

Manufacturing

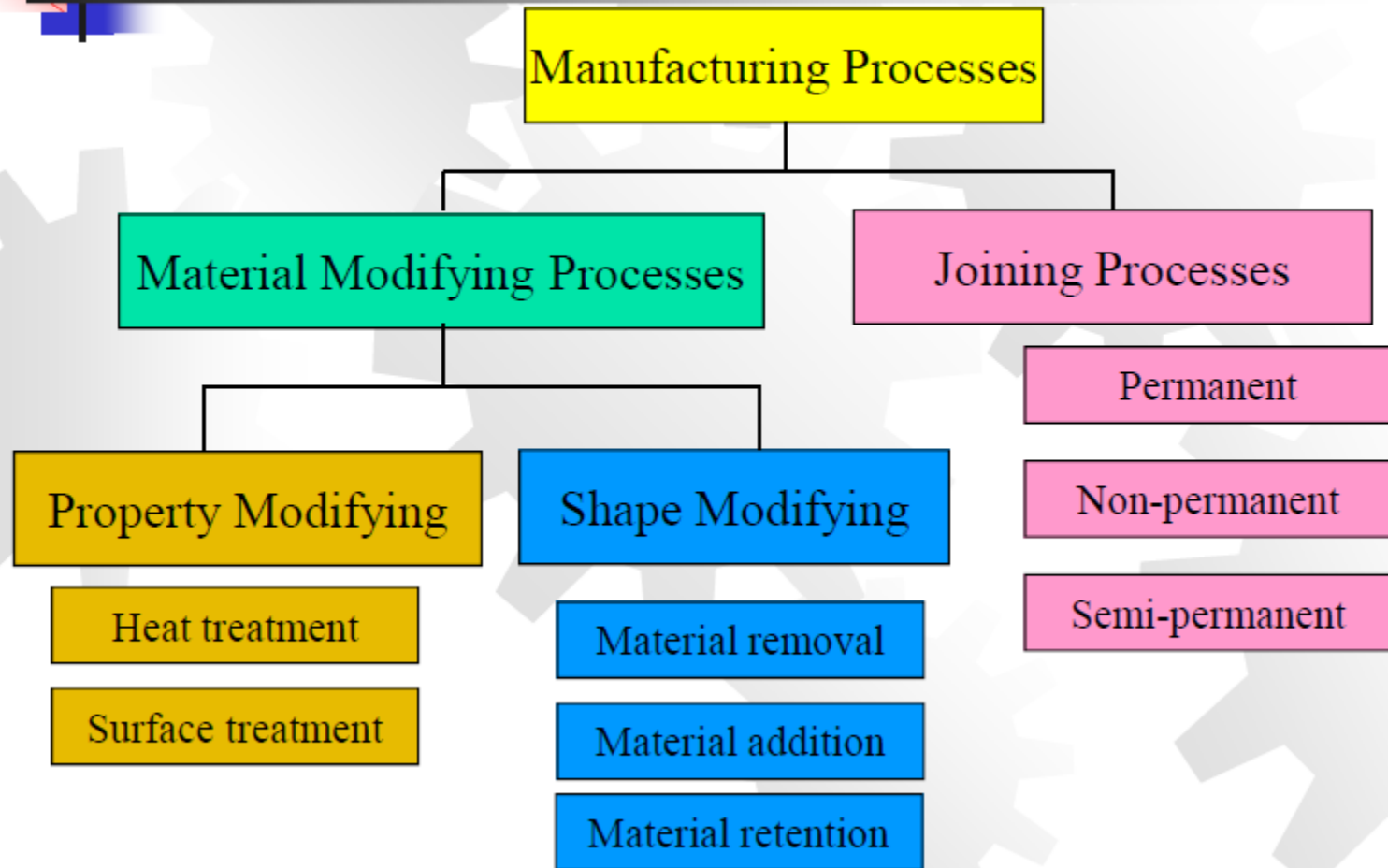
Manufacturing basically implies making of goods or articles and providing services to meet the needs of mankind.

Manufacturing process is that part of the production process which is directly concerned with the change of form or dimensions of the part being produced.

Evolution of Manufacturing

- Began about 5000 to 4000 B.C with the production of various articles of wood, ceramic, stone and metal
- Derived from Latin word *manu factus* – meaning “made by hand”
- The word *manufacture* first appeared in 1567
- The word *manufacturing* appeared in 1683
- Production is also used interchangeably .

Manufacturing process





CASTING

Casting since about 4000 BC...



Ancient Greece; bronze
statue casting circa 450BC



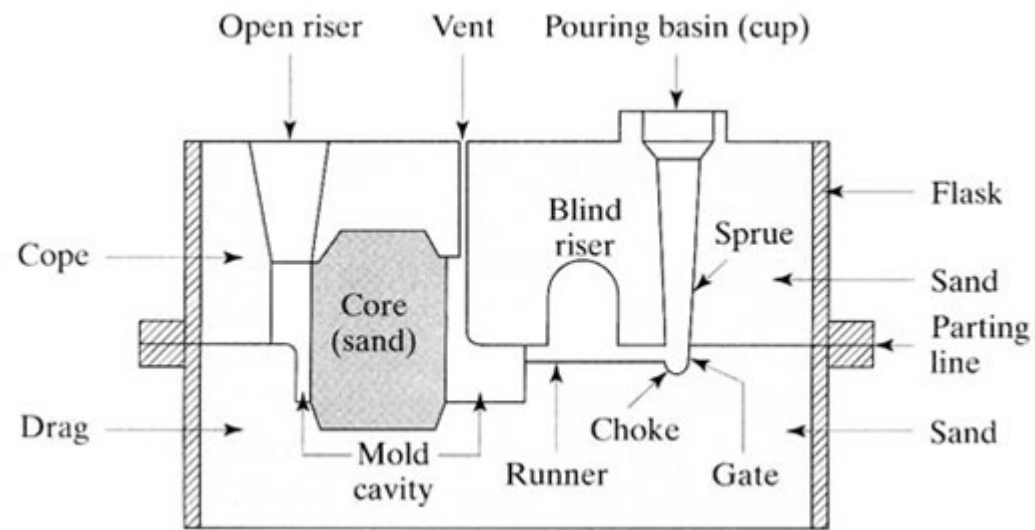
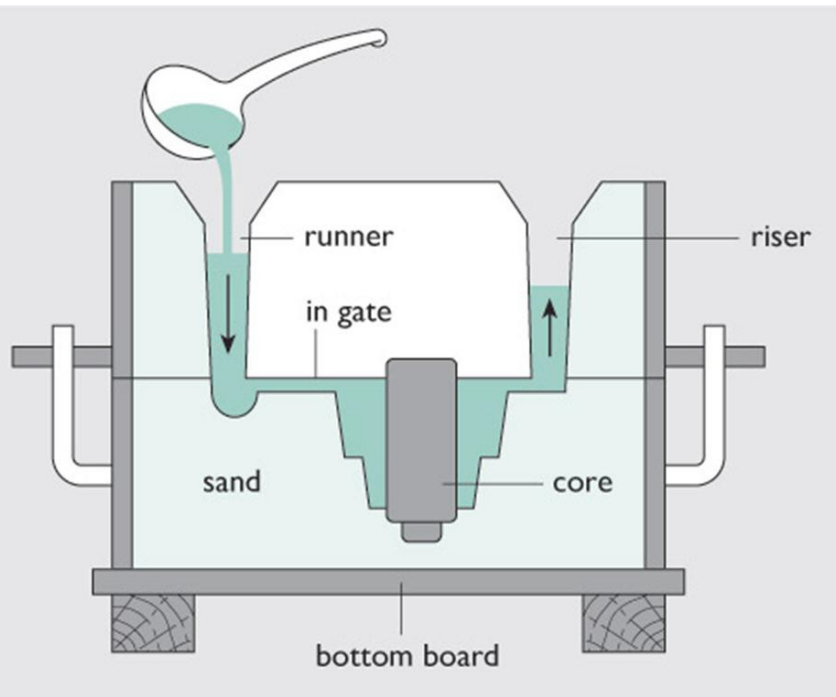
Iron works in early Europe,
e.g. cast iron cannons from
England circa 1543

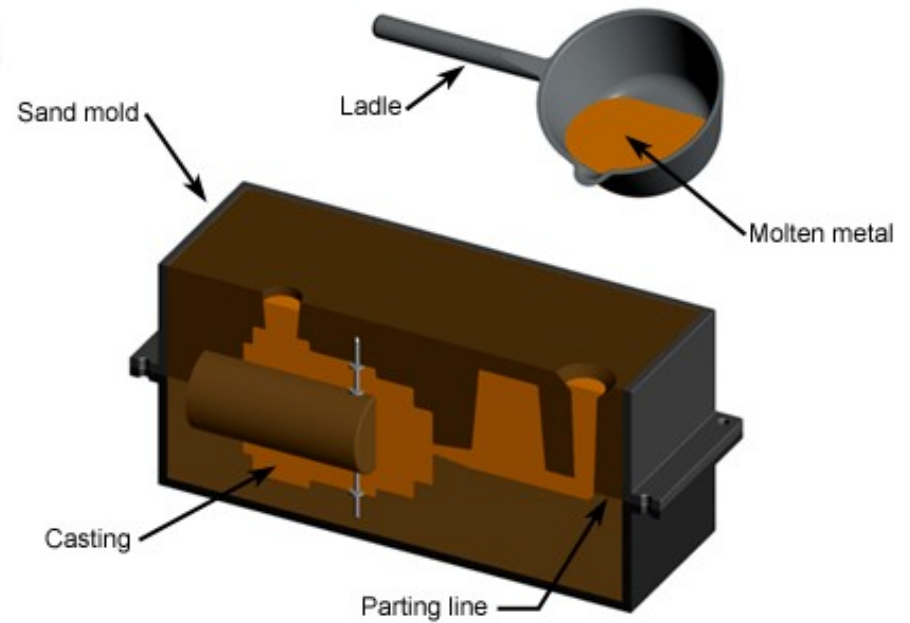
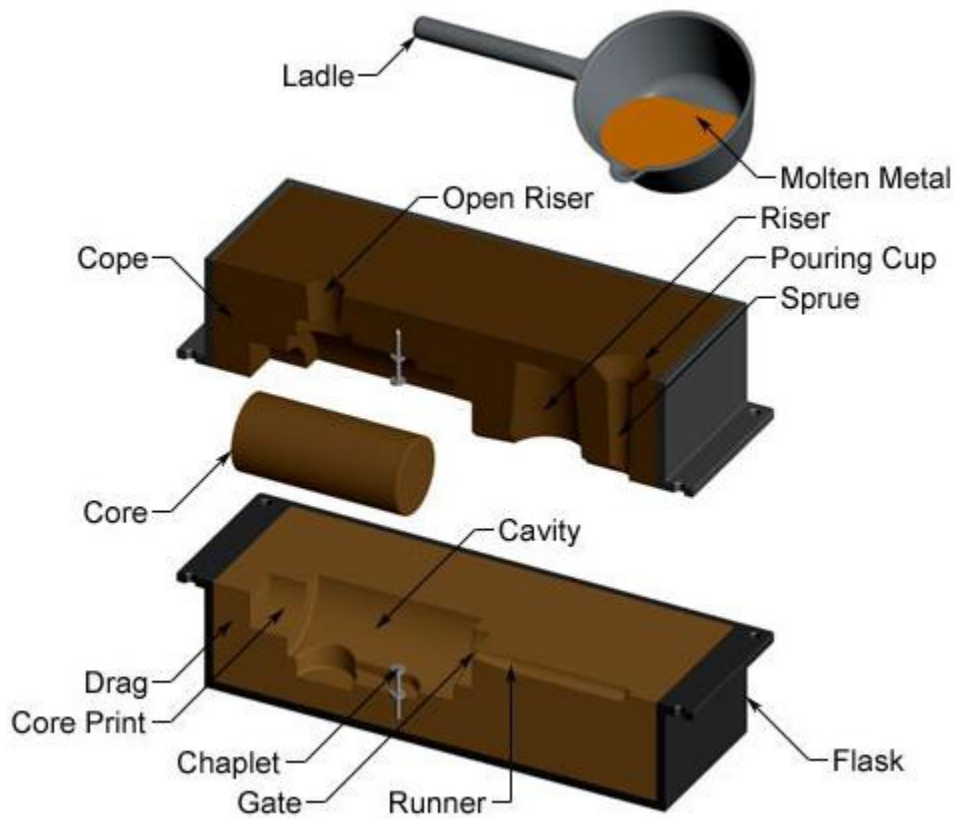
Casting Process

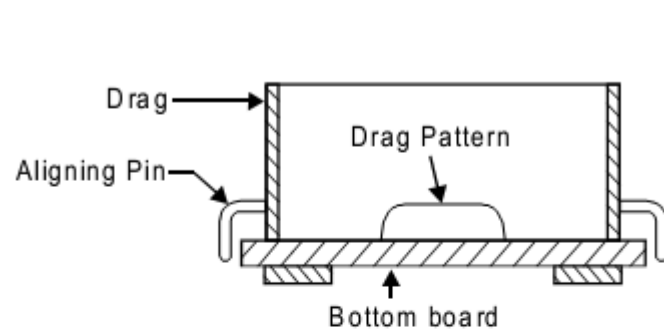
- Casting process is one of the **earliest metal shaping techniques** known to human being.
- It means **pouring molten metal into a refractory mold cavity and allows it to solidify.**
- The solidified object is taken out from the mold either by breaking or taking the mold apart.
- The **solidified object is called casting** and the technique followed in method is known as casting process.

Six basic steps in this process:

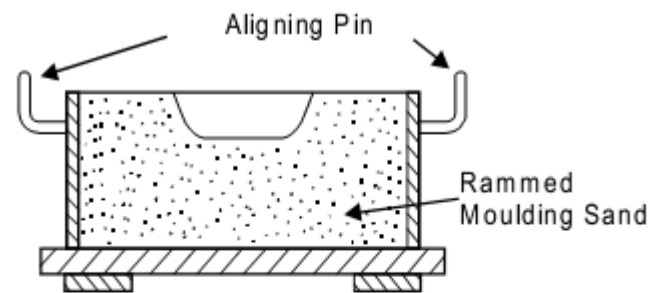
- Place a pattern in sand to create a mold.
- Incorporate the pattern and sand in a gating system.
- Remove the pattern.
- Fill the mold cavity with molten metal.
- Allow the metal to cool.
- Break away the sand mold and remove the casting.



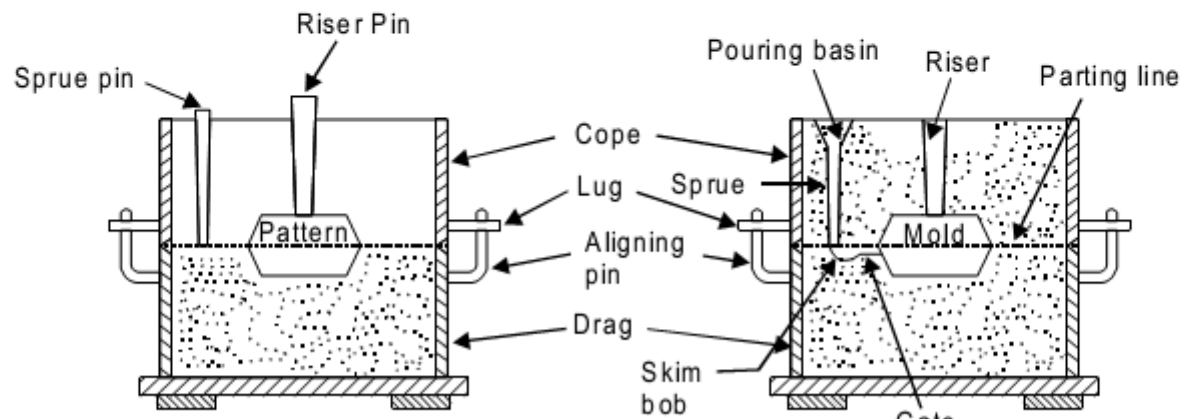




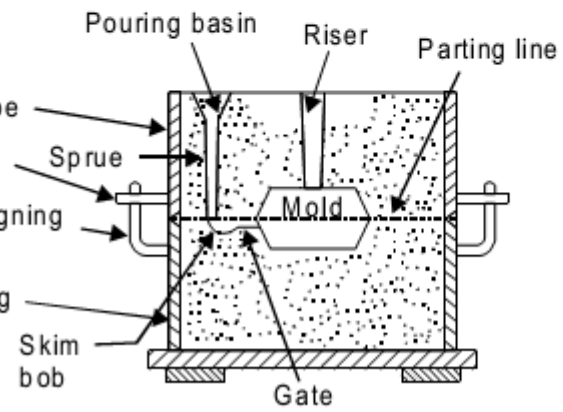
(a)



(b)



(c)



(d)

Casting Terminology

- **Pattern:** An approximate duplicate or true replica of required product of casting
- **Flask/Box:** The rigid metal or a wooden frame that holds the moulding material
- **Cope:** Top half of the moulding box
- **Drag:** Bottom half of the moulding box
- **Core:** As and shape that is inserted into a mould to produce internal features of a casting such as holes.

Continue.....

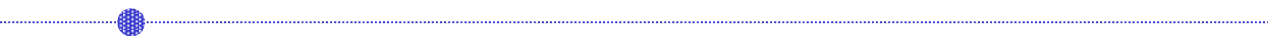
- **Riser**: A vertical opening in the mould
- Act as a vent for gases
- Helps to confirm that the mould is completely filled
- Act as a **reservoir** of molten metal to feed and compensate for shrinkage during solidification of a casting

Continue....

