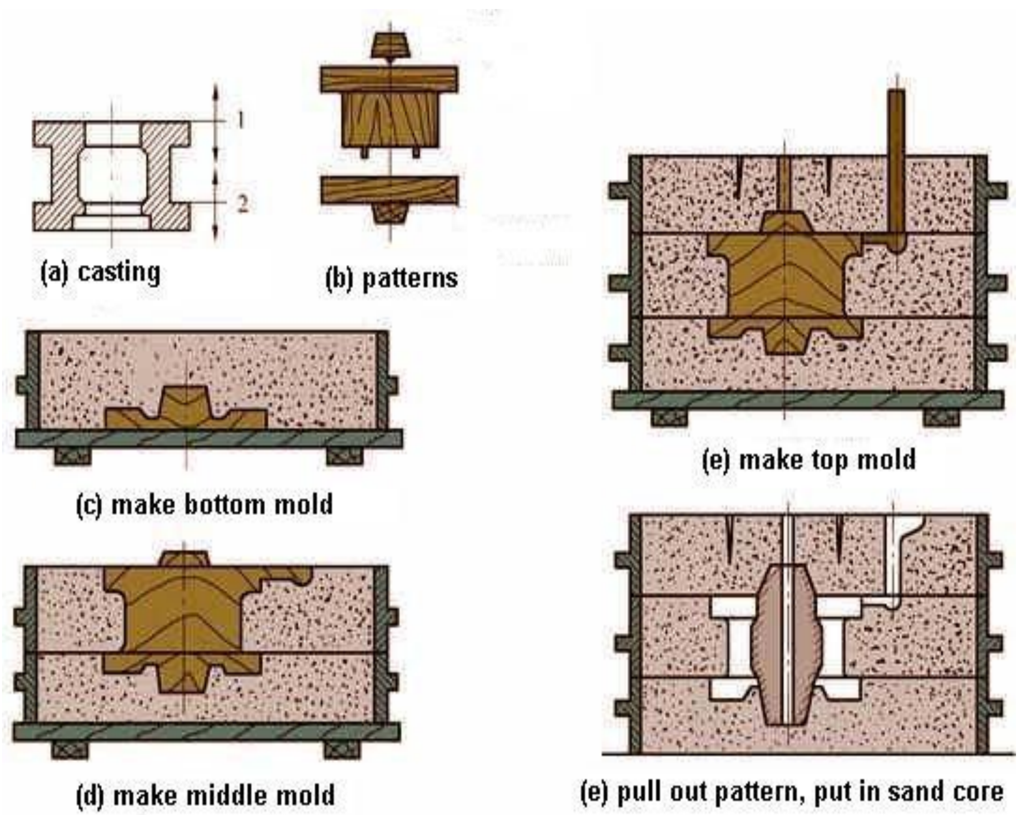


This moulding method is simple and has very wide application. However, if the mould boxes could not be fixed accurately, then mismatch will happen, and it will affect the accuracy of castings. Moreover, the parting line will affect the surface quality too.

Different types of Pattern

3. Multiple piece pattern or Multiple-part moulding

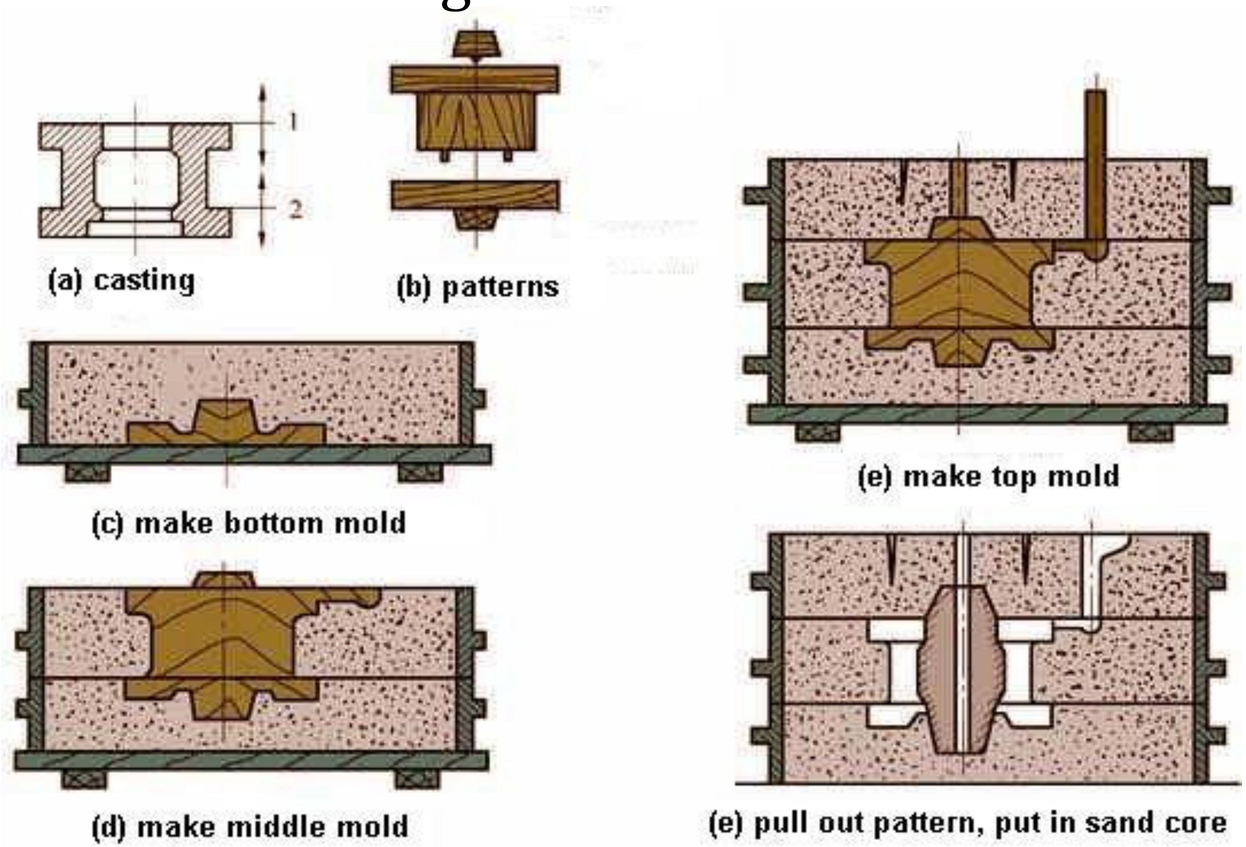
Multiple piece pattern or Multiple-part moulding, which will use three or more sand boxes to produce one casting. If the two ends of casting have larger cross sections than middle position, then two-part moulding will not be able to produce it. The following diagram shows a scored pulley casting by three part moulding method.



Different types of Pattern

3. Multiple piece pattern or Multiple-part moulding

This method needs three or more parts of patterns assembled. There will be two parting surfaces. The moulding process is complex and so lower production rate. The mismatch of sand flasks will be easier to happen. So, it only is suitable to produce small amount castings.

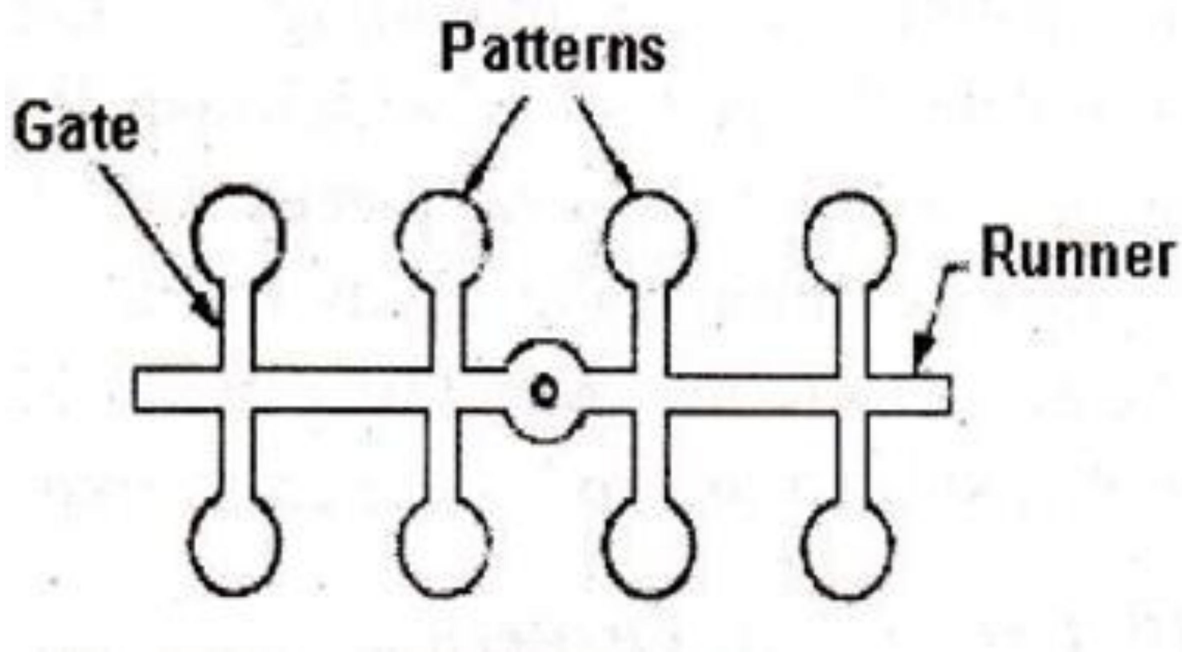


Different types of Pattern

4. Gated pattern

- The gating pattern eliminates hand-cutting the gates.
- Small quantities of castings result with this type of patterns.
- The gate can be made in two ways, one by cutting the channel or channels with a gate cutter, or by the pattern having a projection attached to the pattern which will form gate or gates during the process of ramming up the mold.

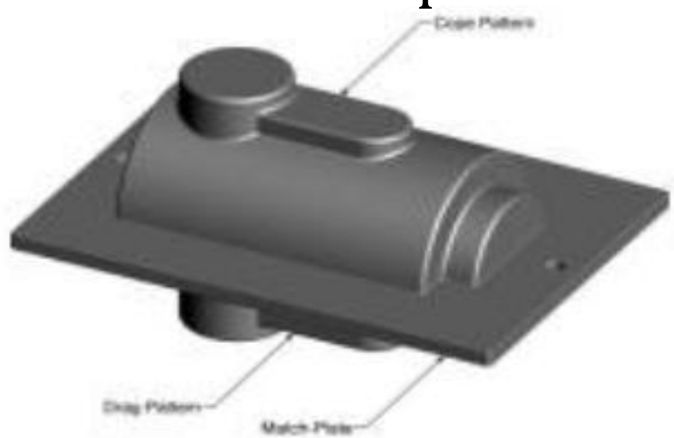
Gated pattern



Different types of Pattern

5. Match plate pattern

- A match-plate pattern is similar to a split pattern, except that each half of the pattern is attached to opposite sides of a single plate.
- The plate is usually made from wood or metal.
- This pattern design ensures proper alignment of the mould cavities in the cope and drag and the runner system can be included on the match plate.
- Match-plate patterns are used for larger production quantities and are often used when the process is automated.



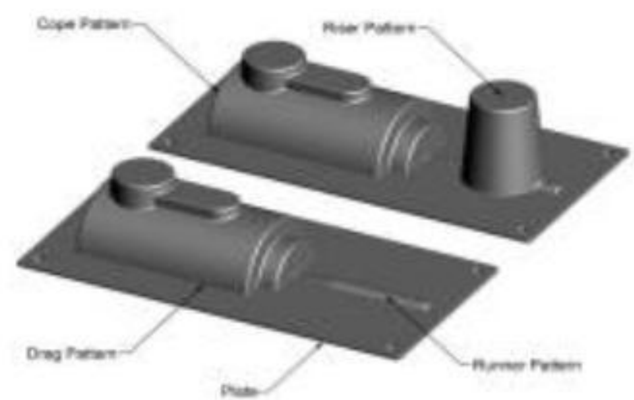
Match Plate Pattern

Different types of Pattern

6. Cope and drag pattern

- It is similar to a match plate pattern, except that each half of the pattern is attached to a separate plate and the mould halves are made independently.
- The plates ensure proper alignment of the mould cavities in the cope and drag and the runner system can be included on the plates.
- Cope and drag patterns are desirable for larger castings, where a match-plate pattern would be too heavy and cumbersome. They are also used for larger production quantities and are often used when the process is automated.

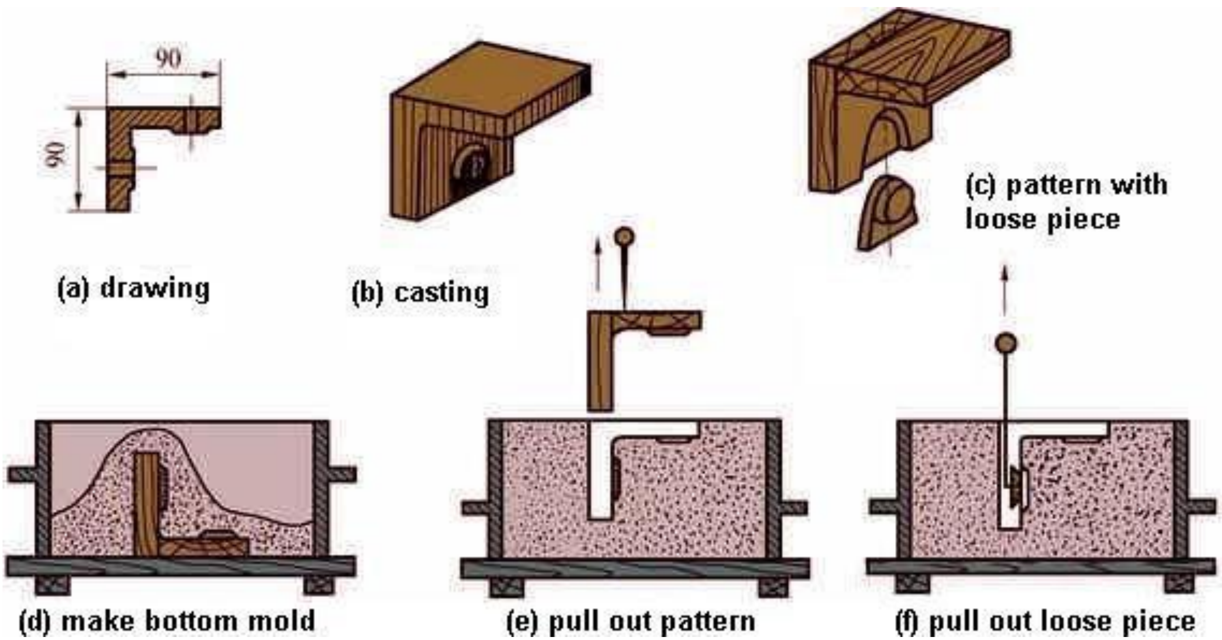
Cope & Drag Pattern



Different types of Pattern

7. Loose piece pattern

If the side face of casting affects the draft of patterns, then we can make some loose pieces fixed on the patterns. So, after moulding, we can pull out the main part of patterns first, then pull out the loose pieces.