- **Gating System:** Channels used to deliver the molten metal to the mould cavity
- **Sprue:** The vertical passage in the gating system
- **Runner:** The horizontal channel of the gating system
- **Gate:** Channel which connects runner and mould

Advantages

- Product can be cast as one piece.
- Very heavy and bulky parts can be manufactured
- Metals difficult to be shaped by other manufacturing processes may be cast (eg: Cast Iron)
- Best for mass production
- Complex shapes can be manufactured

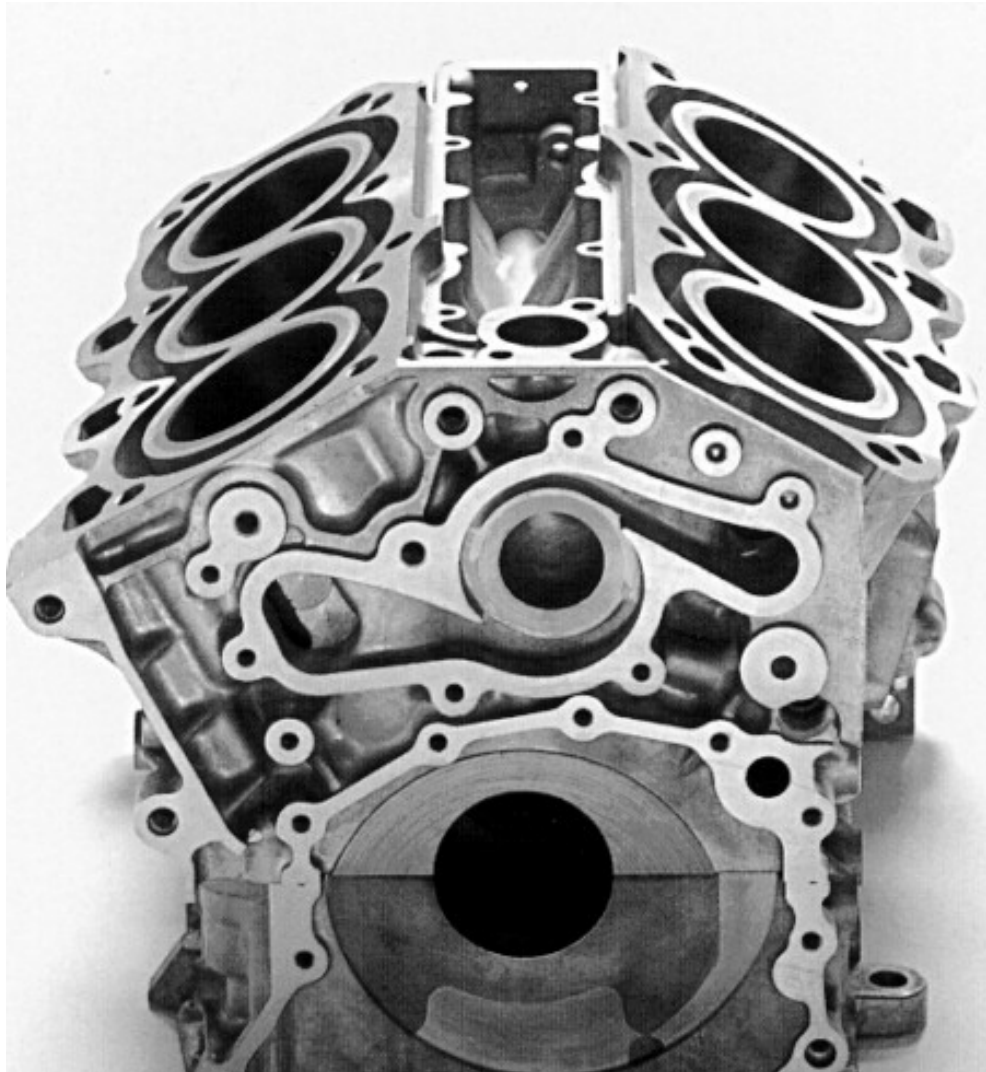
- 
- VERSATILE: complex geometry, internal cavities, hollow sections
 - VERSATILE: small (~10 grams) → very large parts (~1000 Kg)
 - ECONOMICAL: little wastage (extra metal is re-used)
 - ISOTROPIC: cast parts have same properties along all directions

Disadvantages of Casting

- Casting process is a labour intensive process
- Not possible for high melting point metals
- Dimensional accuracy, surface finish and the amount of defects depends on the casting process
- Allowances required.

Applications

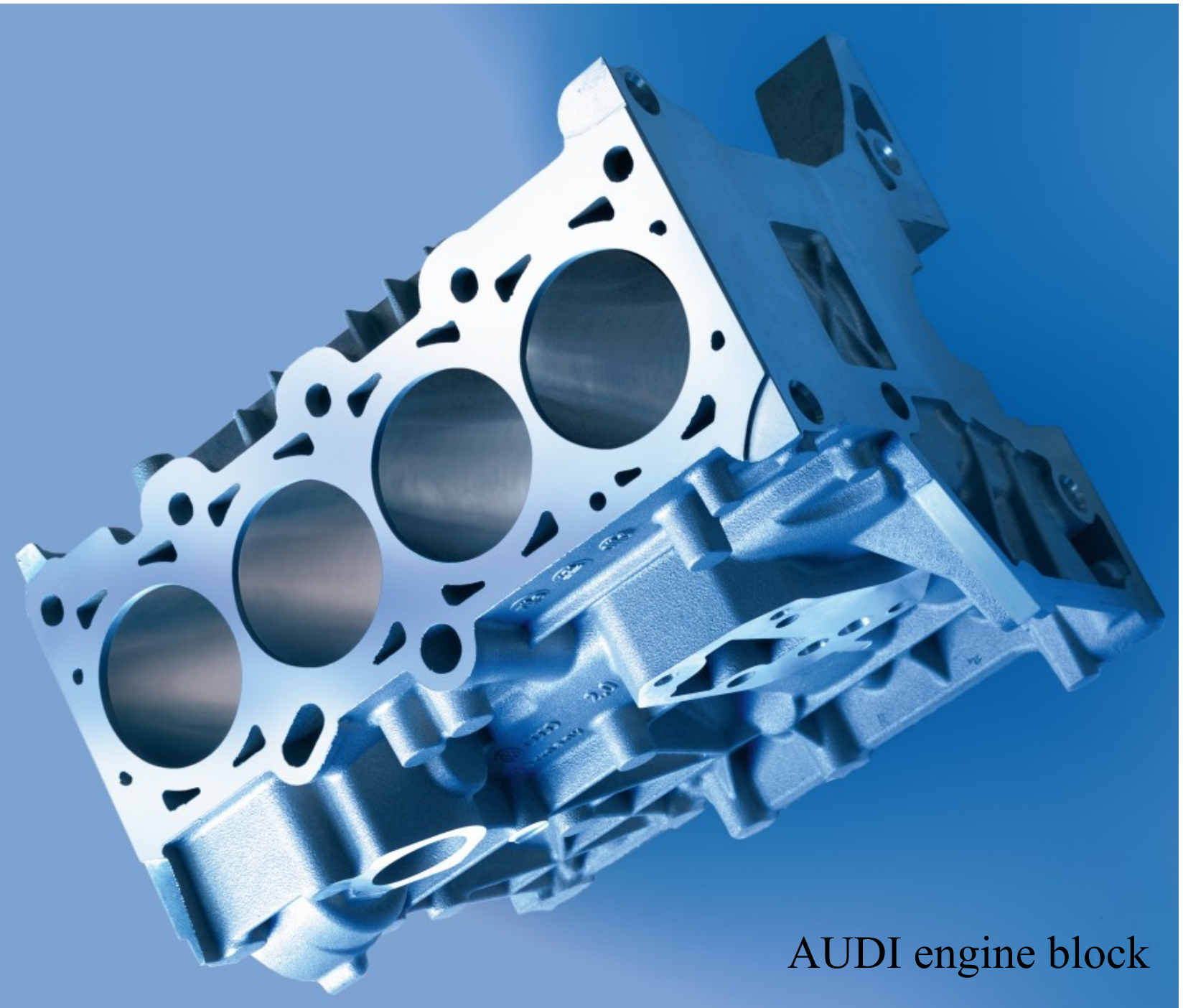
- Transportation vehicles(eg.:engines)
- Machine tool structures.
- Turbine vanes
- Mill housing
- Valves
- Sanitary fittings
- Agricultural parts
- Construction & atomic energy applications.



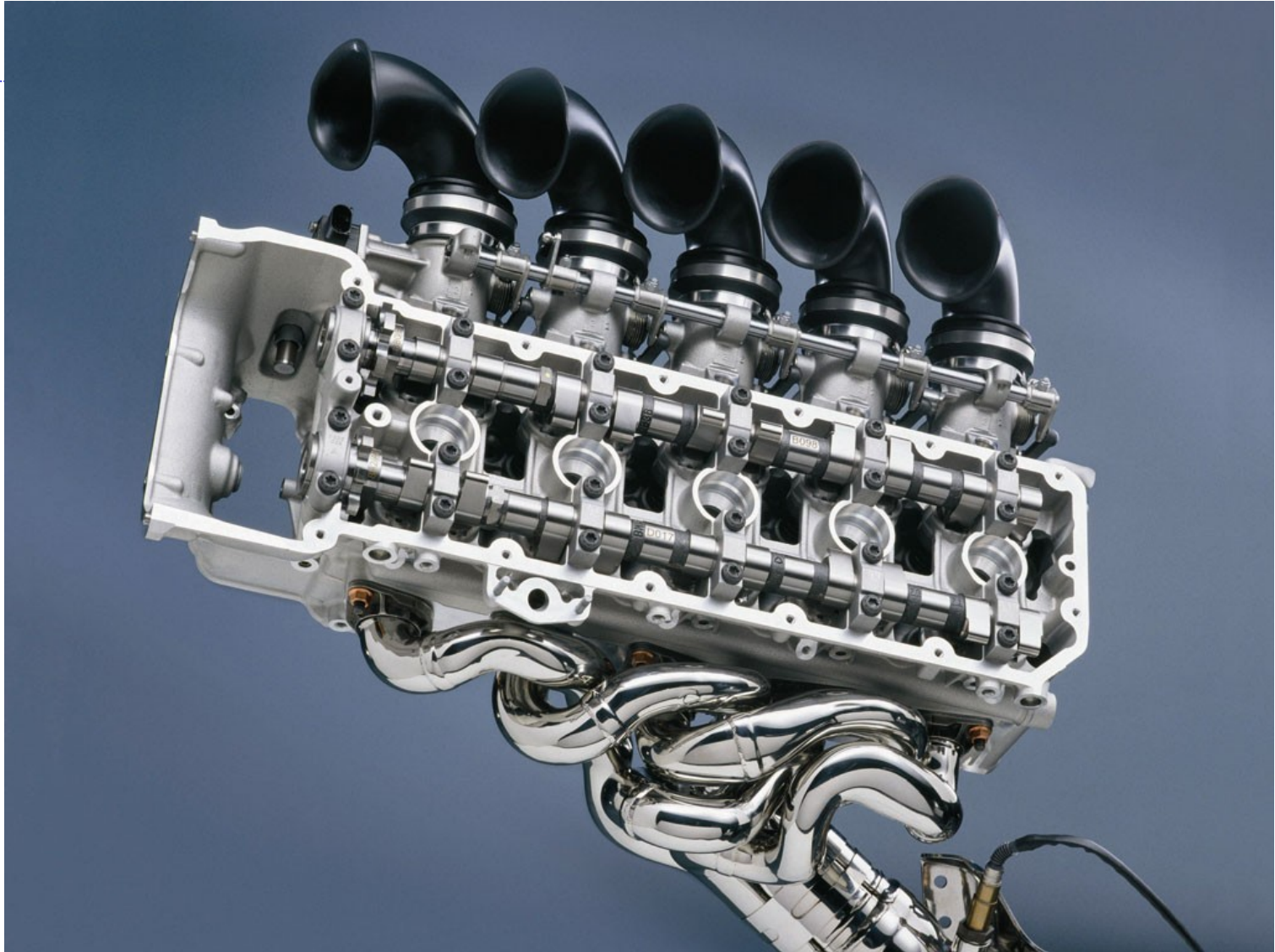
V6 engine block



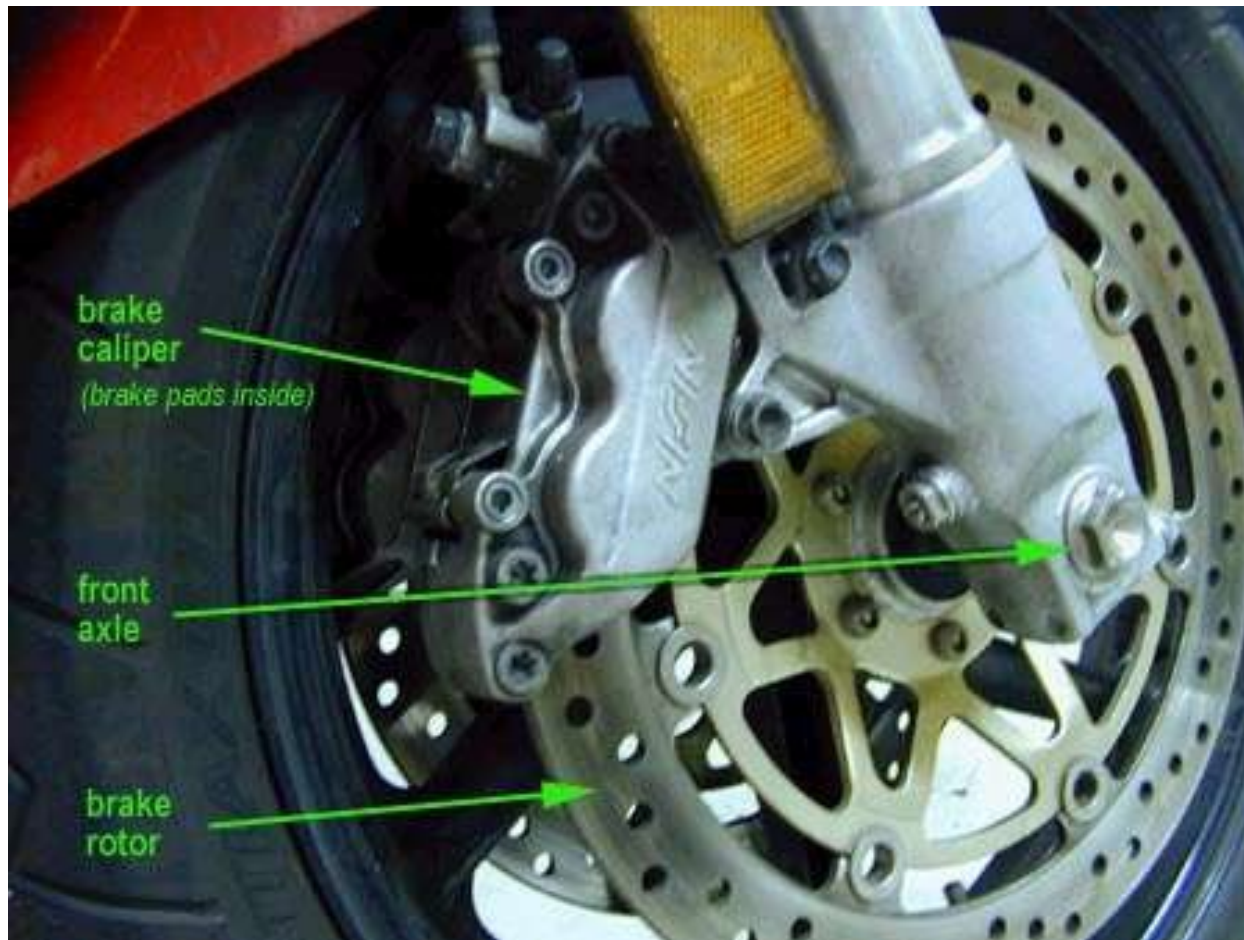
Crank Shaft



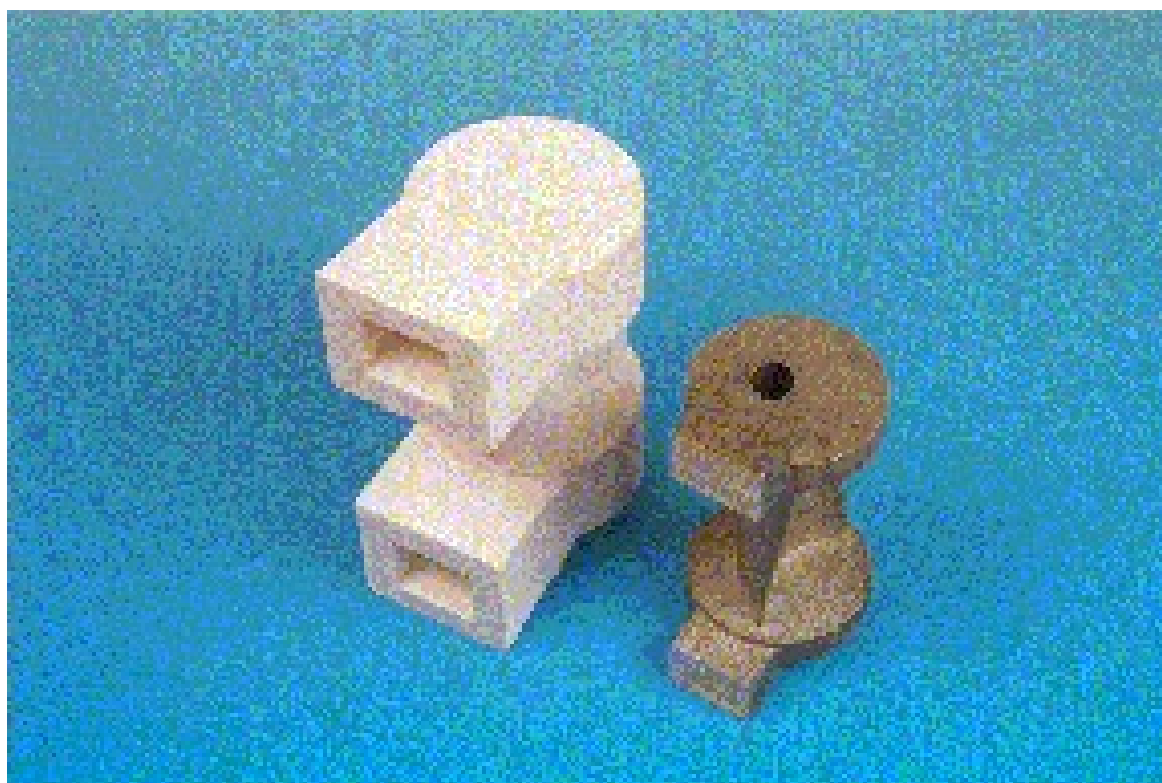
AUDI engine block



BMW cylinder head



Brake assembly





Pattern

- Pattern is the **principal tool** during the casting process.
- A pattern is a **model or the replica** of the object **(to be casted)**
- It may be defined as a **model or form around which sand is packed to give rise to a cavity known as mold cavity in which when molten metal is poured, the result is the cast object.**
- A pattern **prepares a mold cavity for the purpose of making a casting.**

OBJECTIVES OF A PATTERN

- **Pattern prepares a mould cavity for the purpose of making a casting.**
- **Pattern possesses core prints which produces seats in form of extra recess for core placement in the mould.**
- **It establishes the parting line and parting surfaces in the mould.**
- **Runner, gates and riser may form a part of the pattern.**
- **Properly constructed patterns minimize overall cost of the casting.**
- **Pattern may help in establishing locating pins on the mould and therefore on the casting with a purpose to check the casting dimensions.**
- **Properly made pattern having finished and smooth surface reduce casting defects.**

Pattern Materials

- **Wood:** Inexpensive, Easily available, Light weight, easy to shape, good surface finish, Poor wear resistance, absorb moisture, less strength, not suitable for machine moulding, easily repaired, warping, weaker than metallic patterns.
- Eg. Shisam, kail, deodar, Teak wood, maogani.
- **Metal:** less wear and tear, not affected by moisture, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes, withstand against corrosion and handling for longer, excellent strength to weight ratio,
- metallic patterns are higher cost, higher weight and tendency of rusting.
- preferred for production of castings in large quantities with same pattern.
- Eg.: cast iron, brass and bronzes and aluminum alloys

- 
- **Plastic:-**Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non sticky to molding sand, durable and they are not affected by the moisture of the molding sand.
 - fragile, less resistant to sudden loading and their section may need metal reinforcement.
 - Eg.:phenolic resin, foam plastic
 - **Plaster:** Intricate shapes can be made, good compressive strength, expands while solidifying, less dimensionally accurate.
 - •Wax: Good surface finish, high accuracy, no need to remove from the mould, less strength.