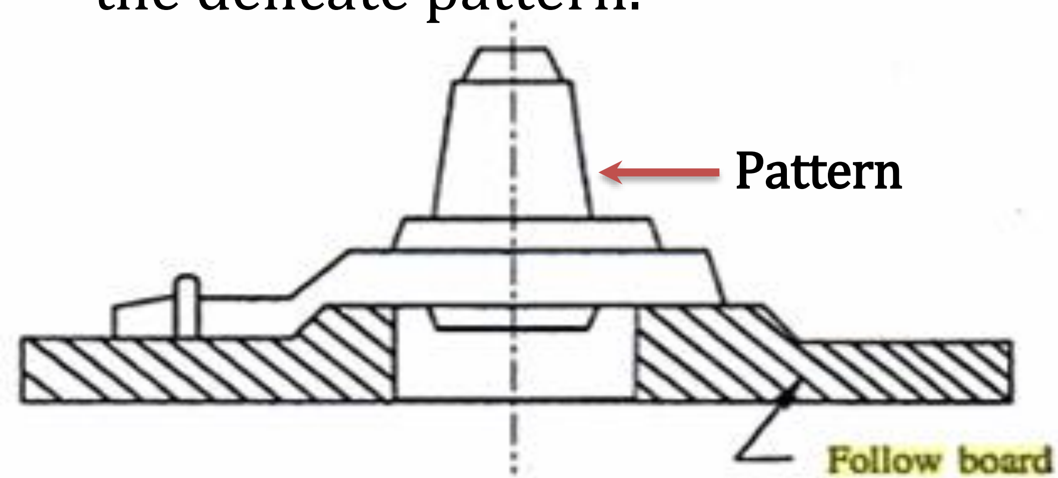


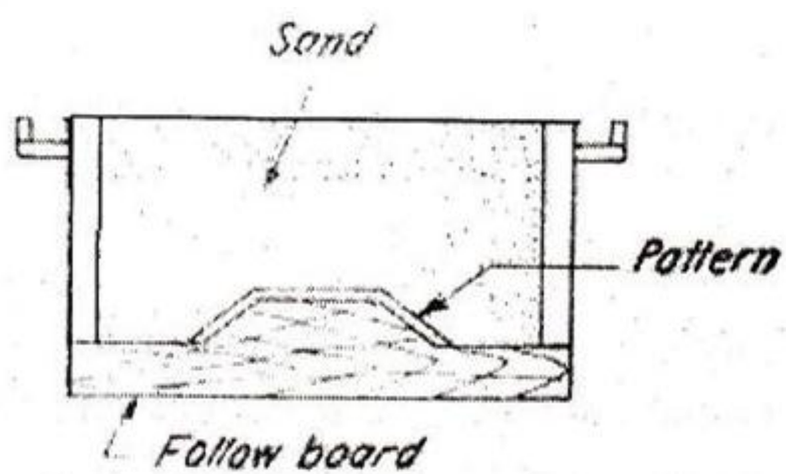
This moulding method requests the sand to be very tight, otherwise, when pull out the main patterns, the loose pieces may damage the nearby sand moulds. This method is only suitable for producing small amount of castings.

Different types of Pattern

8. Follow board pattern

- This type of pattern is adopted for those castings there are some portions which are structurally weak and if not supported properly are likely to break under the force of ramming.
- Hence the bottom board is modified as a follow board to closely fit the contour of the weak pattern and thus support it during the ramming of the drag.
- During the preparation of the cope, no follow board is necessary because the sand which is compacted in the drag will support the delicate pattern.

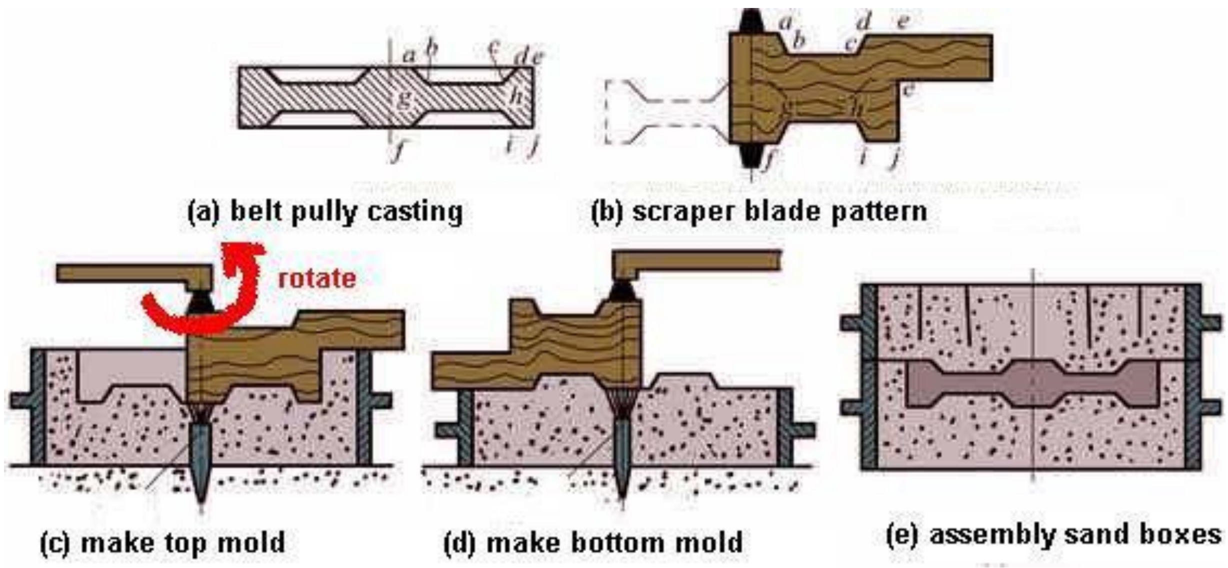




Different types of Pattern

9. Sweep pattern

Sweep moulding uses the scraper blade to replace normal patterns. The scraper blade could rotate with the fixed shaft, so could make the round sand moulds with the designed shapes.



(a) belt pully casting (b) scraper blade pattern

(c) make top mold (d) make bottom mold (e) assembly sand boxes

This moulding method could reduce the pattern costs, but the operation needs more skills, and the production rate is very low. In addition, it has strict requirements to the shapes of castings. This method normally used to produce axially symmetrical castings, such as flywheel and rings.

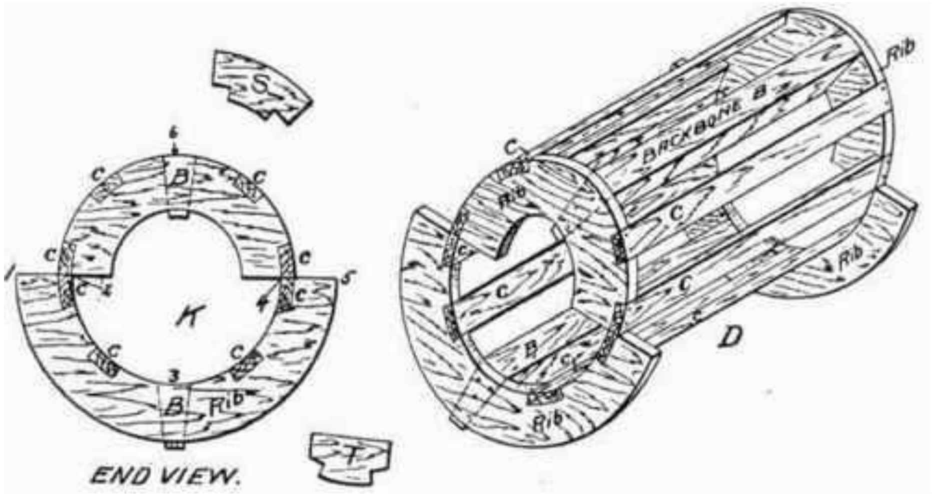
Different types of Pattern

10. Skeleton pattern

- A pattern constructed in skeleton form. This is a frame work of wooden bars which represent the interior and exterior form and the metal thickness of the required casting. This type of pattern is only used for huge castings.

- The skeleton pattern is well adapted to irregular hollow castings, such as the steam nozzle with three outlets.

- In building this pattern, the three outlet flanges are built in halves of segment work, and these are joined by skeleton framing made up as a backbone, ribs and blocks for each half.



Core and Core Prints

- Castings are often required to have holes, recesses, etc. of various sizes and shapes.
- These impressions can be obtained by using cores.
- So where coring is required, provision should be made to support the core inside the mould cavity. Core prints are used to serve this purpose.
- The core print is an added projection on the pattern and it forms a seat in the mould on which the sand core rests during pouring of the mould.
- The core print must be of adequate size and shape so that it can support the weight of the core during the casting operation.
- Depending upon the requirement a core can be placed horizontal, vertical and can be hanged inside the mould cavity.

Core and Core Prints

- ❖ A typical job, its pattern and the mould cavity with core and core print is shown in Figure.

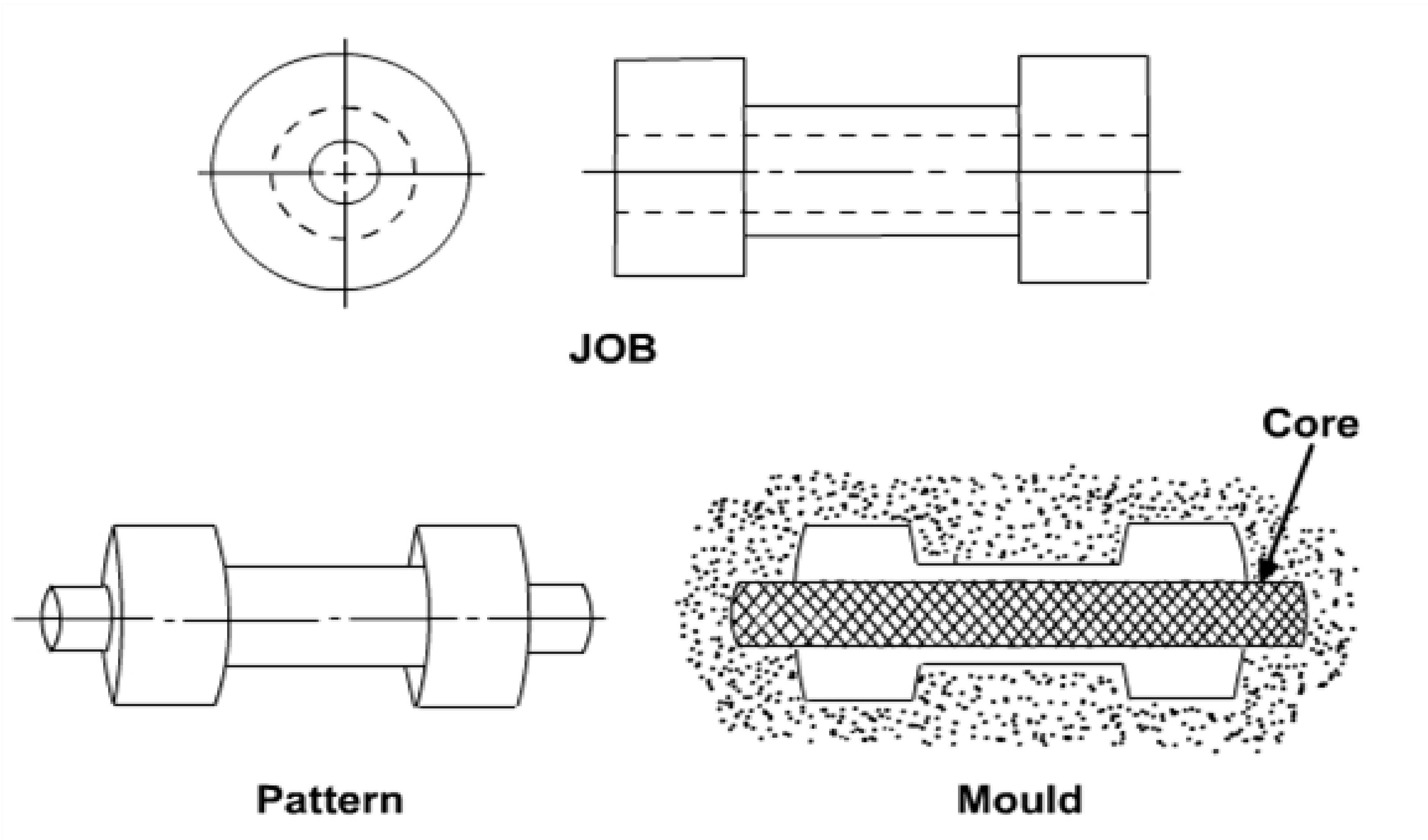


Fig: A Typical Job, its Pattern and the Mould Cavity

Manufacturing Technology – I

Unit 1-Metal Castings

Classification of Casting Processes

Classification of casting Processes

Casting processes can be classified into following FOUR categories:

1. Conventional moulding Processes

- Green Sand moulding
- Dry Sand moulding
- Flask less moulding

2. Chemical Sand moulding Processes

- Shell moulding
- Sodium Silicate moulding
- No-Bake moulding

Classification of casting Processes

Casting processes can be classified into following FOUR categories:

3. Permanent mould Processes

- Gravity Die casting
- Low and High Pressure Die Casting

4. Special Casting Processes

- Lost Wax or Investment mold casting
- Ceramics Shell moulding
- Evaporative Pattern Casting
- Vacuum Sealed moulding
- Centrifugal Casting

1. Conventional moulding Processes :

Green Sand moulding

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

1. Conventional moulding Processes :

Green Sand moulding

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

Disadvantages

- Surface Finish of the castings obtained by this process is not good and machining is often required to achieve the finished product.