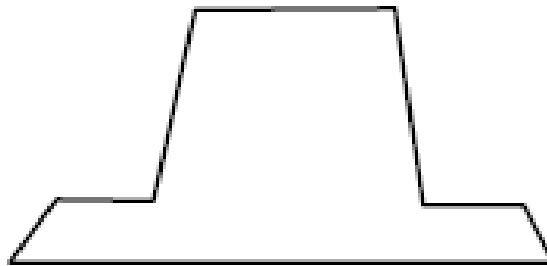
FACTORS EFFECTING SELECTION OF PATTERN MATERIAL

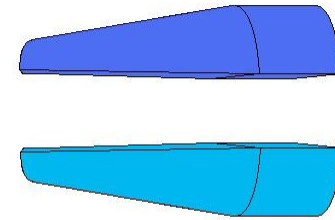
1. Number of castings to be produced. Metal pattern are preferred when castings are required large in number.
2. Type of mould material used.
3. Kind of molding process.
4. Method of molding (hand or machine).
5. Degree of dimensional accuracy and surface finish required.
6. Minimum thickness required.
7. Shape, complexity and size of casting.
8. Cost of pattern and chances of repeat orders of the pattern

TYPES OF PATTERN

- Single-piece or solid pattern

- Solid pattern is made of single piece without joints, partings lines or loose pieces.
- It is the simplest form of the pattern.
- Typical single piece pattern is shown in Fig.
- Simplest type, inexpensive used for limited production

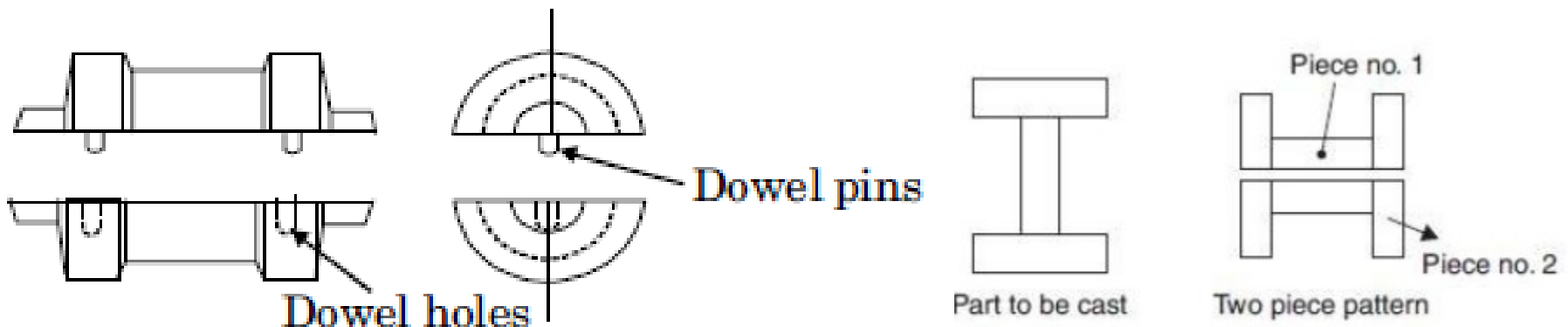




SPLIT PATTERN

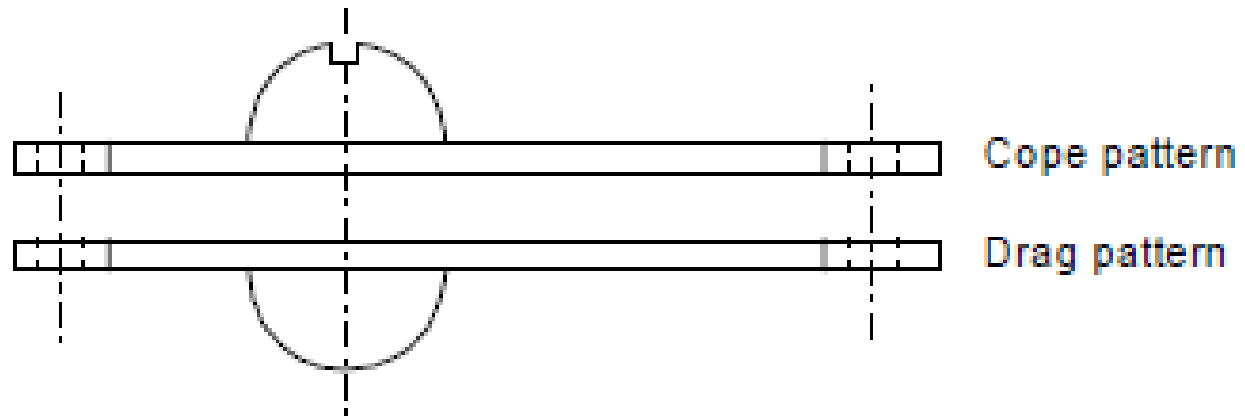
• Two-piece or split pattern

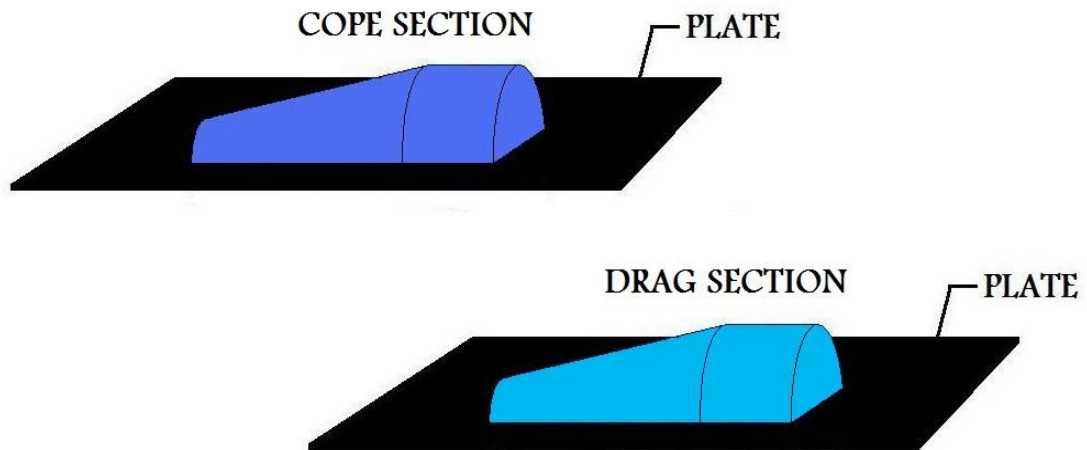
- When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is split in two parts.
- Split pattern is made in two pieces which are joined at the parting line by means of dowel pins.
- The splitting at the parting line is done to facilitate the withdrawal of the pattern.
- A typical example is shown in Fig.



• Cope and drag pattern

- In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator.
- The pattern is made up of two halves, which are mounted on different plates. A typical example of match plate pattern is shown in Fig.

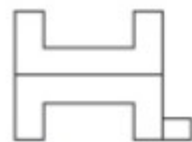
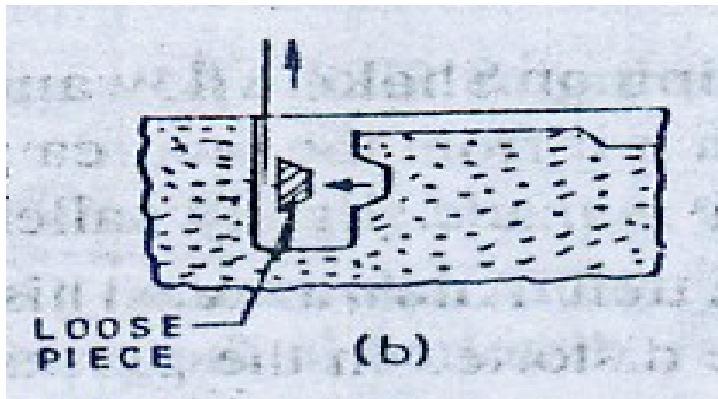




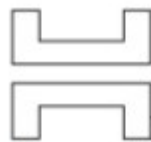
COPE AND DRAG PATTERN

• Loose-piece Pattern

- used when pattern is difficult for withdrawal from the mould.
- Loose pieces are provided on the pattern and they are the part of pattern.
- The main pattern is removed first leaving the loose piece portion of the pattern in the mould.
- Finally the loose piece is withdrawal separately leaving the intricate mould.

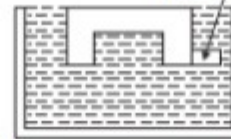


Casting

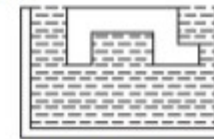


Split pattern with
loose piece

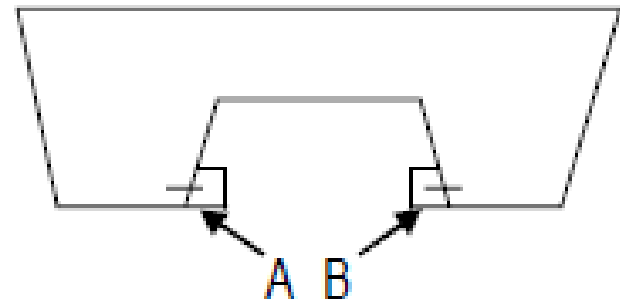
Loose piece



Moulding box with cavity
after main pattern has
been lifted, loose piece
left behind.

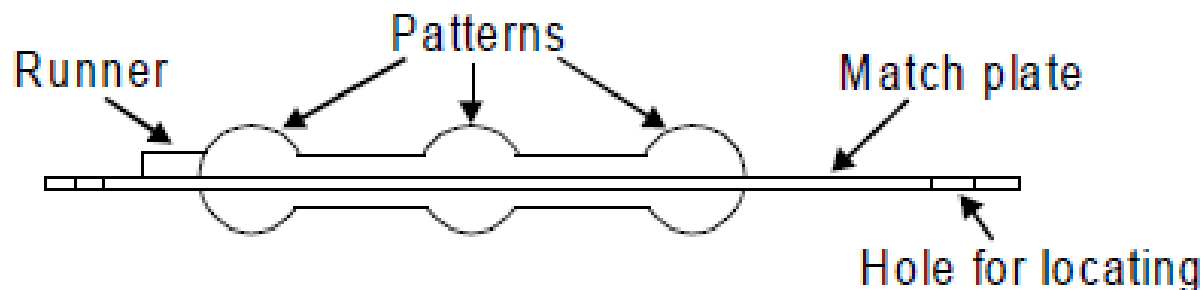


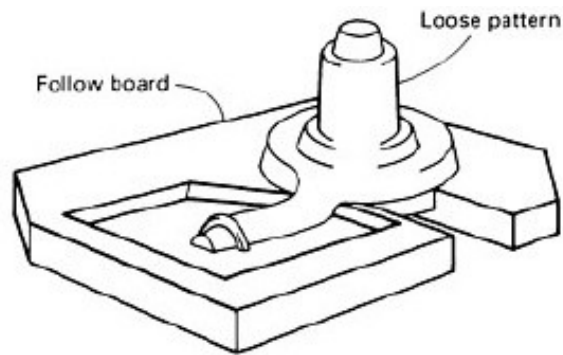
Mould cavity
after loose
piece removed



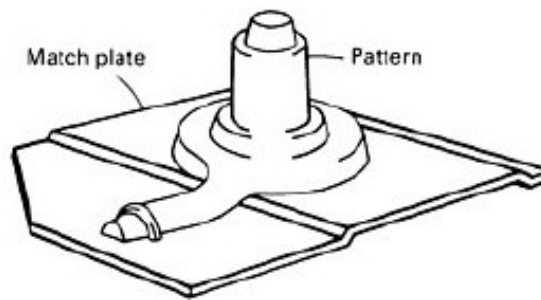
- **Match plate pattern**

- This pattern is made in two halves and is mounted on the opposite sides of a wooden or metallic plate, known as match plate.
- The gates and runners are also attached to the plate.
- This pattern is used in machine molding. A typical example of match plate pattern is shown in Fig.

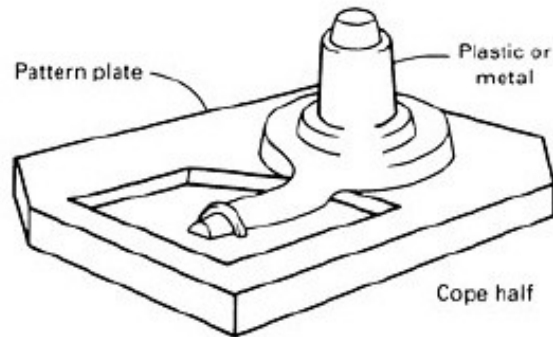




(a)



(b)



(c)

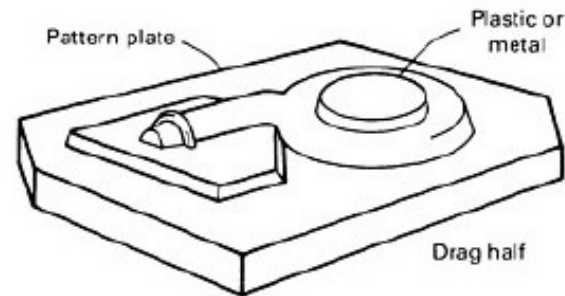
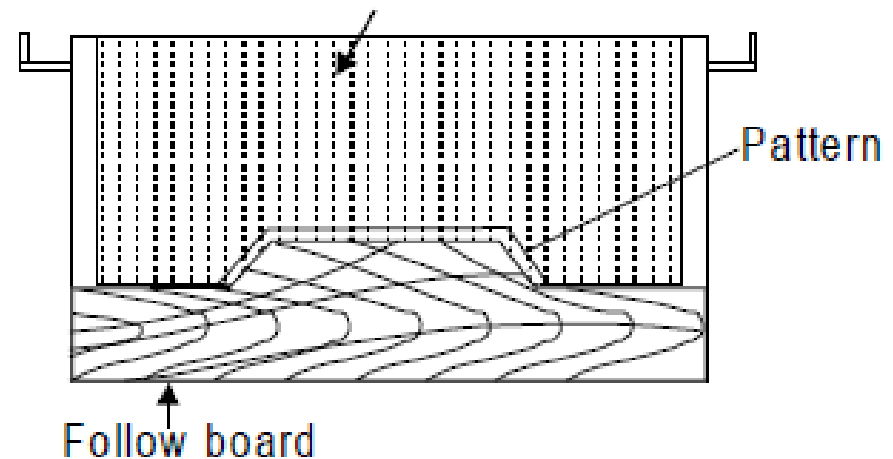
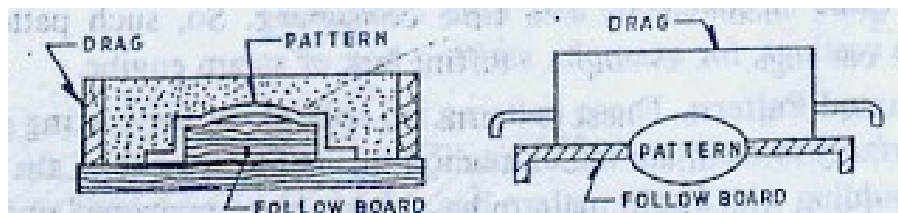


Figure: Three types of patterns used to produce a water pump casting in various quantities. (a) Wood pattern on a follow board, good for 20 to 30 castings. (b) Match plate pattern for up to 50,000 castings depending on material. (c) Cope and drag plastic (up to 20,000 castings) or metal (100,000 or more castings) pattern.

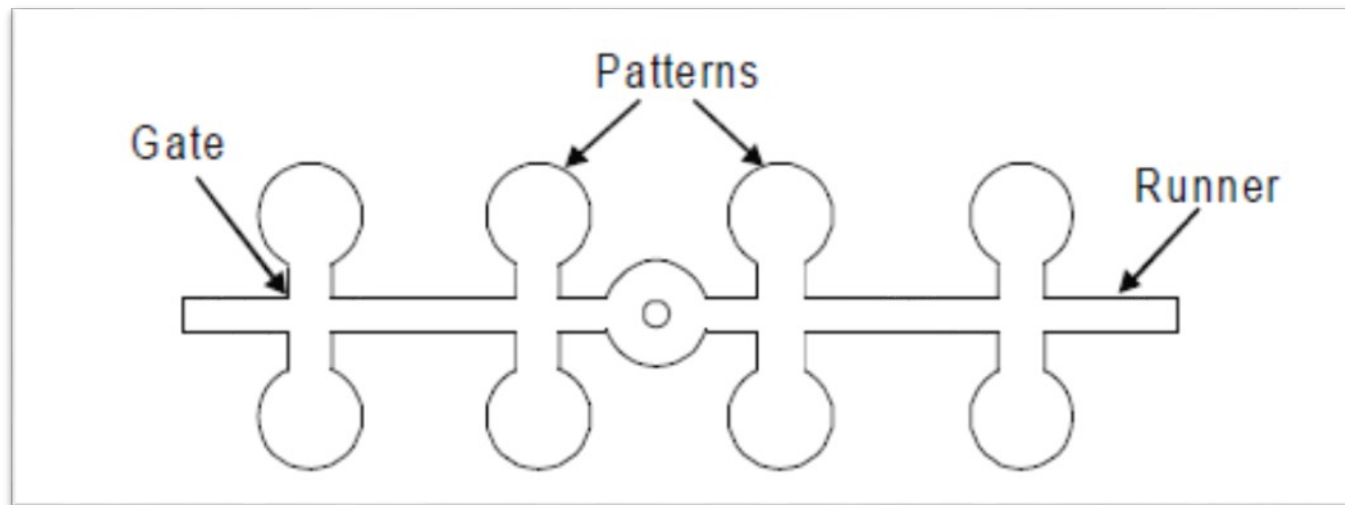
• Follow board pattern

- When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a molding board for the first molding operation as shown in Fig.



- **Gated pattern**

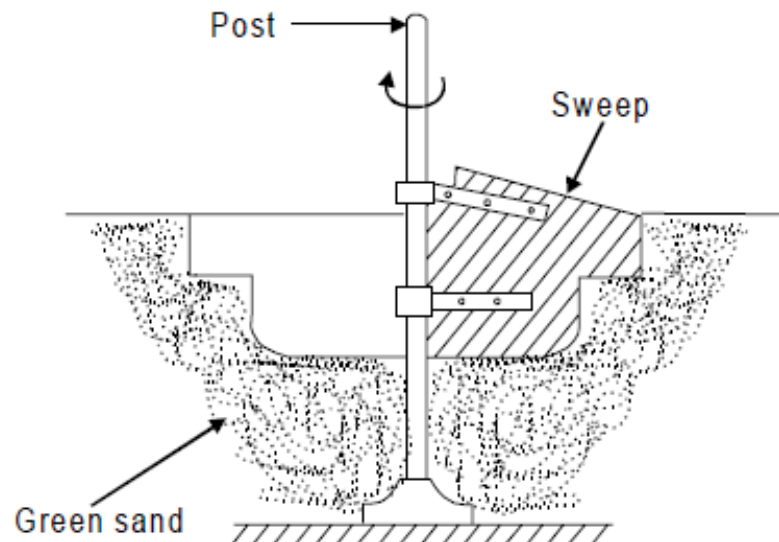
- In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Fig.
- These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.





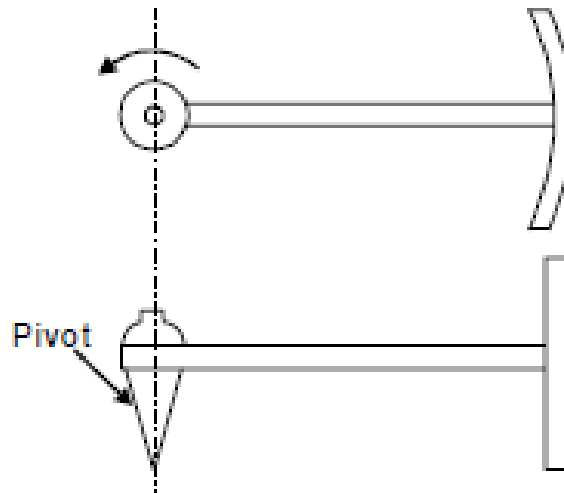
- **Sweep pattern**

- Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle as shown in Fig.
- Sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould.
- The pivot end is attached to a stake of metal in the center of the mould.



• Segmental pattern

- Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc.
- Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould.
- The movement of segmental pattern is guided by the use of a central pivot. A segment pattern for a wheel rim is shown in Fig.



- **Shell pattern**

- Shell patterns are used mostly for piping work or for producing drainage fittings. This pattern consists of a thin cylindrical or curved metal piece parted along the center line.
- The two halves of the pattern are held in alignment by dowels.
- The outside surface of the pattern is used to make the mould for the fitting required while the inside can serve as a core box.

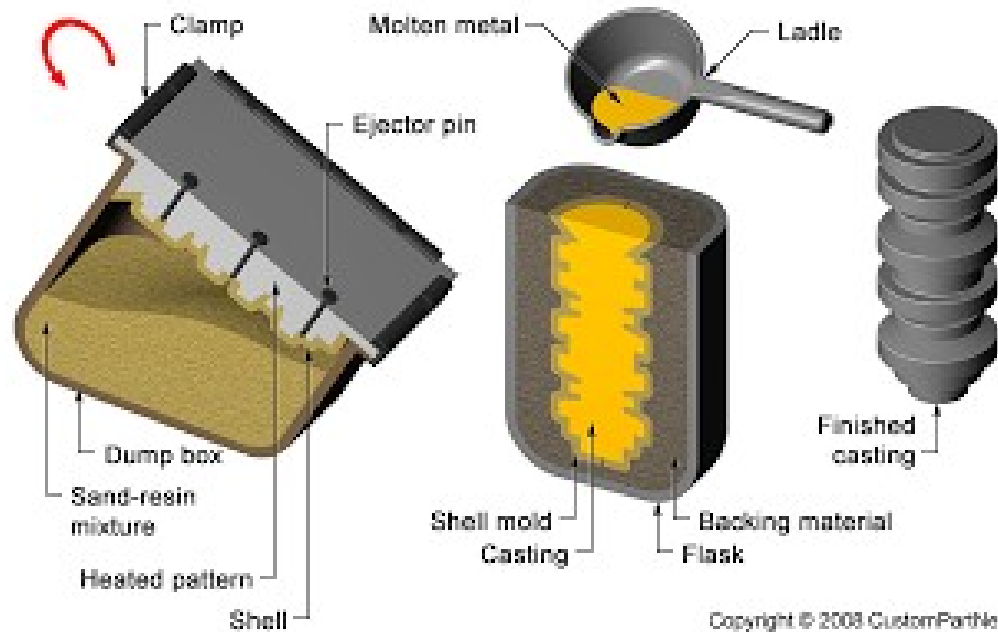
Shell-Making

(Cross-section)

Shell Mold Casting

(Cross-section)

Casting



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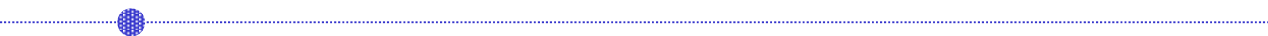


PATTERN ALLOWANCES

- The size of a pattern is never kept the same as that of the desired casting because of the fact that during cooling the casting is subjected to various effects and hence to compensate for these effects, corresponding allowances are given in the pattern.
- These various allowances given to pattern can be enumerated as, allowance for shrinkage, allowance for machining, allowance for draft, allowance for rapping or shake, allowance for distortion and allowance for mould wall movement.

- **Shrinkage Allowance**

- In practice, all common cast metals shrink a significant amount when they are cooled from the molten state. The total contraction in volume is divided into the following parts:
 - 1. Liquid contraction, i.e. the contraction during the period in which the temperature of the liquid metal or alloy falls from the pouring temperature to the liquidus temperature.
 - 2. Contraction on cooling from the liquidus to the solidus temperature, i.e. solidifying contraction.
 - 3. Contraction that results thereafter until the temperature reaches the room temperature. This is known as solid contraction.
- The first two of the above are taken care of by proper gating and risering. Only the last one, i.e. the solid contraction is taken care of by the pattern makers by giving a positive shrinkage allowance. This contraction allowance is different for different metals.

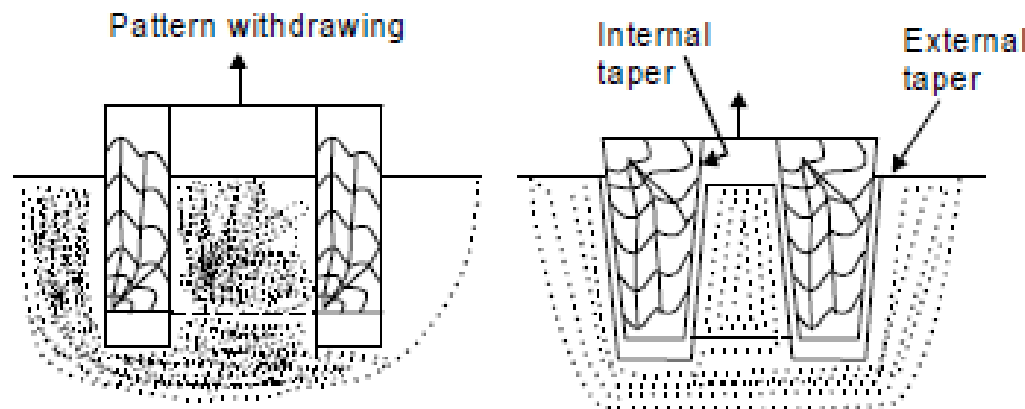
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- The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt.. Brass 16 mm/mt., Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. In fact, there is a special rule known as the pattern marks contraction rule in which the shrinkage of the casting metals is added.
 - **The pattern must be made over size to compensate for contraction of liquid metal on cooling. This addition to the dimension of the pattern is known as shrinkage allowance.**

- **Machining Allowance**

- It is a positive allowance
- given to compensate for the amount of material that is lost in machining or finishing the casting.
- If this allowance is not given, the casting will become undersize after machining.
- this allowance depends on the size of casting, methods of machining and the degree of finish.
- value varies from 3 mm. to 18 mm.
- pattern must be made over size for machining purpose
- This extra amount of dimensions provided in the pattern is known as Machining allowance.

• Taper allowance

- positive allowance
- given on all the vertical surfaces of pattern to make withdrawal easier.
- taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt.
- These values are greatly affected by the size of the pattern and the molding method
- In machine molding its, value varies from 10 mm to 50 mm/mt.



- **Rapping or Shake Allowance**

- Before withdrawing the pattern it is rapped and thereby the size of the mould cavity increases.
- by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size.
- insignificant in the case of small and medium size castings,
- but it is significant in the case of large castings. negative allowance pattern is made slightly smaller in dimensions 0.5-1.0 mm.

Distortion Allowance

- This allowance is applied to the castings which have the tendency to distort during cooling due to thermal stresses developed.
- For example a casting in the form of U shape will contract at the closed end on cooling, while the open end will remain fixed in position.
- Therefore, to avoid the distortion, the legs of U pattern must converge slightly so that the sides will remain parallel after cooling.



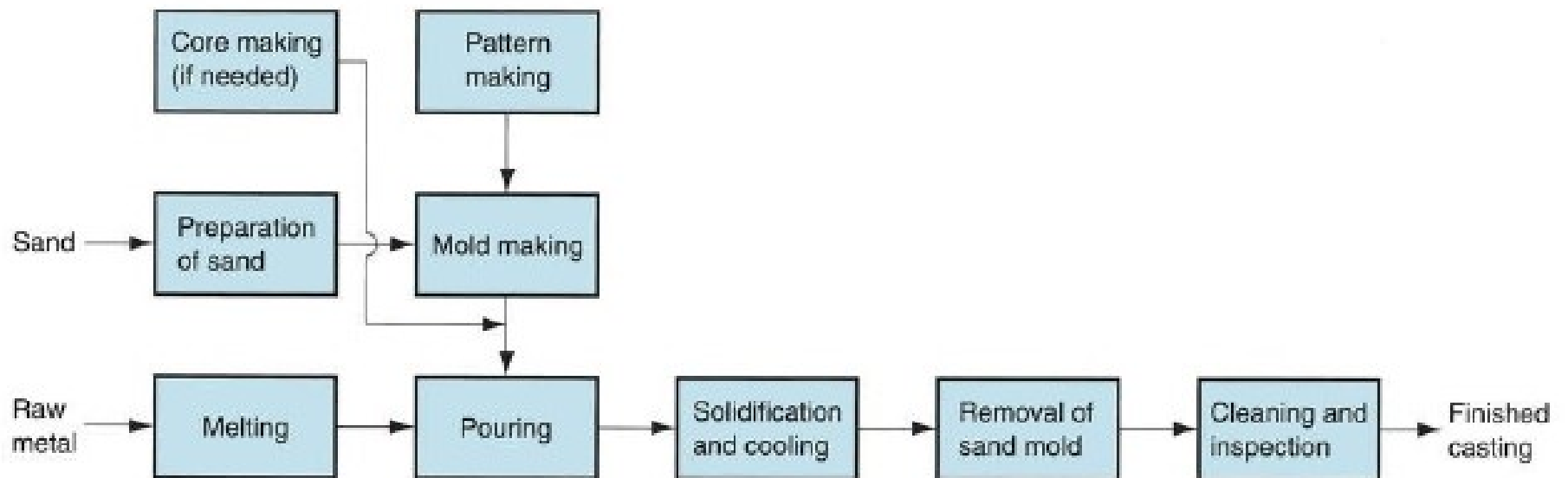
(a)



(b)

- **COLOR CODIFICATION FOR PATTERNS**

- Surfaces to be left unfinished after casting are to be painted as **black**.
- Surface to be machined are painted as **red**.
- Core prints are painted as **yellow**.
- Seats for loose pieces are painted as **red stripes on yellow background**.
- Stop-offs is painted as **black stripes on yellow base**.



Mould

- suitable and workable material possessing high refractoriness in nature
- material can be metallic or non-metallic
- For metallic category, the common materials are cast iron, mild steel and alloy steels.
- non-metallic group molding sands, plaster of paris, graphite, silicon carbide and ceramics
- molding sand is the most common utilized non-metallic molding material because of its certain inherent properties namely refractoriness, chemical and thermal stability at higher temperature, high permeability and workability along with good strength.

- 
- **molding sand** is the most common utilized non-metallic molding material
 - because of its certain inherent properties namely,
 - **refractoriness,**
 - **chemical and thermal stability at higher temperature,**
 - **high permeability and**
 - **workability along with good strength.**
 - **highly cheap and easily available.**

MOLDING SAND

- **Sources** of receiving **molding sands**
- beds of sea,
- rivers,
- lakes,
- granular elements of rocks,
- and deserts.

- sources of molding sands available in India

- 1 Batala sand (Punjab)

- 2 Ganges sand (Uttar Pradesh)

- 3 Oyaria sand (Bihar)

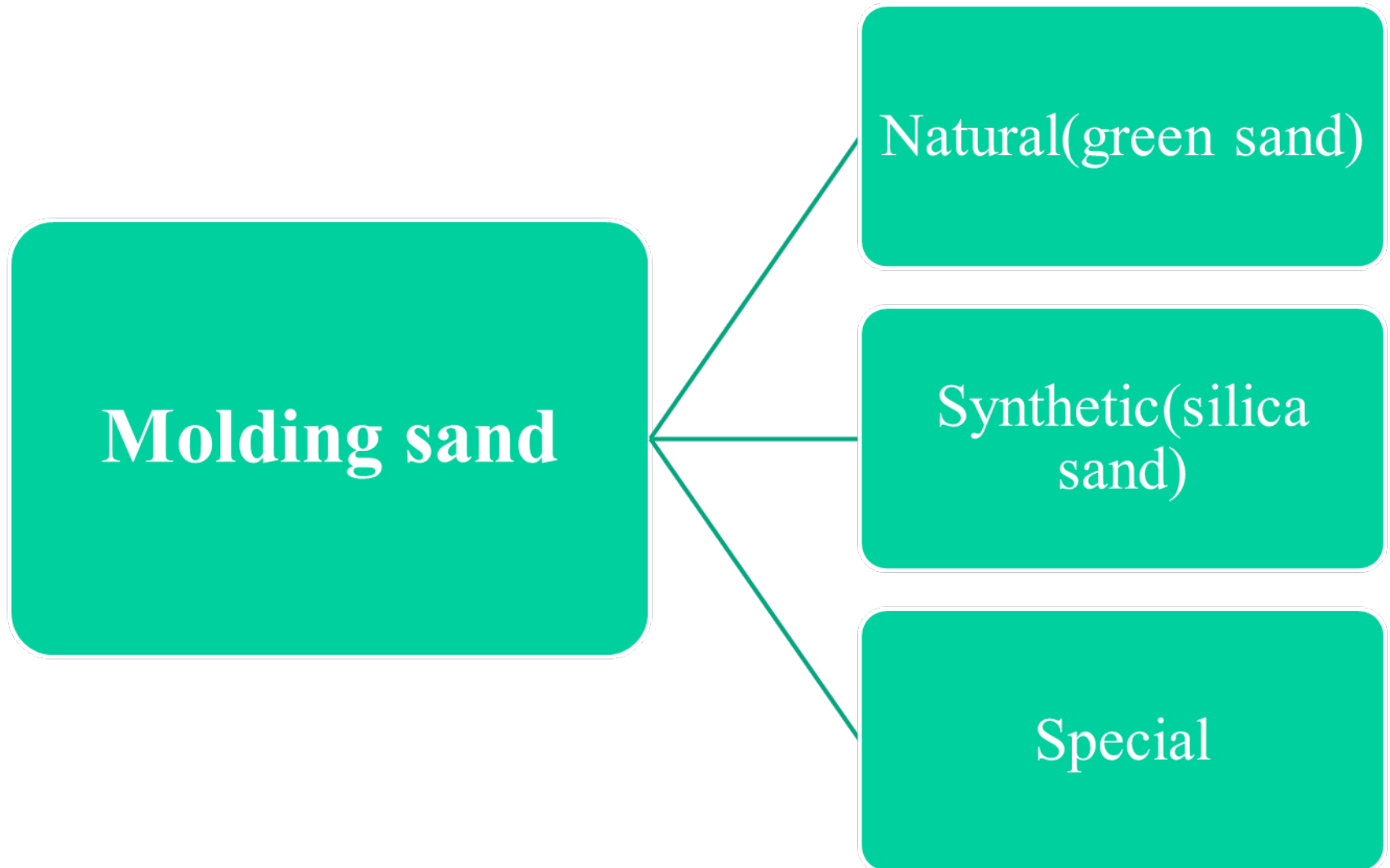
- 4 Damodar and Barakar sands (Bengal- Bihar Border)

- 5 Londha sand (Bombay)

- 6 Gigatamannu sand (Andhra Pradesh) and

- 7 Avadi and Veeriyambakam sand (Madras)

Types of molding sand





Natural Molding sand:

- known as green sand
- having appreciable amount of clay which acts as a binder between sand grains
- obtained by crushing and milling of soft yellow sand stone, carboniferous etc
- Ease of availability
- Low cost
- High flexibility
- Mostly used for ferrous and non ferrous metal casting



Synthetic sand

- known as silica sand
- not having binder(clay) in natural form
- desired strength and properties developed by separate addition of binder like bentonite, water and other materials.
- More expensive than natural sand



Special sands

- Zircon-cores of brass and bronze casting
- Olivine-for non ferrous casting
- Chromite-for heavy steel casting
- Chrome-magnesite-used as facing materials in steel casting.

Types of moulding sand

(According to use)

Green sand

Dry sand

Facing sand

Backing sand

System sand

Parting sand

Loam sand

Core sand

Green sand

- Green sand is also known as tempered or natural sand
- mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%.
- The clay and water furnish the bond for green sand. It is fine, soft, light, and porous.
- Green sand is damp, when squeezed in the hand and it retains the shape and the impression to give to it under pressure.
- Molds prepared by this sand are not requiring backing and hence are known as green sand molds.



Dry sand

- Green sand that has been dried or baked in suitable oven after the making mold and cores, is called dry sand.
- more strength,
- rigidity and
- thermal stability.
- mainly suitable for larger castings.
- mold prepared in this sand are known as dry sand molds.



Loam sand

- Loam is mixture of sand and clay with water to a thin plastic paste.
- sand possesses high clay as much as 30-50% and 18% water.
- Patterns are not used for loam molding and shape is given to mold by sweeps.
- particularly employed for loam molding used for large grey iron castings.
- This sand is used for loam sand moulds for making very heavy castings usually with the help of sweeps and skeleton patterns.



Facing sand

- Facing sand is just prepared and forms **the face of the mould**.
- It is directly **next to the surface of the pattern** and it comes into contact molten metal when the mould is poured.
- **high strength refractoriness**.
- made of **silica sand and clay**, without the **use of used sand**.
- Different forms of **carbon are used** to **prevent the metal burning** into the sand.
- A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal.
- sometimes mixed with 6-15 times as much fine molding sand to make facings.
- The **layer of facing sand** in a mold usually **ranges from 22-28 mm**. From **10 to 15% of the whole amount** of molding sand is the facing sand.



Backing sand

- Backing sand or floor sand is used to back up the facing sand and is used to fill the whole volume of the molding flask.
- Used molding sand is mainly employed for this purpose.
- The backing sand is sometimes called black sand because that old



System sand

- In mechanized foundries where machine molding is employed.
- A so-called system sand is used to fill the whole molding flask.
- The used sand is cleaned and re-activated by the addition of water and special additives. This is known as system sand.
- Since the whole mold is made of this system sand, the properties such as strength, permeability and refractoriness of the molding sand must be higher than those of backing sand.



Parting sand

- without binder and moisture to keep the green sand not to stick to the pattern
- to allow the sand on the parting surface the cope and drag to separate without clinging.
- This is clean clay-free silica sand which serves the same purpose as parting dust.



Core sand

- is used for making cores and it is sometimes
- also known as oil sand.
- This is highly rich silica sand mixed with oil binders such as core oil which composed of linseed oil, resin,
- light mineral oil and other bind materials.
- Pitch or flours and water may also be used in large cores for the sake of economy.

Properties of Moulding Sand

- **Refractoriness**

- Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting.
- poor refractoriness
- burn on to the casting surface and
- no smooth casting surface can be obtained.
- degree of refractoriness depends on the SiO_2 i.e. quartz content, and the shape and grain size of the particle.
- higher the SiO_2 content higher is the refractoriness of the molding
- Refractoriness is measured by the sinter point of the sand rather than its melting point.

- **Permeability**

- It is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it.
- All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective.
- Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand.
- The extent of ramming of the sand directly affects the permeability.

- **Cohesiveness**

- It is property by virtue of which the sand grain particles interact and attract each other within the molding sand.
- Thus, the binding capability of the molding sand gets enhanced to increase the green, dry and hot strength property of molding and core sand.

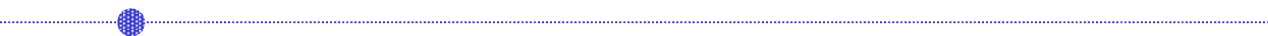
• **Green strength**

- By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal.
- The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould.
- For this, the sand grains must be adhesive, i.e. they must be capable of attaching themselves to another body and therefore, and sand grains having high adhesiveness will cling to the sides of the molding box.



- **Dry strength**

- As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal.
- The dry strength also prevents the enlargement of mould cavity cause by the metallostatic pressure of the liquid metal.

- 
- Strength of the moulding sand depends on:
 - 1. Grain size and shape
 - 2. Moisture content
 - 3. Density of sand after ramming
 - · The strength of the mould increases with a decrease of grain size and an increase of clay content and density after ramming. The strength also goes down if moisture content is higher than an optimum value.

- **Flowability or plasticity**

- It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions.
- Generally sand particles resist moving around corners or projections.
- In general, flowability increases with decrease in green strength, and, decrease in grain size.
- The flowability also varies with moisture and clay content.



- **Adhesiveness**

- · It is the important property of the moulding sand and it is defined as the sand particles must be capable of adhering to another body, then only the sand should be easily attach itself with the sides of the moulding box and give easy of lifting and turning the box when filled with the sand.



- **Collapsibility**

- After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal.
- In absence of this property the contraction of the metal is hindered by the mold and thus results in tears and cracks in the casting.
- This property is highly desired in cores.

CONSTITUENTS OF MOLDING SAND

- The main constituents of molding sand involve
- silica sand,
- binder,
- moisture content and
- additives.