Sand mould Making Procedure

The procedure for making mould of a cast iron wheel is shown in (Figures (a),(b),(c)).

- The first step in making mould is to place the pattern on the moulding board.
- The drag is placed on the board (Figure (a)).
- Dry facing sand is sprinkled over the board and pattern to provide a non sticky layer.
- moulding sand is then riddled into cover the pattern with the fingers; then the drag is completely filled.
- The sand is then firmly packed in the drag by means of hand rammers. The ramming must be proper i.e. it must neither be too hard or soft.
- After the ramming is over, the excess sand is levelled off with a straight bar known as a strike rod.

Sand mould Making Procedure

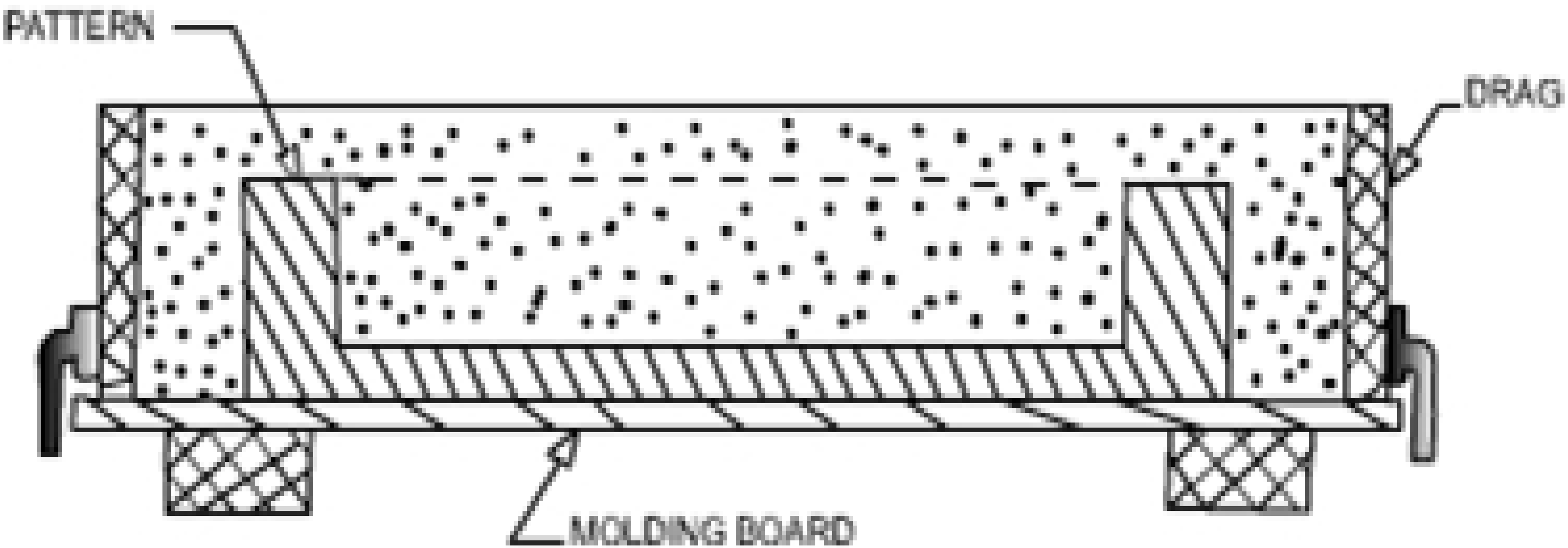


Fig (a) Sand mould Making

Sand mould Making Procedure

- With the help of vent rod, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification.
- The finished drag flask is now rolled over to the bottom board exposing the pattern.
- Cope half of the pattern is then placed over the drag pattern with the help of locating pins.
- The cope flask on the drag is located aligning again with the help of pins ((Figure (b)).
- The dry parting sand is sprinkled all over the drag and on the pattern.
- A sprue pin for making the sprue passage is located at a small distance from the pattern.

Sand mould Making Procedure

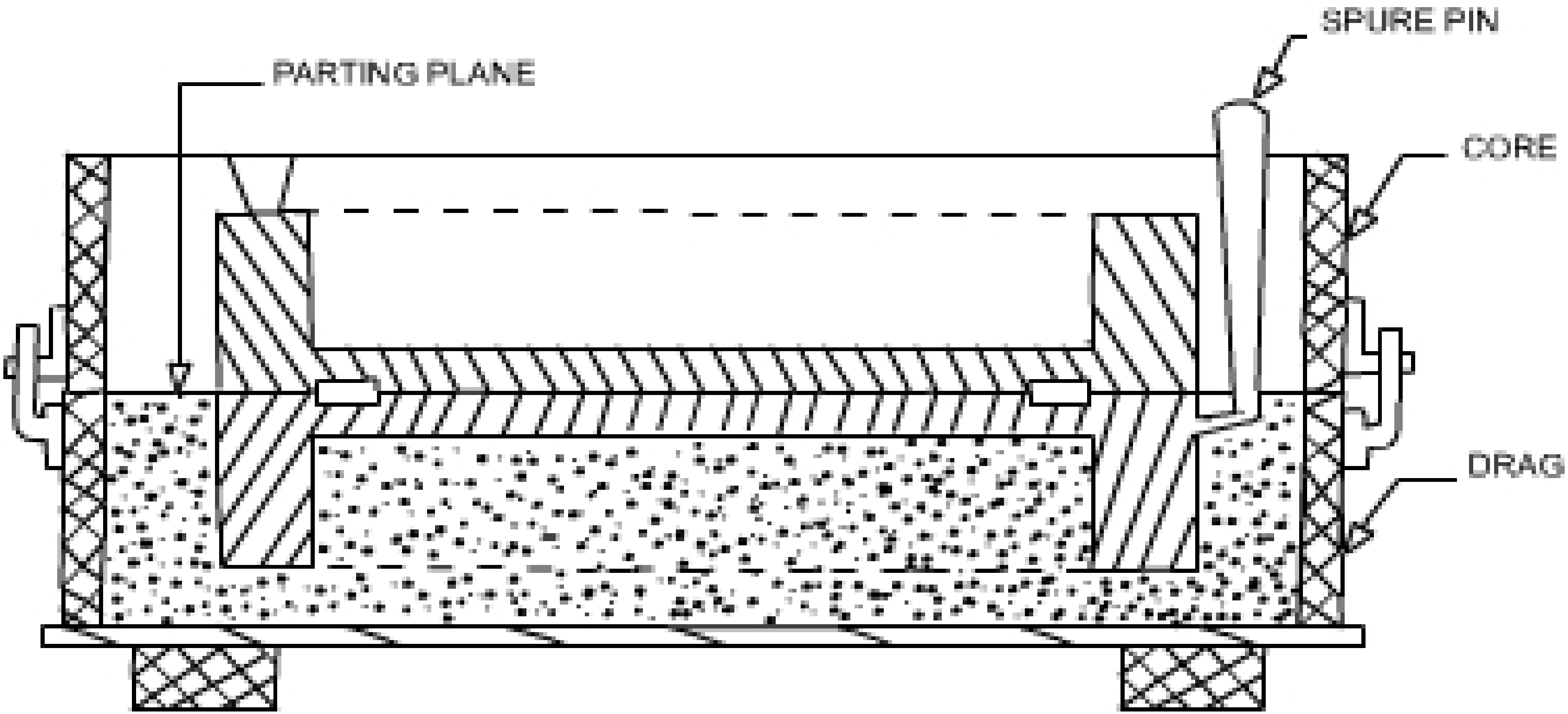


Fig (b) Sand mould Making

Sand mould Making Procedure

- Also, riser pin, if required, is placed at an appropriate place.
- The operation of filling, ramming and venting of the cope proceed in the same manner as performed in the drag.
- The sprue and riser pins are removed first and a pouring basin is scooped out at the top to pour the liquid metal.
- Then pattern from the cope and drag is removed and facing sand in the form of paste is applied all over the mould cavity and runners which would give the finished casting a good surface finish.
- The mould is now assembled. The mould now is ready for pouring (Figure (c))