- **Silica sand**

- Silica sand in form of granular quartz is the main constituent of molding sand
- having enough refractoriness
- which can impart strength,
- stability and
- permeability to molding and core sand.
- along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities.
- The silica sand can be specified according to the size (**small, medium and large silica sand grain**) and
- the shape (**angular, sub-angular and rounded**).

Binder

- In general, the binders can be either inorganic or organic substance.
- The inorganic group includes clay **sodium silicate and port land cement** etc.
- In foundry shop, the clay acts as binder which may be **Kaolonite, Ball Clay, Fire Clay, Limonite, Fuller's earth and Bentonite.**
- Binders included in the organic group are **dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde etc.**
- **Organic binders are mostly used for core making.**
- Among all the above binders, the bentonite variety of clay is the most common. However, this clay alone can not develop bonds among sand grains without the presence of moisture in molding sand and core sand.

Moisture

- The amount of moisture content in the molding sand varies generally between 2 to 8 percent.
- This amount is added to the mixture of clay and silica sand for developing bonds.
- This is the amount of water required to fill the pores between the particles of clay without separating them.
- This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand.
- The effect of clay and water decreases permeability with increasing clay and moisture content.
- The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing.
- For increasing the molding sand characteristics some other additional materials beside basic constituents are added which are known as additives.

Additives

- **Dextrin**
- carbohydrates
- increases dry strength of the molds.
- **Corn flour**
- It belongs to the starch family of carbohydrates
- is used to increase the collapsibility of the molding and core sand.
- **Coal dust**
- To avoid oxidation of pouring metal
- For production of grey iron and malleable cast iron castings.
- **Sea coal**
- sand grains become restricted and cannot move into a dense packing pattern.
- **Pitch**
- form of soft coal (0.02 % to 2%)
- **Wood flour:** 0.05 % to 2%
- To avoid expansion defects.
- increases collapsibility of both of mold and core.
- **Silica flour**
- added up to 3% which increases the
- hot strength and finish on the surfaces of the molds and cores.
- It also reduces metal penetration in the walls of the molds and cores

Sand Testing

- Molding sand and core sand depend upon shape, size composition and distribution of sand grains, amount of clay, moisture and additives.
- **The increase in demand for good surface finish and higher accuracy in castings necessitates certainty in the quality of mold and core sands.**
- Sand testing often allows the use of less expensive local sands. It also ensures reliable sand mixing and enables a utilization of the inherent properties of molding sand.
- Sand testing on delivery will immediately detect any variation from the standard quality, and adjustment of the sand mixture to specific requirements so that the casting defects can be minimized.
- **It allows the choice of sand mixtures to give a desired surface finish.** Thus sand testing is one of the dominating factors in foundry and pays for itself by obtaining lower per unit cost and.

- 
- 1. Moisture content test
 - 2. Clay content test
 - 3. Grain fitness test
 - 4. Permeability test
 - 5. Strength test
 - 6. Refractoriness test
 - 7. Mould hardness test

- **Moisture Content Test**

- Moisture is the property of the moulding sand it is defined as the amount of water present in the moulding sand. Low moisture content in the moulding sand does not develop strength properties. High moisture content decreases permeability.
- **Procedures are:**
 - 1. 20 to 50 gms of prepared sand is placed in the pan and is heated by an infrared heater bulb for 2 to 3 minutes.
 - 2. The moisture in the moulding sand is thus evaporated.
 - 3. Moulding sand is taken out of the pan and reweighed.
 - 4. The percentage of moisture can be calculated from the difference in the weights, of the original moist and the consequently dried sand samples.
- **Percentage of moisture content = $(W1-W2)/(W1)$ %**
- Where, W1-Weight of the sand before drying,
- W2-Weight of the sand after drying





• Clay Content Test

- Clay influences strength, permeability and other moulding properties. It is responsible for bonding sand particles together.
- Procedures are:
 - 1. Small quantity of prepared moulding sand was dried
 - 2. Separate 50 gms of dry moulding sand and transfer wash bottle.
 - 3. Add 475cc of distilled water + 25cc of a 3% NaOH.
 - 4. Agitate this mixture about 10 minutes with the help of sand stirrer.
 - 5. Fill the wash bottle with water up to the marker.
 - 6. After the sand etc., has settled for about 10 minutes, Siphon out the water from the wash bottle.
 - 7. Dry the settled down sand.
 - 8. The clay content can be determined from the difference in weights of the initial and final sand samples.
- **Percentage of clay content = $(W1-W2)/(W1) * 100$**
- Where, W1-Weight of the sand before drying,
- W2-Weight of the sand after drying.

- **Grain fitness test:**

- The grain size, distribution, grain fitness are determined with the help of the fitness testing of moulding sands. The apparatus consists of a number of standard sieves mounted one above the other, on a power driven shaker.
- The shaker vibrates the sieves and the sand placed on the top sieve gets screened and collects on different sieves depending upon the various sizes of grains present in the moulding sand.
- The top sieve is coarsest and the bottom-most sieve is the finest of all the sieves. In between sieve are placed in order of fineness from top to bottom.
- Procedures are:
 - 1. Sample of dry sand (clay removed sand) placed in the upper sieve
 - 2. Sand is vibrated for definite period
 - 3. The amount of same retained on each sieve is weighted.
 - 4. Percentage distribution of grain is computed.



- **Flowability Test**

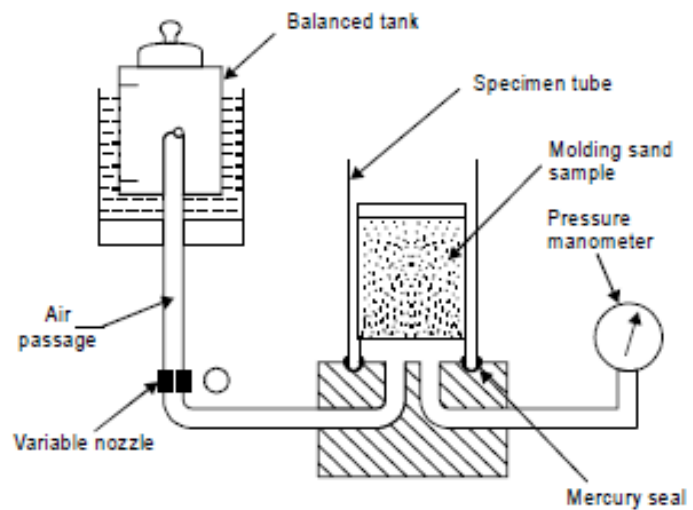
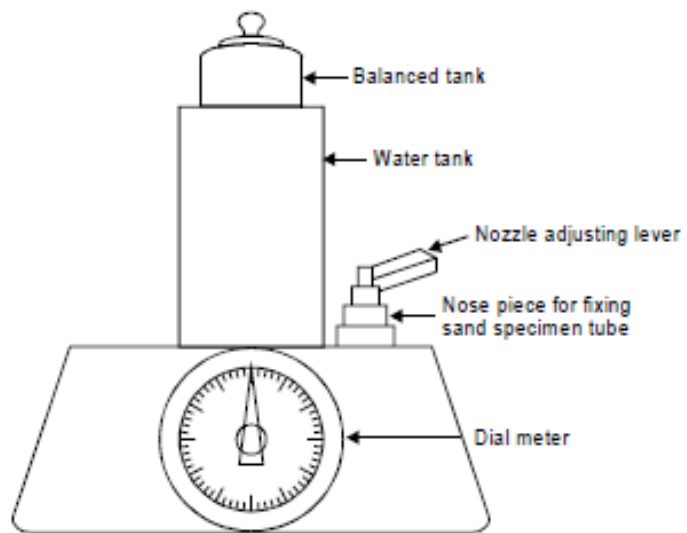
- Flowability of the molding and core sand usually determined by the movement of the rammer plunger between the fourth and fifth drops and is indicated in percentages.
- This reading can directly be taken on the dial of the flow indicator.
- Then the stem of this indicator rests again top of the plunger of the rammer and it records the actual movement of the plunger between the fourth and fifth drops.

- **Permeability Test**

- **Permeability test:**

- The quantity of air that will pass through a standard specimen of the sand at a particular pressure condition is called the permeability of the sand.
- Following are the major parts of the permeability test equipment:
 1. An inverted bell jar, which floats in a water.
 2. Specimen tube, for the purpose of hold the equipment
 3. A manometer (measure the air pressure)

- Steps involved are:
- 1. The air (2000cc volume) held in the bell jar is forced to pass through the sand specimen.
- 2. At this time air entering the specimen equal to the air escaped through the specimen
- 3. Take the pressure reading in the manometer.
- 4. Note the time required for 2000cc of air to pass the sand
- 5. Calculate the permeability number
- 6. **Permeability number (N) = ((V x H) / (A x P x T))**
- Where,
- V-Volume of air (cc)
- H-Height of the specimen (mm)
- A-Area of the specimen (mm²)
- P-Air pressure (gm / cm²)
- T-Time taken by the air to pass through the sand (seconds)

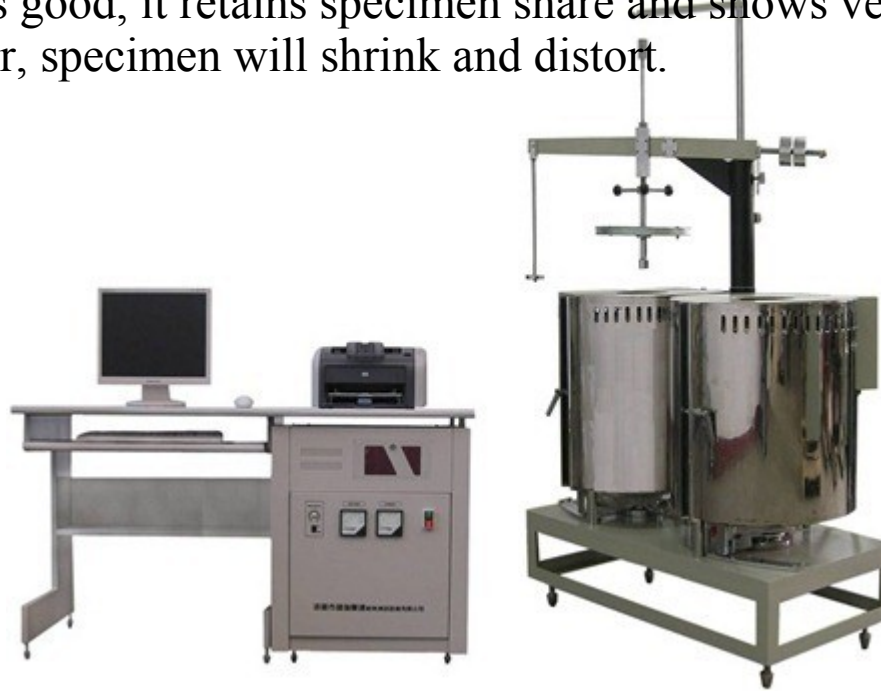




• Refractoriness Test

- The refractoriness of the molding sand is judged by heating the American Foundry Society (A.F.S) standard sand specimen to very high temperatures ranges depending upon the type of sand.
- The heated sand test pieces are cooled to room temperature and examined under a microscope for surface characteristics or by scratching it with a steel needle.
- If the silica sand grains remain sharply defined and easily give way to the needle. Sintering has not yet set in.
- In the actual experiment the sand specimen in a porcelain boat is placed into an electric furnace.
- It is usual practice to start the test from 1000°C and raise the temperature in steps of 100°C to 1300°C and in steps of 50° above 1300°C till sintering of the silica sand grains takes place.
- At each temperature level, it is kept for at least three minutes and then taken out from the oven for examination under a microscope for evaluating surface characteristics or by scratching it with a steel needle.

- The refractoriness is used to measure the ability of the sand to withstand the higher temperature.
- Steps involved are:
 1. Prepare a cylindrical specimen of sand
 2. Heating the specimen at 1500 C for 2 hours
 3. Observe the changes in dimension and appearance
 4. If the sand is good, it retains specimen shape and shows very little expansion. If the sand is poor, specimen will shrink and distort.



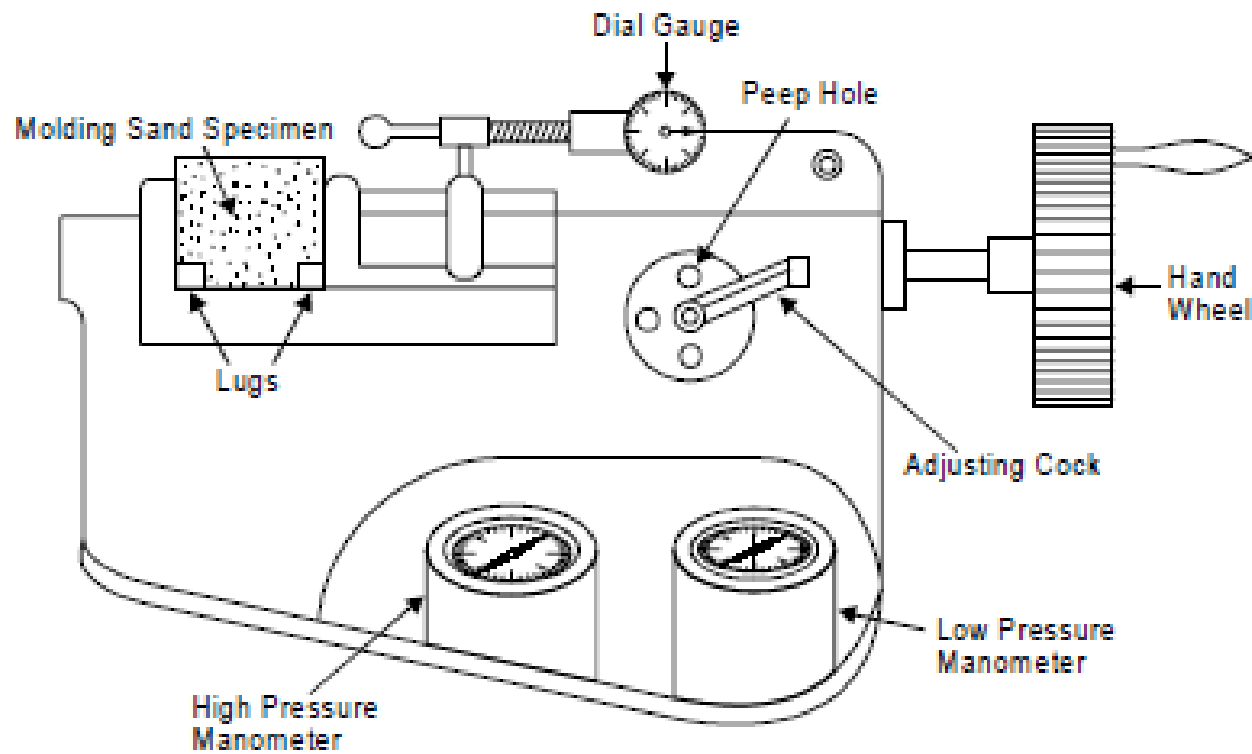


• **Strength Test**

- Green strength and dry strength is the holding power of the various bonding materials.
- Generally green compression strength test is performed on the specimen of green sand (wet condition).
- The sample specimen may of green sand or dry sand which is placed in lugs and compressive force is applied slowly by hand wheel until the specimen breaks.
- The reading of the needle of high pressure and low pressure manometer indicates the compressive strength of the specimen in kgf/cm².
- The most commonly test performed is compression test which is carried out in a compression sand testing machine

- Measurements of strength of moulding sands can be carried out on the universal sand strength testing machine. The strength can be measured in compression, shear and tension.
- The sands that could be tested are green sand, dry sand or core sand. The compression and shear test involve the standard cylindrical specimen that was used for the permeability test.





- **Mould hardness test:**

- Hardness of the mould surface can be tested with the help of an “indentation hardness tester”. It consists of indicator, spring loaded spherical indenter.
- The spherical indenter is penetrates into the mould surface at the time of testing. The depth of penetration w.r.t. the flat reference surface of the tester.
- **Mould hardness number = $((P) / (D - (D^2 - d^2)))$**
- Where,
- P- Applied Force (N)
- D- Diameter of the indenter (mm)
- d- Diameter of the indentation (mm)



SAND CONDITIONING

- Natural sands are generally not well suited for
- casting purposes. On continuous use of molding sand, the clay coating on the sand particles gets thinned out causing decrease in its strength.
- Thus proper sand conditioning accomplish uniform distribution of binder
- around the sand grains, control moisture content, eliminate foreign particles and aerates the sands.
- Therefore, there is a need for sand conditioning for achieving better results.
- The sand constituents are then brought at required proper proportion and mixed thoroughly.
- Next, the whole mixture is mulled suitably till properties are developed. After all the foreign particles are removed from and the sand is free from the hard lumps etc., proper amount of pure sand, clay and required additives are added to for the loss because of the burned, clay and other corn materials.
- As the moisture content of the returned sand known, it is to be tested and after knowing the moisture the required amount of water is added.

- 
- Now these things are mixed thoroughly in a mixing muller.
 - The main objectives of a mixing muller is to distribute the binders, additives and moisture or water content uniformly all around each sand grain and helps to develop the optimum physical properties by kneading on the sand grains.
 - Inadequate mulling makes the sand mixture weak which can only be compensated by adding more binder.
 - Thus the adequate mulling economizes the use of binders. There are two methods of adding clay and water to sand.
 - In the first method, first water is added to sand followed by clay, while in the other method, clay addition is followed by water. It has been suggested that the best order of adding ingredients to clay bonded sand is sand with water followed by the binders.
 - In this way, the clay is more quickly and uniformly spread on to all the sand grains.

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- method, clay addition is followed by water.
- It has been suggested that the best order of adding ingredients to clay bonded sand is sand with water followed by the binders.
- In this way, the clay is more quickly and uniformly spread on to all the sand grains. An additional advantage of this mixing order is that less dust is produced during the mulling operation.
- **The muller usually consists of a cylindrical pan in which two heavy rollers; carrying two ploughs, and roll in a circular path. While the rollers roll, the ploughs scrap the sand from the sides and the bottom of the pan and place it in front of For producing a smearing action in the sand, the rollers are set slightly off the true radius and they move out of the rollers can be moved up and down without difficulty mounted on rocker arms.**
- After the mulling is completed sand can be discharged through a door. The mechanical aerators are generally used for aerating or separating the sand grains by increasing the flowability through whirling the sand at a high speed by an impeller towards the inner walls of the casting.

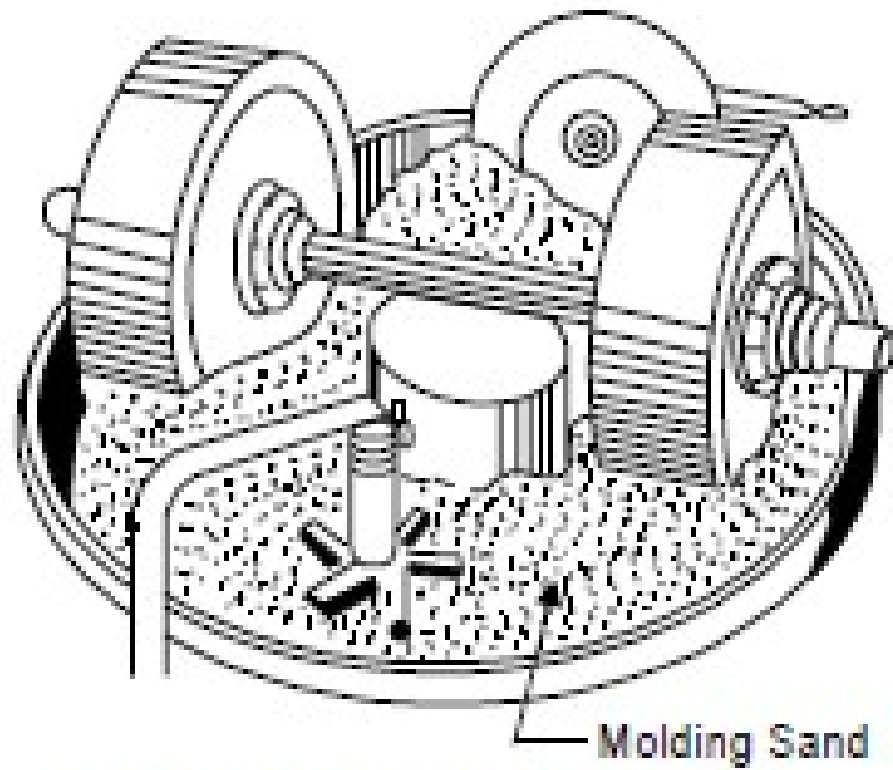


Fig. 12.5 Sand mixing muller

- **STEPS INVOLVED IN MAKING A SAND MOLD**

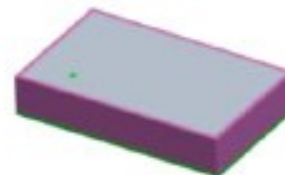
- Initially a suitable size of molding box for creating suitable wall thickness is selected for a two piece pattern. Sufficient care should also be taken in such that sense that the molding box must adjust mold cavity, riser and the gating system (sprue, runner and gates etc.).
- 2. Next, place the drag portion of the pattern with the parting surface down on the bottom (ram-up) board as shown in Fig. 12.6 (a).
- 3. The facing sand is then sprinkled carefully all around the pattern so that the pattern does not stick with molding sand during withdrawn of the pattern.
- 4. The drag is then filled with loose prepared molding sand and ramming of the molding sand is done uniformly in the molding box around the pattern. Fill the molding sand once again and then perform ramming. Repeat the process three four times,



Create Pattern



Place flask over
cope portion of the
pattern



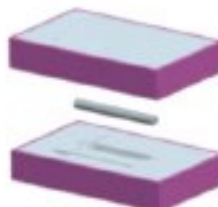
Fill flask with sand and
remove cope pattern



Place flask over
drag portion of the
pattern



Fill flask with sand and
remove drag pattern



Assemble core in the
mold and assemble
the cope and drag



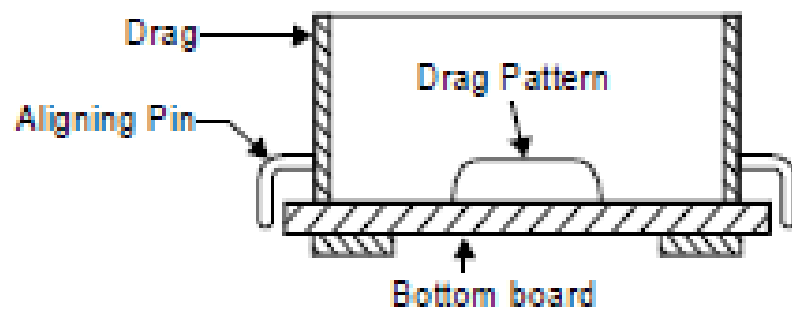
Pour metal into mold



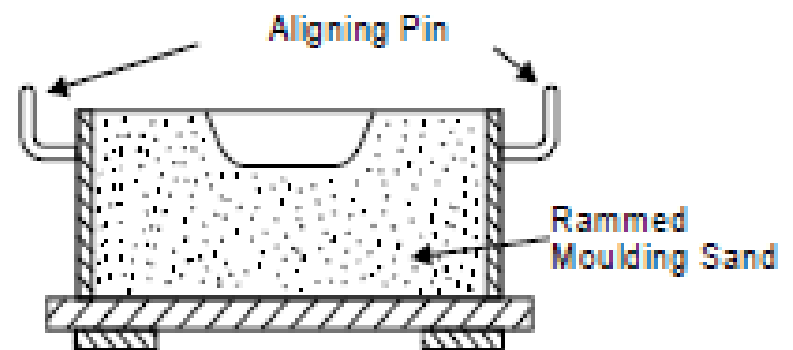
Shakeout mold and
trim off gating system

- 
- 5. The excess amount of sand is then removed using strike off bar to bring molding sand at the same level of the molding flask height to complete the drag.
 - 6. The drag is then rolled over and the parting sand is sprinkled over on the top of the drag
 - 7. Now the cope pattern is placed on the drag pattern and alignment is done using dowel pins.
 - 8. Then cope (flask) is placed over the rammed drag and the parting sand is sprinkled all around the cope pattern.

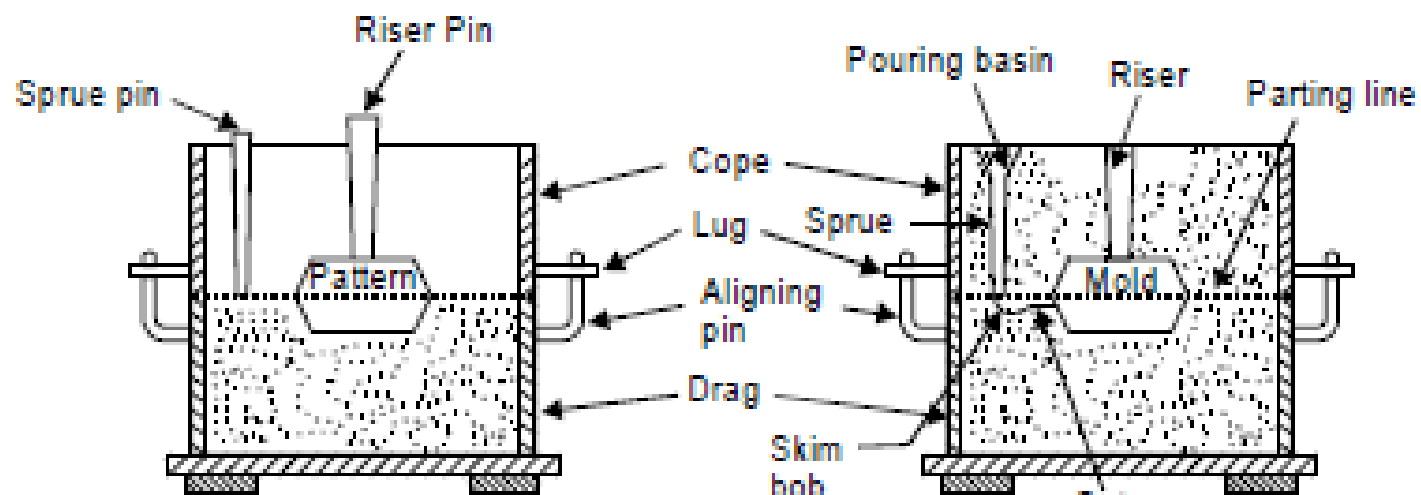
- Sprue and riser pins are placed in vertically position at suitable locations using support of molding sand. It will help to form suitable sized cavities for pouring molten metal etc. [Fig. (c)].
- 10. The gagers in the cope are set at suitable locations if necessary. They should not be located too close to the pattern or mold cavity otherwise they may chill the casting and fill the cope with molding sand and ram uniformly.
- 11. Strike off the excess sand from the top of the cope.
- 12. Remove sprue and riser pins and create vent holes in the cope with a vent wire.
- The basic purpose of vent creating vent holes in cope is to permit the escape of gases generated during pouring and solidification of the casting.
- 13. Sprinkle parting sand over the top of the cope surface and roll over the cope on the bottom board.
- 14. Rap and remove both the cope and drag patterns and repair the mold suitably if needed and dressing is applied
- 15. The gate is then cut connecting the lower base of sprue basin with runner and then the mold cavity.
- 16. Apply mold coating with a swab and bake the mold in case of a dry sand mold.
- 17. Set the cores in the mold, if needed and close the mold by inverting cope over drag.
- 18. The cope is then clamped with drag and the mold is ready for pouring,



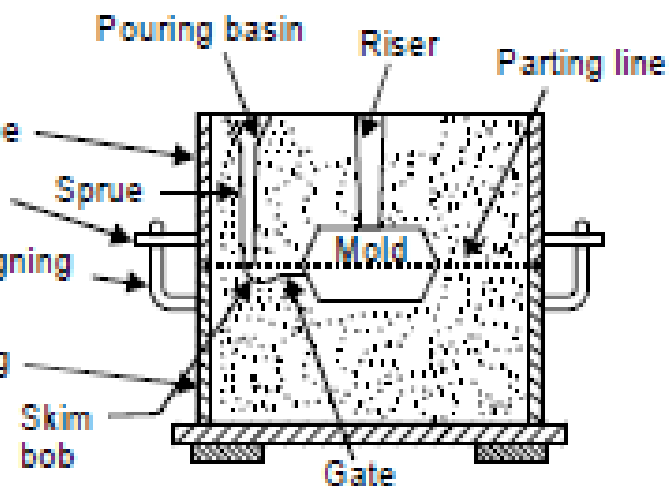
(a)



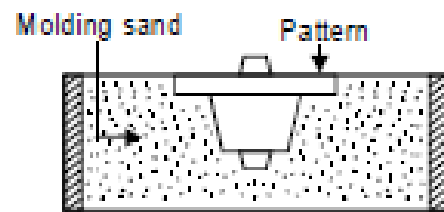
(b)



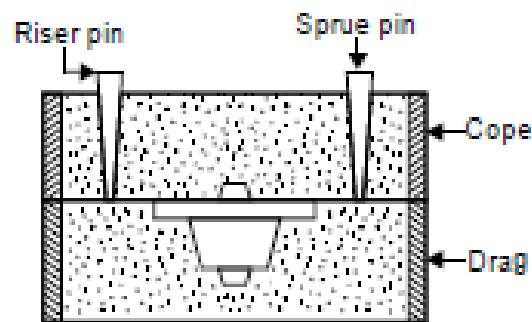
(c)



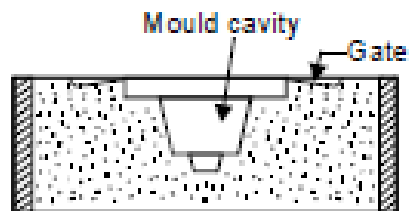
(d)



(a)



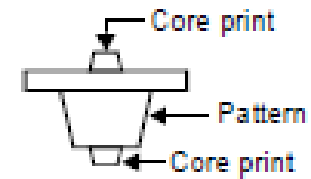
(b)



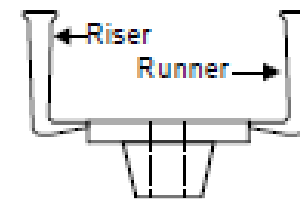
(c)



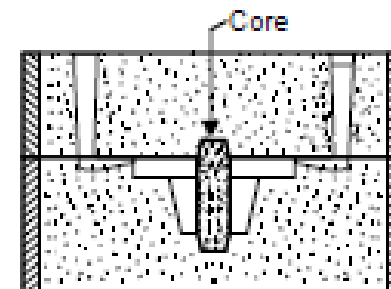
(i) Required casting



(ii) Pattern to be used



(iii) Casting after being knocked out



(d)



Cores and Core Making

Core

- Cores are compact mass of core sand (special kind of molding sand) prepared separately that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting.
- The environment in which the core is placed is much different from that of the mold. In fact the core has to withstand the severe action of hot metal which completely surrounds it.
- They may be of the type of green sand core and dry sand core.
- Therefore the core must meet the following functions or objectives which are given as under.

- 
1. Core produces hollowness in castings in form of internal cavities.
 2. It must be sufficiently permeable to allow the easy escape of gases during pouring and solidification.
 3. It may form a part of green sand mold
 4. It may be deployed to improve mold surface.
 5. It may provide external under cut features in casting.
 6. It may be inserted to achieve deep recesses in the casting.
 7. It may be used to strengthen the mold.
 8. It may be used to form gating system of large size mold.

CORE SAND

- It is special kind of molding sand. Keeping the above mentioned objectives in view, the special considerations should be given while selecting core sand. Those considerations involves
- (i) The cores are subjected to a very high temperature and hence the core sand should be highly refractory in nature
- (ii) The permeability of the core sand must be sufficiently high as compared to that of the molding sands so as to allow the core gases to escape through the limited area of the core recesses generated by core prints
- (iii) The core sand should not possess such materials which may produce gases while they come in contact with molten metal and
- (iv) The core sand should be collapsible in nature, i.e. it should disintegrate after the metal solidifies, because this property will ease the cleaning of the casting.

- 
- The main constituents of the core sand are pure silica sand and a binder. Silica sand is preferred because of its high refractoriness. For higher values of permeability sands with coarse grain size distribution are used.
 - The main purpose of the core binder is to hold the grains together, impart strength and sufficient degree collapsibility.
 - Beside these properties needed in the core sand, the binder should be such that it produces minimum amount of gases when the molt metal is poured in the mould.
 - Although, in general the binder are inorganic as well as organic ones, but for core making, organic binders are generally preferred because they are combustibile and can be destroyed by heat at higher temperatures thereby giving sufficient collapsibility to the core sand.

CORE AND CORE BOX

- Cores are compact mass of core sand that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting.
- The environment in which the core is placed is much different from that of the mold. In fact the core (Fig.) has to withstand the severe action of hot metal which completely surrounds it.
- Cores are classified according to shape and position in the mold.

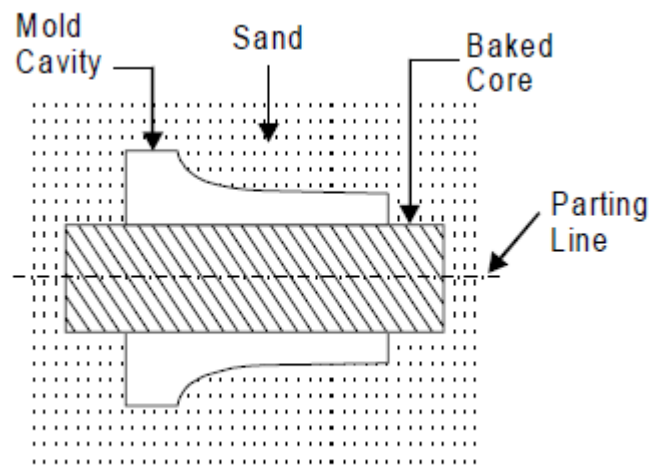


Fig. 10.12 Horizontal core

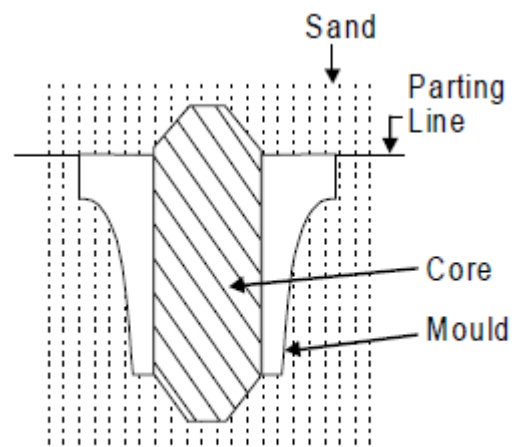


Fig. 10.14 Balanced core

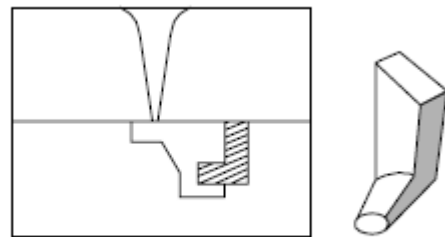


Fig. 10.15 Drop core

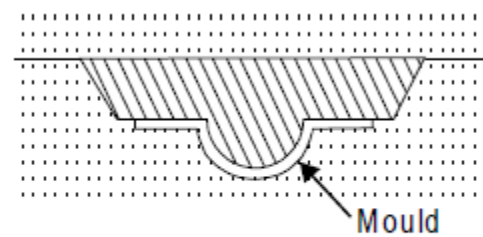


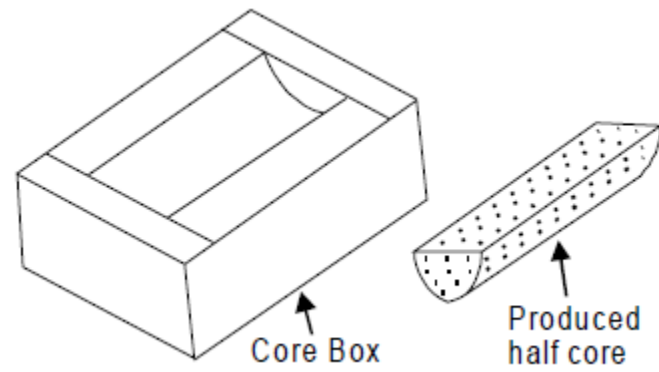
Fig. 10.16 Hanging core

Core box

- Cores are made by means of core boxes comprising of either single or in two parts.
- Core boxes are generally made of wood or metal and are of several types.
- The main types of core box are half core box, dump core box, split core box, strickle core box, right and left hand core box and loose piece core box.

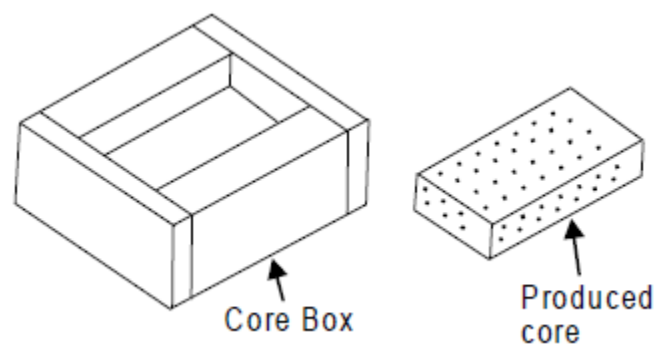
- **Half core box**

- This is the most common type of core box. The two identical halves of a symmetrical core prepared in the half core box are shown in Fig.
- Two halves of cores are pasted or cemented together after baking to form a complete core.



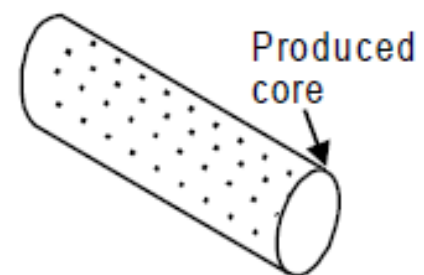
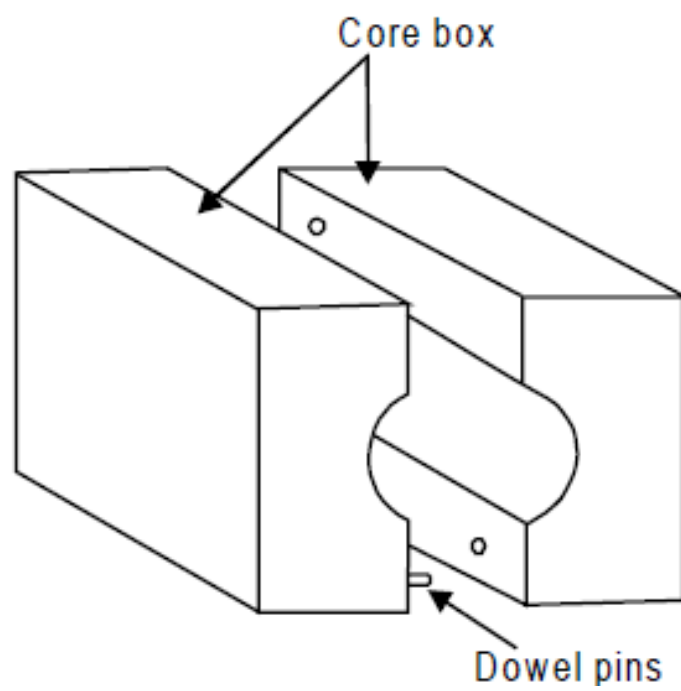
- **Dump core box**

- Dump core box is similar in construction to half core box as shown in Fig. .
- The cores produced do not require pasting, rather they are complete by themselves.
- If the core produced is in the shape of a slab, then it is called as a slab box or a rectangular box.
- A dump core-box is used to prepare complete core in it. Generally cylindrical and rectangular cores
- are prepared in these boxes.