Sand mould Making Procedure

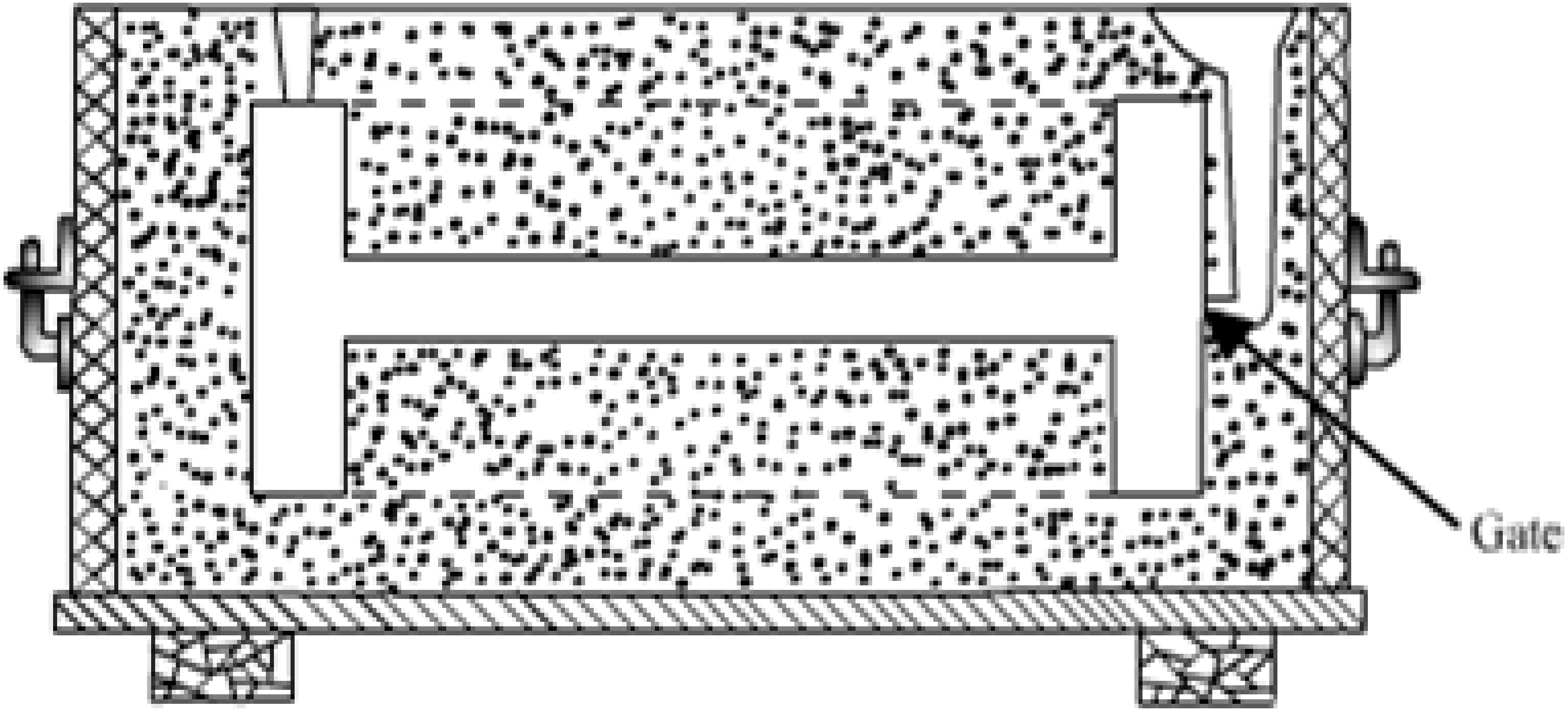


Fig (c) Sand mould Making

Sand mould Making ProcedureVideo (Click Here)

1. Conventional moulding Processes :

Dry Sand moulding

- When it is desired that the gas forming materials are to be lowered in the moulds, air-dried moulds are sometimes preferred to green sand moulds.
- Two types of drying of moulds are often required.
  - ✓ Skin drying and
  - ✓ Complete mould drying.
- In skin drying a firm mould face is produced. Shakeout of the mould is almost as good as that obtained with green sand moulding.
- The most common method of drying the mould is by useing hot air, gas or oil flame. Skin drying of the mould can be accomplished with the aid of torches, directed at the mould surface.

1. Conventional moulding Processes :

Flask less Moulding

- Flask-Less Moulding is another Sand Casting process. It can be a dry sand or a green sand moulding variation, that has been automated for speed and high volume output, of identical castings.
- In flask-less moulding, in either a vertical or a horizontal, a sand filled flask is rebuilt and used over and over, in this totally mechanized, and automated sand moulding process.
- In flask-less moulding, the halves of the pattern form a vertical chamber wall against which sand is blown and compacted.
- Then, the mould haves are packed horizontally, with the parting line oriented vertically and moved along a pouring conveyor.

1. Conventional moulding Processes :

Flask less Moulding

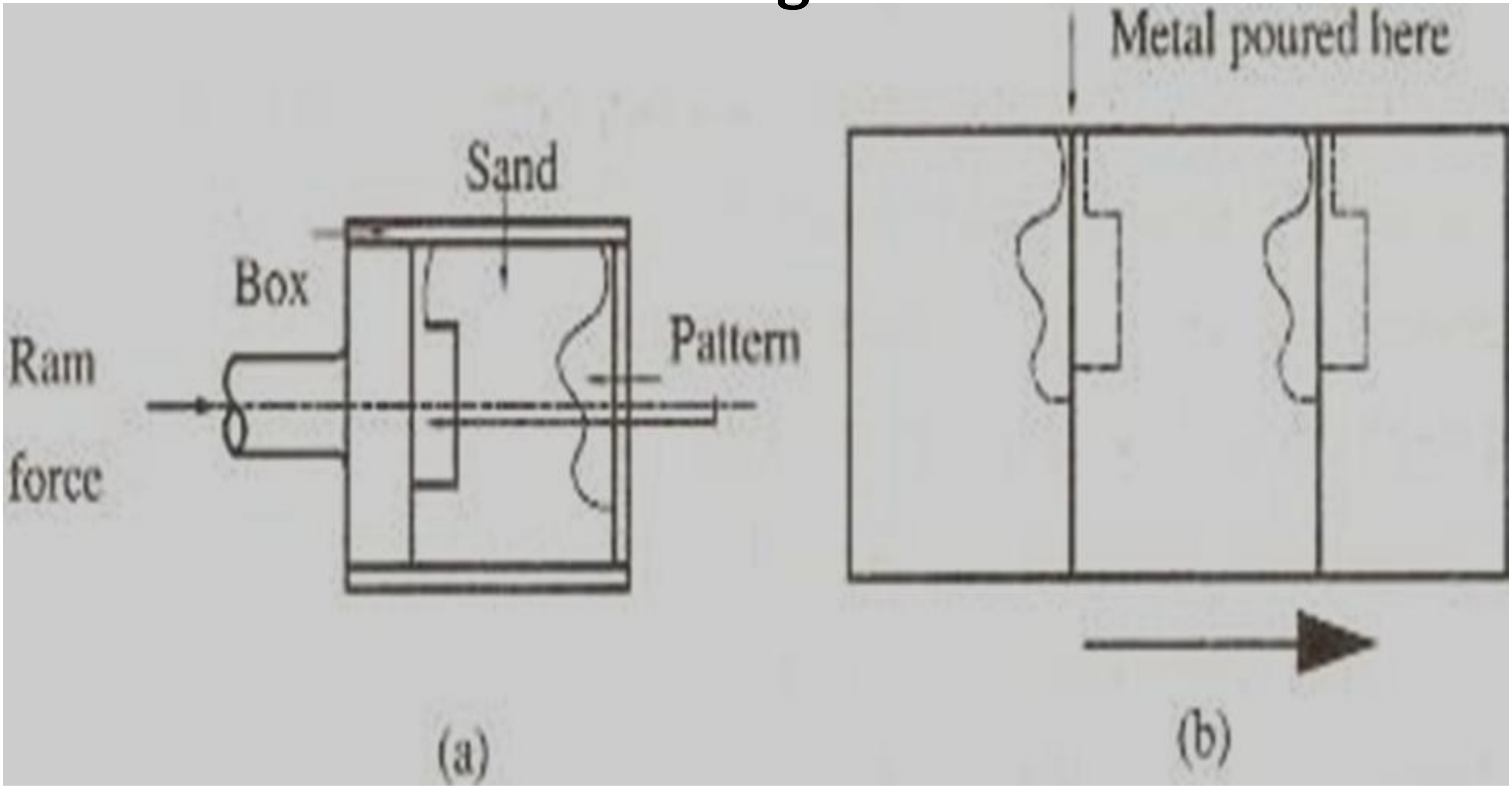
- This operation is simple and eliminates the need to handle flasks, allowing for very high production rates.
- The benefits of these systems are very impressive - uniformity, high density moulds, high output of products, elimination of mould shift, all of which drastically reduce labour expense.
- Flask-less moulding provides a mould hardness that is consistent though out the mould.
- The operator can adjust to different cope, drag heights and total squeeze pressure to accommodate different mould densities and mould hardness to meet the moulding application.
- The operator can adjust the sand fill allowing the adjustment for variations in each pattern.

1. Conventional moulding Processes :

Flask less Moulding

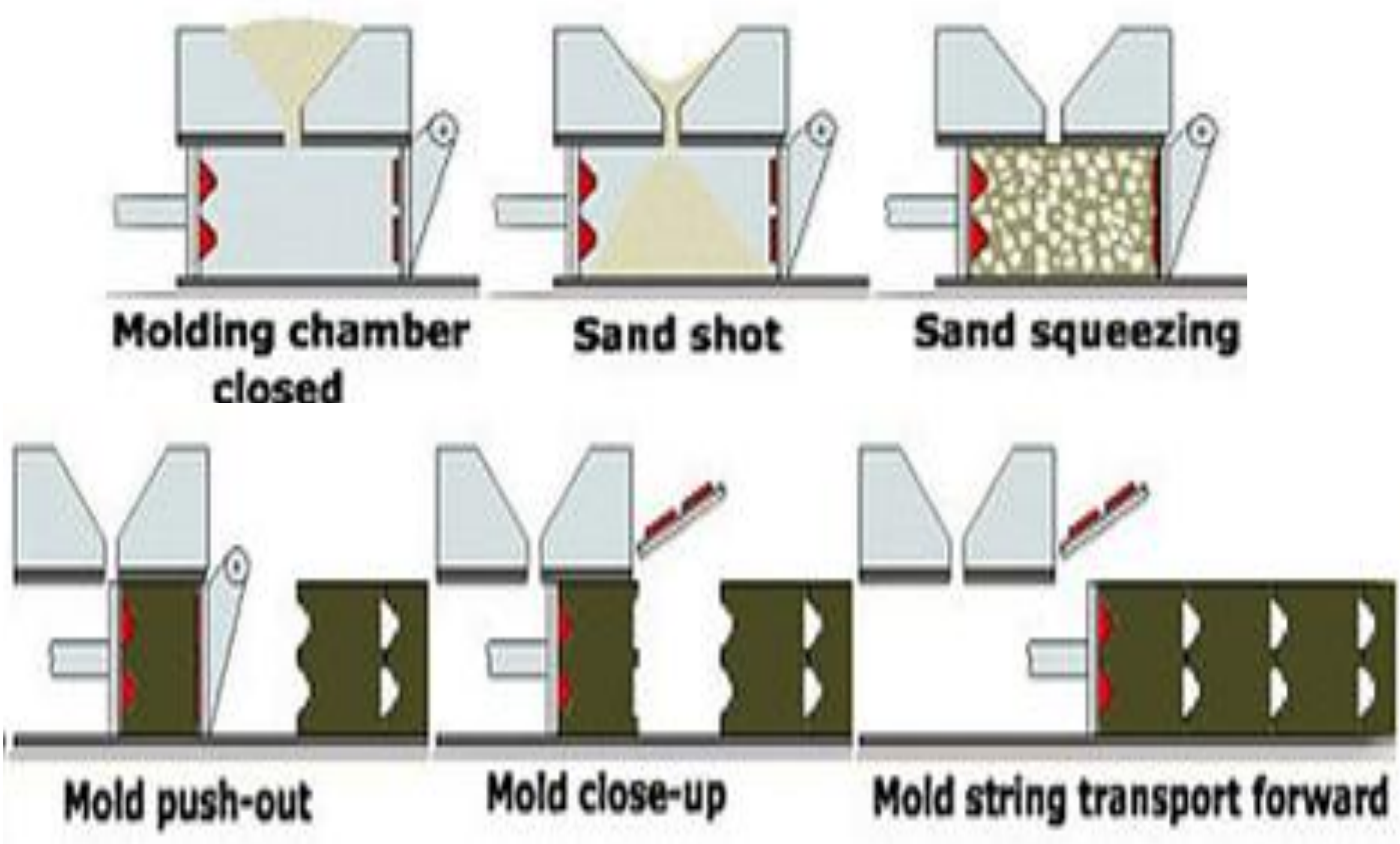
- It is possible produce complex moulds and mould with deep pockets, which are difficult with traditional, normal sand casting procedures
- Rapid core setting, easy inspection of cores, high casting quality, reduced finishing time, quick pattern change, exceptional mould to mould consistency, high productivity are some of the many reasons to use flask-less moulding.