- **Split core box**

- Split core boxes are made in two parts as shown in Fig. 10.19. They form the complete
- core by only one ramming.
- The two parts of core boxes are held in position by means of clamps and their alignment is maintained by means of dowel pins and thus core is produced.

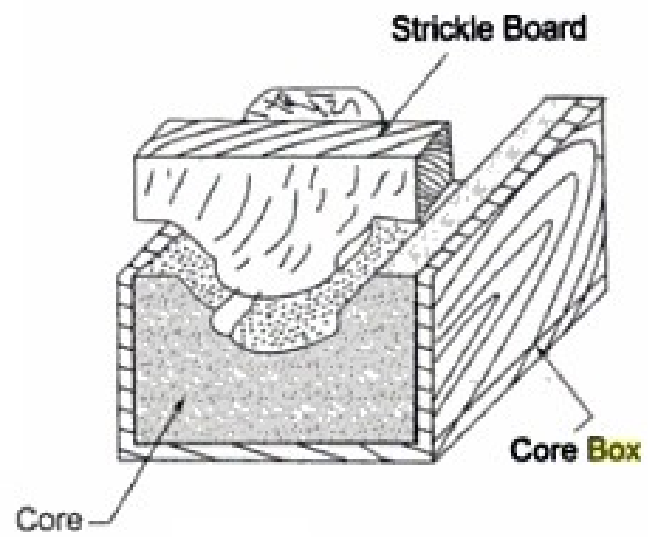


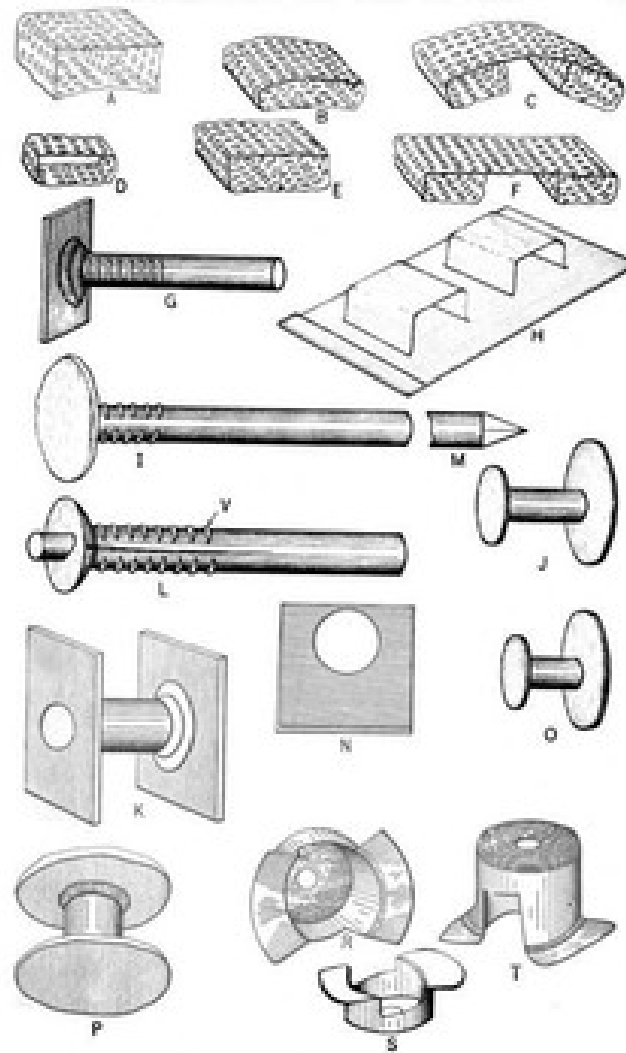
- **Right and left hand core box**

- Some times the cores are not symmetrical about the center line. In such cases, right and left hand core boxes are used.
- The two halves of a core made in the same core box are not identical and they cannot be pasted together.

- **Strickle core box**

- This type of core box is used when a core with an irregular shape is desired. The
- required shape is achieved by striking off the core sand from the top of the core box with a wooden piece, called as strickle board.
- The strickle board has the same contour as that of the required core.





- **CORE BOX ALLOWANCES**

- Materials used in making core generally swell and increase in size. This may lead to
- increase the size of core.
- The larger cores sometimes tend to become still larger.
- This increase in size may not be significant in small cores, but it is quite significant in large cores and therefore certain amount of allowance should be given on the core boxes to compensate for this increase the cores.
- It is not possible to lay down a rule for the amount of this allowance as this will depend upon the material used, but it is customary to give a negative allowance of 5 mm /mt.

CORE MAKING

- Core making basically is carried out in four stages namely
- **core sand preparation,**
- **core making,**
- **core baking and**
- **core finishing.**

- **Core Sand Preparation**

- Preparation of satisfactory and homogenous mixture of core sand is not possible by manual means.
- Therefore for getting better and uniform core sand properties using proper sand constituents and additives, the core sands are generally mixed with the help of any of the following mechanical means namely roller mills and core sand mixer using vertical revolving arm type and horizontal paddle type mechanisms.
- In the case of roller mills, the rolling action of the mulling machine along with the turning over action caused by the ploughs gives a
- uniform and homogeneous mixing.
- Roller mills are suitable for core sands containing cereal binders, whereas the core sand mixer is suitable for all types of core binders.
- These machines perform the mixing of core sand constituents most thoroughly.



- # Core Making Process

- Core blowing machines
- The basic principle of core blowing machine comprises of filling the core sand into the
- core box by using compressed air. The velocity of the compressed air is kept high to obtain
- a high velocity of core sand particles, thus ensuring their deposit in the remote corners the
- core box.

- **Core ramming machines**

- Cores can also be prepared by ramming core sands in the core boxes by machines based on the principles of squeezing, jolting and slinging. Out of these three machines, jolting and slinging are more common for core making.

- **Core drawing machines**

- The core drawing is preferred when the core boxes have deep draws. After ramming sand in it, the core box is placed on a core plate supported on the machine bed.
- A rapping action on the core box is produced by a vibrating vertical plate. This rapping action helps in drawing off the core from the core box.
- After rapping, the core box, the core is pulled up thus leaving the core on the core plate.

- **Core baking**

- Once the cores are prepared, they will be baked in a baking ovens or furnaces.
- The main purpose of baking is to drive away the moisture and hard en the binder, thereby giving strength to the core.
- The core drying equipment's are usually of two kinds namely core ovens and dielectric bakers.

- **Continuous type ovens**

- Continuous type ovens are preferred basically for mass production. In these types, core carrying conveyors or chain move continuously through the oven.
- The baking time is controlled by the speed of the conveyor.
- The continuous type ovens are generally used for baking of small cores.

- **Batch type ovens**

- Batch type ovens are mainly utilized for baking variety of cores in batches.
- The cores are commonly placed either in drawers or in racks which are finally placed in the ovens.
- The core ovens and dielectric bakers are usually fired with gas, oil or coal.

- **Dielectric bakers**

- These bakers are based on dielectric heating. The core supporting plates are not used in this baker because they interfere with the potential distribution in the electrostatic field.
- To avoid this interference, cement bonded asbestos plates may be used for supporting the cores.
- The main advantage of these ovens is that they are faster in operation and a good temperature control is possible with them.
- After baking of cores, they are smoothened using dextrin and water soluble binders.

- **CORE FINISHING**

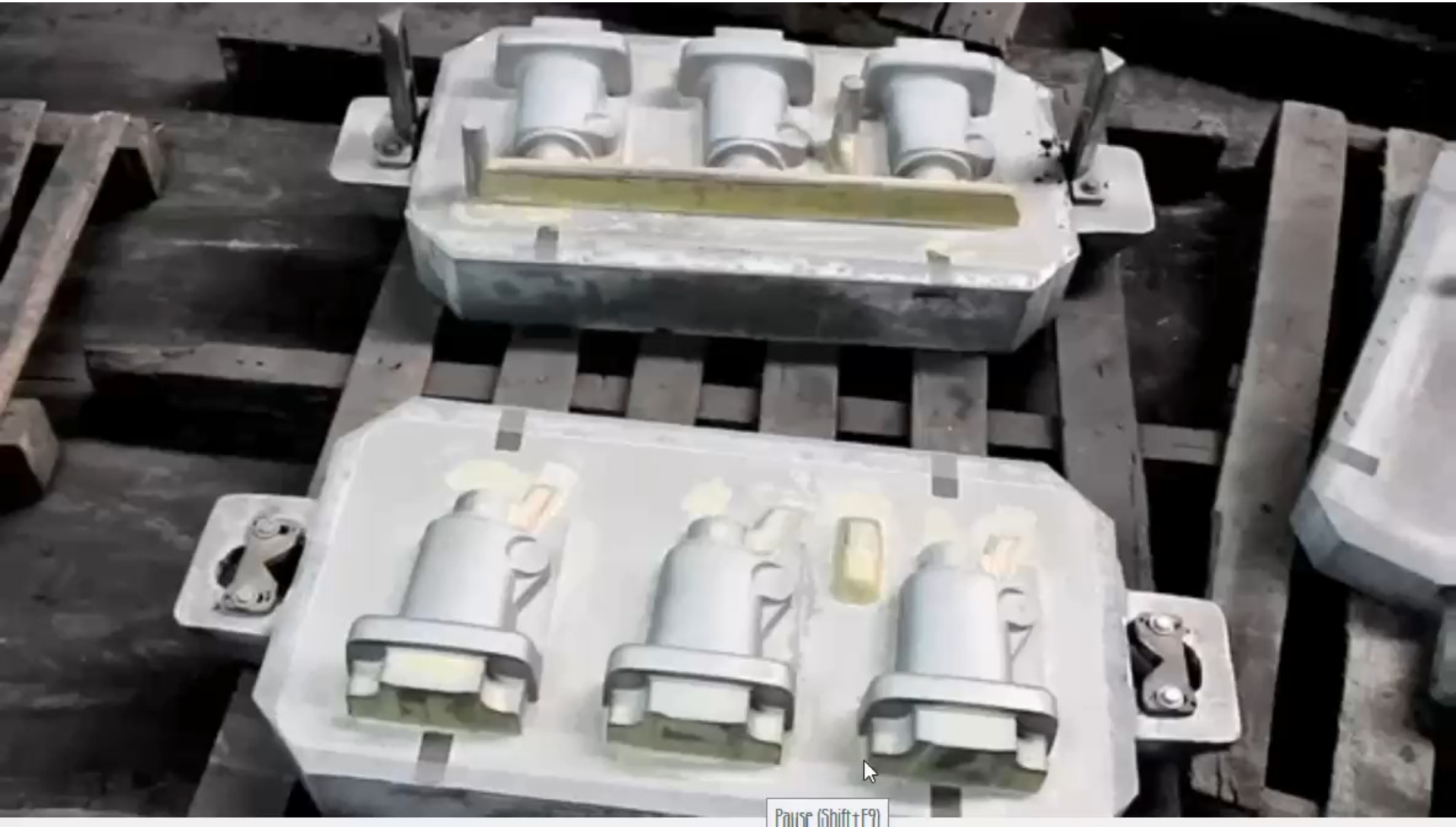
- The cores are finally finished after baking and before they are finally set in the mould. The fins, bumps or other sand projections are removed from the surface of the cores by rubbing or filing.
- The dimensional inspection of the cores is very necessary to achieve sound casting.
- Cores are also coated with refractory or protective materials using brushing dipping and spraying means to improve their refractoriness and surface finish.
- The coating on core prevents the molten metal from entering in to the core.
- Bars, wires and arbors are generally used to reinforce core from inside as per size of core using core sand. For handling bulky cores, lifting rings are also provided.

Molding m/cs

- **Moulding Machines**

- Molding machine acts as a device by means of a large number of co-related parts and mechanisms, transmits and directs various forces and motions in required directions so as to help the preparation of a sand mould.
- The major functions of molding machines involves ramming of molding sand, rolling over or inverting the mould, rapping the pattern and withdrawing the pattern from the mould.
- Most of the molding machines perform a combination of two or more of functions. However, ramming of sand is the basic function of most of these machines.
- Use of molding machine is advisable when large number of repetitive castings is to be produced as hand molding may be tedious, time consuming, laborious and expensive comparatively.

Video



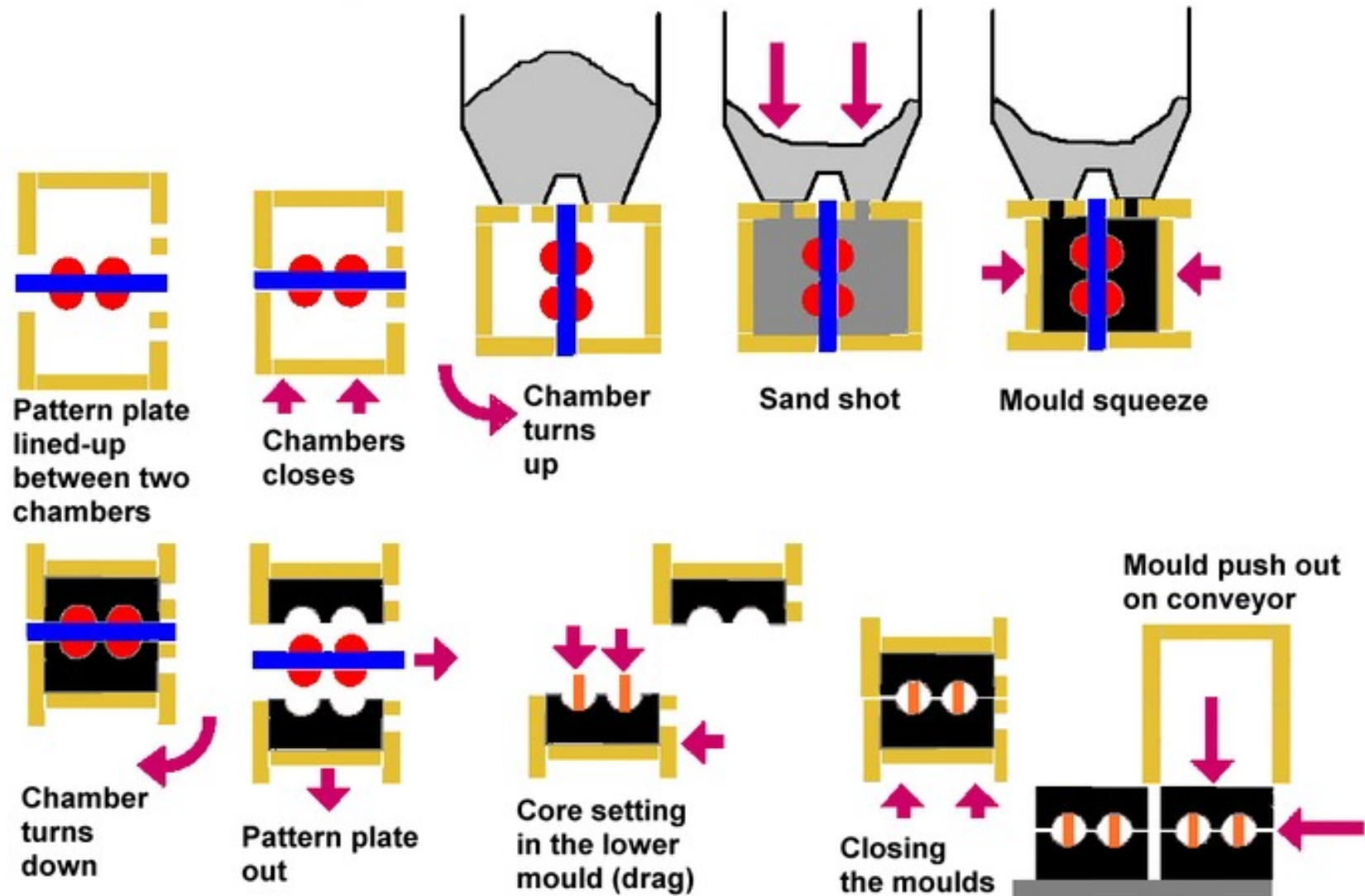
Pause (Shift+F9)



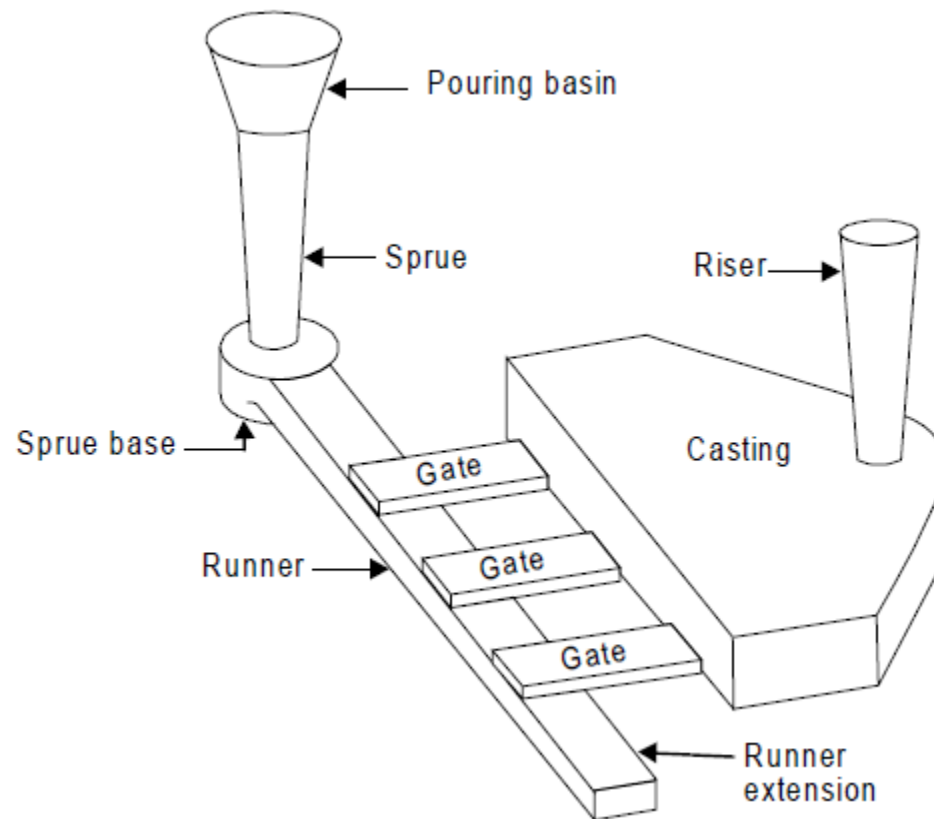
• **Squeezer machine**

- These machines may be hand operated or power operated.
- The pattern is placed over the machine table, followed by the molding box. In hand-operated machines, the platen is lifted by hand operated mechanism.
- In power machines, it is lifted by the air pressure on a piston in the cylinder in the same way as in jolt machine. The table is raised gradually.
- The sand in the molding box is squeezed between plate and the upward rising table thus enabling a uniform pressing of sand in the molding box.
- The main advantage of power operated machines in comparison hand operated machines is that more pressure can be applied in power operated.

DISAs MATCH-PLATE SAND MOULDING PRINCIPLE



GATING SYSTEM IN MOLD



Parts of Gating Systems

- **1. Pouring basin**

- It is the conical hollow element or tapered hollow vertical portion of the gating system which helps to feed the molten metal initially through the path of gating system to mold cavity.