Vertical Flask-less Moulding



- Fig (a) : Sand is squeezed between Two halves of the pattern
- Fig (b) : Assembled Mould pass along an assembly line for pouring

Vertical Flask-less Moulding



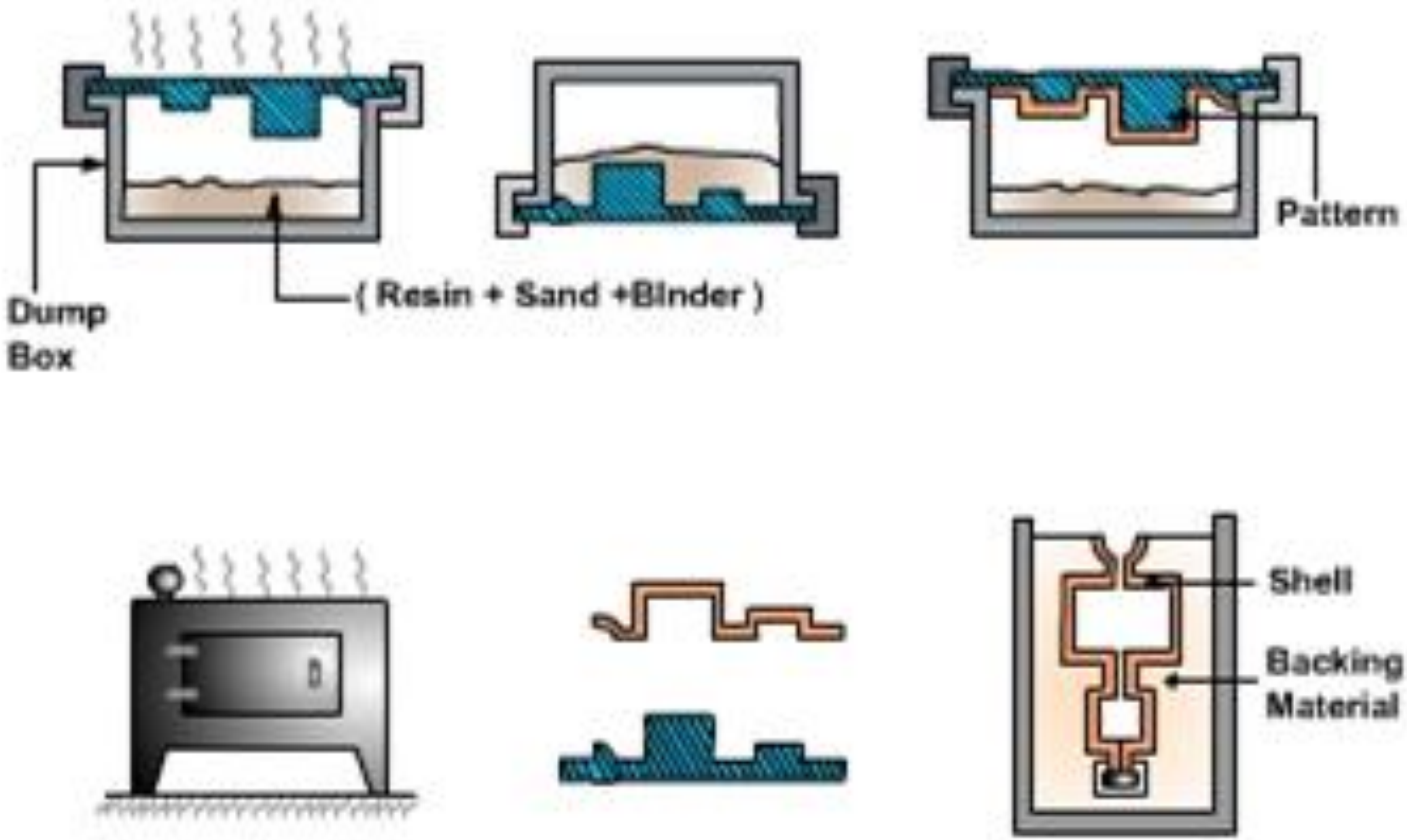
2. Chemical Sand moulding Processes:

Shell moulding 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 mould.
- This process can produce complex parts with good surface finish 1.25 µm to 3.75 µm, and dimensional tolerance of 0.5 %. A good surface finish & good size tolerance reduce the need for M/C'ing.
- The process overall is quite cost effective due to reduced machining and clean-up costs. The materials that can be used with this process are cast irons, & aluminium & copper alloys.

2. Chemical Sand moulding Processes:

Shell moulding Process



2. Chemical Sand moulding Processes:

Sodium Silicate moulding Process

- In this process, the refractory material is coated with a sodium silicate-based binder.
- For moulds, 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 mould. 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 mould.
- The sodium silicate process is one of the most environmentally acceptable of the chemical processes available.

2. Chemical Sand moulding Processes:

Sodium Silicate moulding Process

Some of the advantages of the process are:

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

Some of the disadvantages of the process are:

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

2. Chemical Sand moulding Processes:

No-Bake moulding

- This is the metal casting industry's second favourite method for producing cast components (green sand moulding is the first).
- No-bake moulding has proven its worth as an efficient means to produce medium and low volumes of complex castings in both ferrous and nonferrous metals.
- In the no-bake process, sand is mixed with a chemical binder/catalyst system and then moulded around the cope and drag halves of the tooling.
- After a specified period of time, the sand mixture hardens (resembling a brick in strength) to form the mould halves and the tooling is drawn.

2. Chemical Sand moulding Processes:

No-Bake moulding

- Then, a refractory coating may be applied to both mould halves before they are brought together to form one complete mould for pouring.
- No-bake moulded cores also can be produced using a similar method and assembled into the mould to form more complex shapes.
- No-bake moulding, like green sand moulding, is known for its flexibility.
- Virtually all metals can be cast via no-bake moulding with component weights ranging from less than a pound to several hundred thousand pounds.

2. Chemical Sand moulding Processes:

No-Bake moulding

For casting designers, no-bake moulding offers:

- Good dimensional tolerances because the rigidity of the mould withstands the pressures exerted by the molten metal.
- Compatibility with most pattern materials, allowing for inexpensive tooling options. In addition, imparts minimal tooling wear.
- Design flexibility for intricate casting shapes.
- Reduced opportunity for gas-related defects as the nitrogen content of most binder systems used for no-bake moulding minimize susceptibility to gas porosity;
- Fine surface finishes and
- Low to medium volume production capability.

3. Permanent Mould Process

- In all the above processes, a mould need to be prepared for each of the casting produced.
- For large-scale production, making a mould, for every casting to be produced, may be difficult and expensive.
- Therefore, a permanent mould, called the die may be made from which a large number of castings can be produced, the moulds are usually made of cast iron or steel, although graphite, copper and aluminium have been used as mould materials.
- The process in which we use a die to make the castings is called **permanent mould casting or gravity die casting,** since the metal enters the mould under gravity.
- Some time in die-casting we inject the molten metal with a high pressure. When we apply pressure in injecting the metal it is called **pressure die casting process**.

3. Permanent Mould Process

Advantages

- Permanent Moulding produces a sound dense casting with superior mechanical properties.
- The castings produced are quite uniform in shape have a higher degree of dimensional accuracy than castings produced in sand
- The permanent mould process is also capable of producing a consistent quality of finish on castings

Disadvantages

- The cost of tooling is usually higher than for sand castings
- The process is generally limited to the production of small castings of simple exterior design, although complex castings such as aluminium engine blocks and heads are now commonplace.

3. Permanent mould Processes

- Gravity Die casting
- Low and High Pressure Die Casting