- **2. Sprue**

- It is a vertical passage made generally in the cope using tapered sprue pin. It is connected at bottom of pouring basin.
- It is tapered with its bigger end at to receive the molten metal the smaller end is connected to the runner.
- It helps to feed molten metal without turbulence to the runner which in turn reaches the mold cavity through gate.

- **3. Gate**

- It is a small passage or channel being cut by gate cutter which connect runner with the mould cavity and through which molten metal flows to fill the mould cavity.
- It feeds the liquid metal to the casting at the rate consistent with the rate of solidification.

- **4. Choke**

- It is that part of the gating system which possesses smallest cross section area. In choked system, gate serves as a choke, but in free gating system sprue serves as a choke.

- **5. Runner**

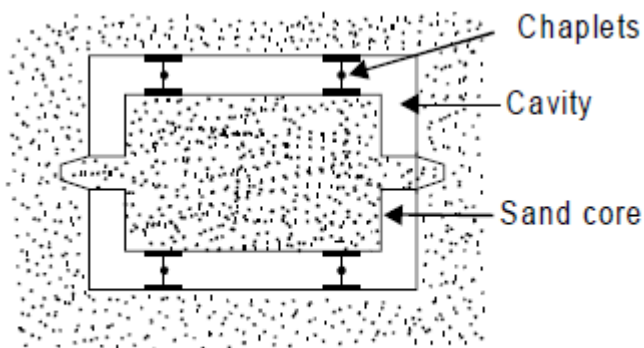
- It is a channel which connects the sprue to the gate for avoiding turbulence and gas entrapment.

- **6. Riser**

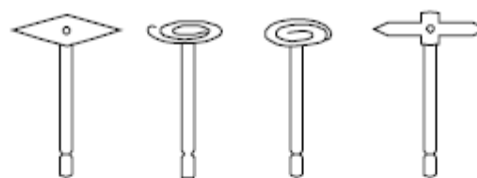
- **It is a passage in molding sand made in the cope portion of the mold. Molten metal rises in it after filling the mould cavity completely.**
- **The molten metal in the riser compensates the shrinkage during solidification of the casting thus avoiding the shrinkage defect in the casting.**
- **It also permits the escape of air and mould gases. It promotes directional solidification too.**

• 7. Chaplets

- Chaplets are metal distance pieces inserted in a mould either to prevent shifting of mould or locate core surfaces.
- The distance pieces in form of chaplets are made of parent metal of which the casting is.
- Its main objective is to impart good alignment of mould and core surfaces and to achieve directional solidification.



Use of chaplets to support a core



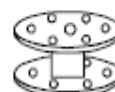
Radiator chaplets



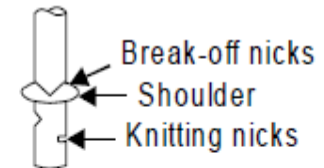
Riveted chaplet

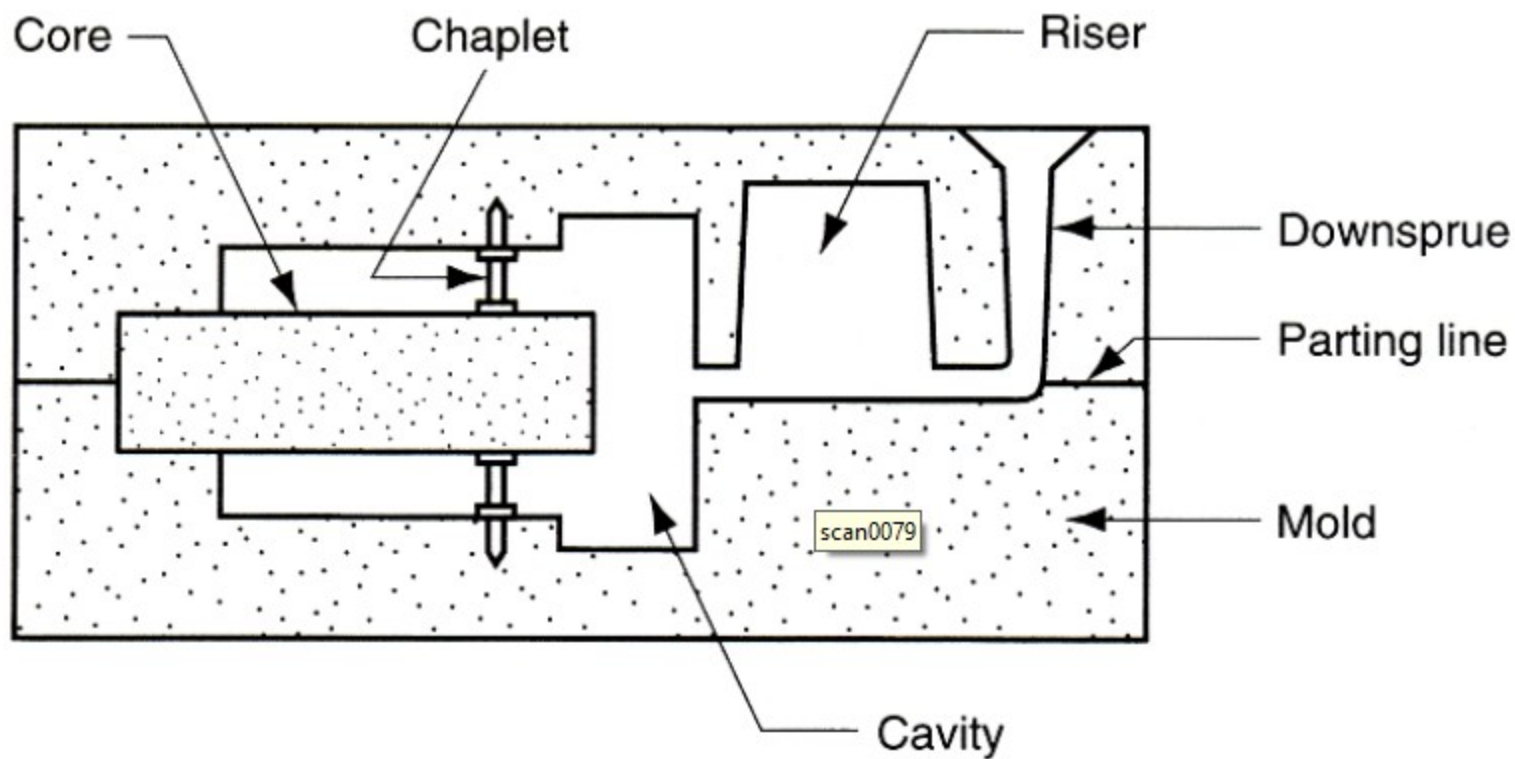


Welded chaplet



Double-head chaplets

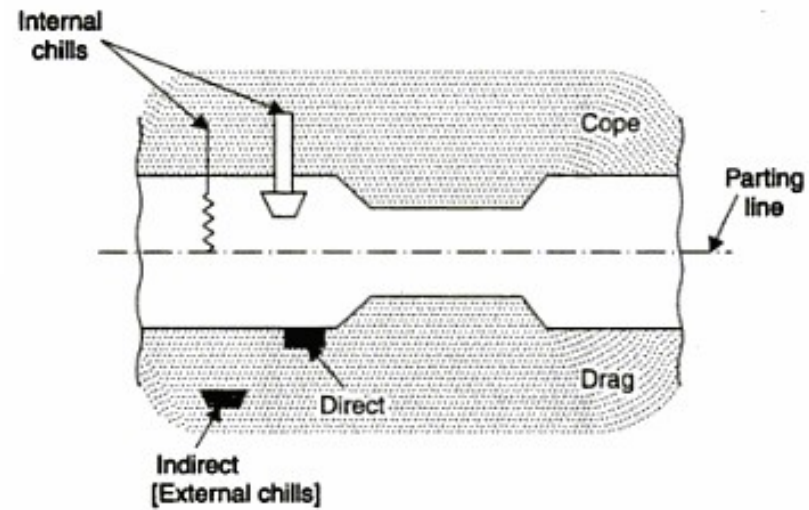
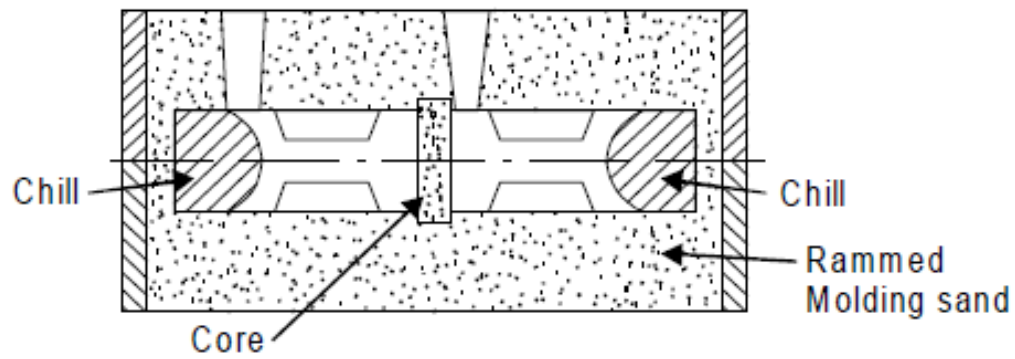
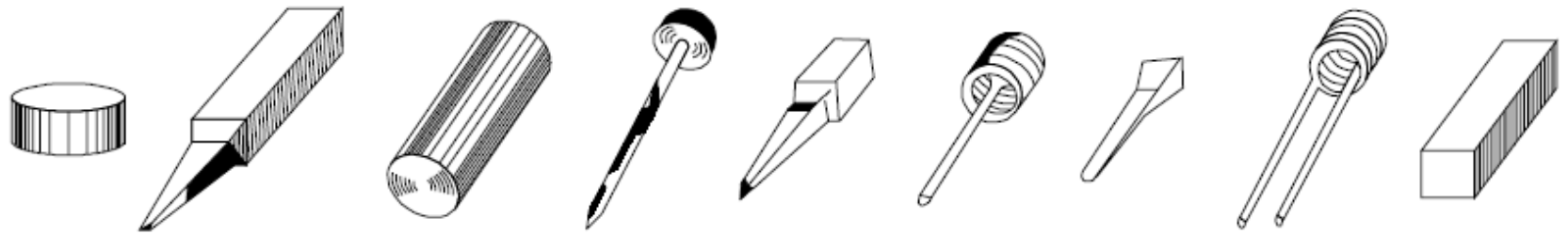






• 8. Chills

- In some casting, it is required to produce a hard surface at a particular place in the casting.
- At that particular position, the special mould surface for fast extraction of heat is to be made.
- The fast heat extracting metallic materials known as chills will be incorporated separately along with sand mould surface during molding.
- After pouring of molten metal and during solidification, the molten metal solidifies quickly on the metallic mould surface in comparison to other mold sand surfaces. This imparts hardness to that particular surface because of this special hardening treatment through fast extracting heat from that particular portion.



FACTORS CONTROLLING GATING DESIGN

- The following factors must be considered while designing gating system.
- (i)** Sharp corners and abrupt changes in at any section or portion in gating system should be avoided for suppressing turbulence and gas entrapment. Suitable relationship must exist between different cross-sectional areas of gating systems.
- (ii)** The most important characteristics of gating system besides sprue are the shape, location and dimensions of runners and type of flow. It is also important to determine the position at which the molten metal enters the mould cavity.
- (iii)** Gating ratio should reveal that the total cross-section of sprue, runner and gate decreases towards the mold cavity which provides a choke effect.
- (iv)** Bending of runner if any should be kept away from mold cavity.
- (v)** Developing the various cross sections of gating system to nullify the effect of turbulence or momentum of molten metal.
- (vi)** Streamlining or removing sharp corners at any junctions by providing generous radius, tapering the sprue, providing radius at sprue entrance

ROLE OF RISER IN SAND CASTING

- Metals and their alloys shrink as they cool or solidify and hence may create a partial vacuum within the casting which leads to casting defect known as shrinkage or void.
- The primary function of riser as attached with the mould is to feed molten metal to accommodate shrinkage occurring during solidification of the casting.
- As shrinkage is very common casting defect in casting and hence it should be avoided by allowing molten metal to rise in riser after filling the mould cavity completely and supplying the molten metal to further feed the void occurred during solidification of the casting because of shrinkage.
- Riser also permits the escape of evolved air and mold gases as the mold cavity is being filled with the molten metal.
- It also indicates to the foundry man whether mold cavity has been filled completely or not. The suitable design of riser also helps to promote the **directional solidification** and hence helps in production of desired sound casting.

• Considerations for Designing Riser

- **Freezing time**
- 1 For producing sound casting, the molten metal must be fed to the mold till it solidifies completely. This can be achieved when molten metal in riser should freeze at slower rate than the casting.
- Freezing time of molten metal should be more for risers than casting. The quantitative risering analysis developed by Caine and others can be followed while designing risers.
- **Feeding range**
- 1. When large castings are produced in complicated size, then more than one riser are employed to feed molten metal depending upon the effective freezing range of each riser.
- 2. Casting should be divided into divided into different zones so that each zone can be feed by a separate riser.
- 3. Risers should be attached to that heavy section which generally solidifies last in the casting.
- 4. Riser should maintain proper temperature gradients for continuous feeding throughout freezing or solidifying.

- **Feed Volume Capacity**

- 1 Riser should have sufficient volume to feed the mold cavity till the solidification of the entire casting so as to compensate the volume shrinkage or contraction of the solidifying metal.
- 2 The metal is always kept in molten state at all the times in risers during freezing of casting. This can be achieved by using exothermic compounds and electric arc feeding arrangement. Thus it results for small riser size and high casting yield.
- 3 It is very important to note that volume feed capacity riser should be based upon freezing time and freezing demand.

- Optimum Riser Design

- In the right amount
- At the right place
- At the right time

- **Problems on riser design**

- Risers are used to compensate for liquid shrinkage and solidification shrinkage. But it only works if the riser cools after the rest of the casting.
- Height of cylindrical riser=1.5x Diameter of riser
- Shapes of riser-cylindrical, rectangular, spherical
- **Chvorinov's rule** states that the solidification time t of molten metal is related to the constant C (which depends on the thermal properties of the mold and the material) and the local volume (V) and surface area (A) of the material, according to the relationship

$$t = C \times \left(\frac{V}{A} \right)^2 .$$

Caine's rule

$$X = \frac{SA_{\text{casting}} / V_{\text{casting}}}{SA_{\text{riser}} / V_{\text{riser}}}$$

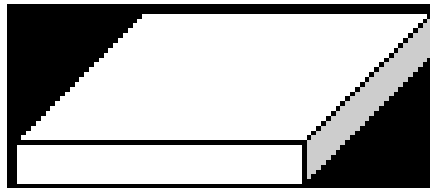
$$X = \{ a / Y - b \} + c$$

Material	a	b	c
Steel	0.10	0.03	1.00
Aluminium	0.10	0.06	1.08
Cast iron, Brass	0.04	0.017	1.00
Grey cast iron	0.33	0.030	1.00
Aluminium bronze	0.24	0.017	1.00
Silicon bronze	0.24	0.017	1.00

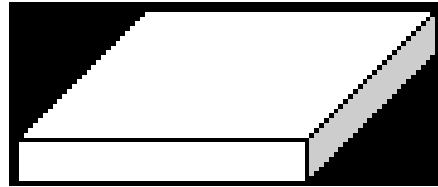


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- In the casting of steel under certain mold conditions, the mold constant in Chvorinov's Rule is known to be 4.0 min/cm^2 , based on previous experience. The casting is a flat plate whose length = 30 cm, width = 10 cm, and thickness = 20 mm. Determine how long it will take for the casting to solidify.

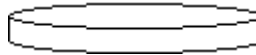


SOLUTION



- $20 \text{ mm} = 2 \text{ cm}$
- Volume $V = 30 \times 10 \times 2 = 600 \text{ cm}^3$
- Area $A = 2(30 \times 10 + 30 \times 2 + 10 \times 2) = 760 \text{ cm}^2$
- Chvorinov's Rule: $T_{TS} = C_m (V/A)^2 = 4(600/760)^2 = \mathbf{2.493 \text{ min}}$

- A disk-shaped part is to be cast out of aluminum. The diameter of the disk = 500 mm and its thickness = 20 mm. If the mold constant = 2.0 sec/mm² in Chvorinov's Rule, how long will it take the casting to solidify?



- **Solution:**
 - **Units are all in sec and mm.**
 - **$R = D/2$**
 - **Volume $V = \pi R^2 t = \pi D^2 t / 4 = \pi(500)^2(20)/4 = 3,926,991 \text{ mm}^3$**
- Area $A = 2(\pi R^2) + \pi D t = 2\pi D^2/4 + \pi D t = \pi(500)^2/2 + \pi(500)(20) = 424,115 \text{ mm}^2$**
- **Chvorinov's Rule: $T_{TS} = C_m (V/A)^2 = 2.0(3,926,991/424,115)^2 = 171.5 \text{ s} = 2.86 \text{ min}$**

- In casting experiments performed using a certain alloy and type of sand mold, it took 155 sec for a cube-shaped casting to solidify. The cube was 50 mm on a side.
(a) Determine the value of the mold constant the mold constant in Chvorinov's Rule. (b) If the same alloy and mold type were used, find the total solidification time for a cylindrical casting in which the diameter = 30 mm and length = 50 mm.

- **Solution:**

-
- (a) Volume $V = (50)^3 = 125,000 \text{ mm}^3$
- Area $A = 6 \times (50)^2 = 15,000 \text{ mm}^2$
- $(V/A) = 125,000/15,000 = 8.333 \text{ mm}$
- Chvorinov's Rule: $T_{TS} = C_m (V/A)^2$
- $C_m = T_{TS} / (V/A)^2 = 155 / (8.333)^2 = 2.232 \text{ s/mm}^2$
-
- (b) Cylindrical casting with $D = 30 \text{ mm}$ and $L = 50 \text{ mm}$.
- Volume $V = \pi D^2 L / 4 = \pi (30)^2 (50) / 4 = 35,343 \text{ mm}^3$
- Area $A = 2 \pi D^2 / 4 + \pi D L = \pi (30)^2 / 2 + \pi (30)(50) = 6126 \text{ mm}^2$
- $V/A = 35,343 / 6126 = 5.77$
- Chvorinov's Rule: $T_{TS} = C_m (V/A)^2$
- $T_{TS} = 2.232 (5.77)^2 = 74.3 \text{ s} = 1.24 \text{ min.}$

- 
- Compare the solidification time for casting of different shapes of same volume (cubic, cylindrical and spherical)($d=h$)
 - Cube=0.0277s
 - Cylinder=0.03263s
 - Spherical=0.482 s

MELTING FURNACES

- Before pouring into the mold, the metal to be casted has to be in the molten or liquid state.
- Furnace is used for carrying out not only the basic ore refining process but mainly utilized to melt the metal also.
- A blast furnace performs basic melting (of iron ore) operation to get pig iron, cupola furnace is used for getting cast iron and an electric arc furnace is used for re-melting steel.
- Different furnaces are employed for melting and re-melting ferrous and nonferrous materials.

Factors responsible for the selection of furnace:-

- (i) Considerations of initial cost and cost of its operation.**
- (ii) Relative average cost of repair and maintenance.**
- (iii) Availability and relative cost of various fuels in the particular locality.**
- (iv) Melting efficiency, in particular speed of melting.**
- (v) Composition and melting temperature of the metal.**
- (vi) Degree of quality control required in respect of metal purification of refining,**
- (vii) Cleanliness and noise level in operation.**
- (viii) Personnel choice or sales influence.**

FURNACES FOR MELTING DIFFERENT MATERIALS

Grey Cast Iron

- (a) Cupola**
- (b) Air furnace**
- (c) Rotary furnace**
- (d) Electric arc furnace**

Steel

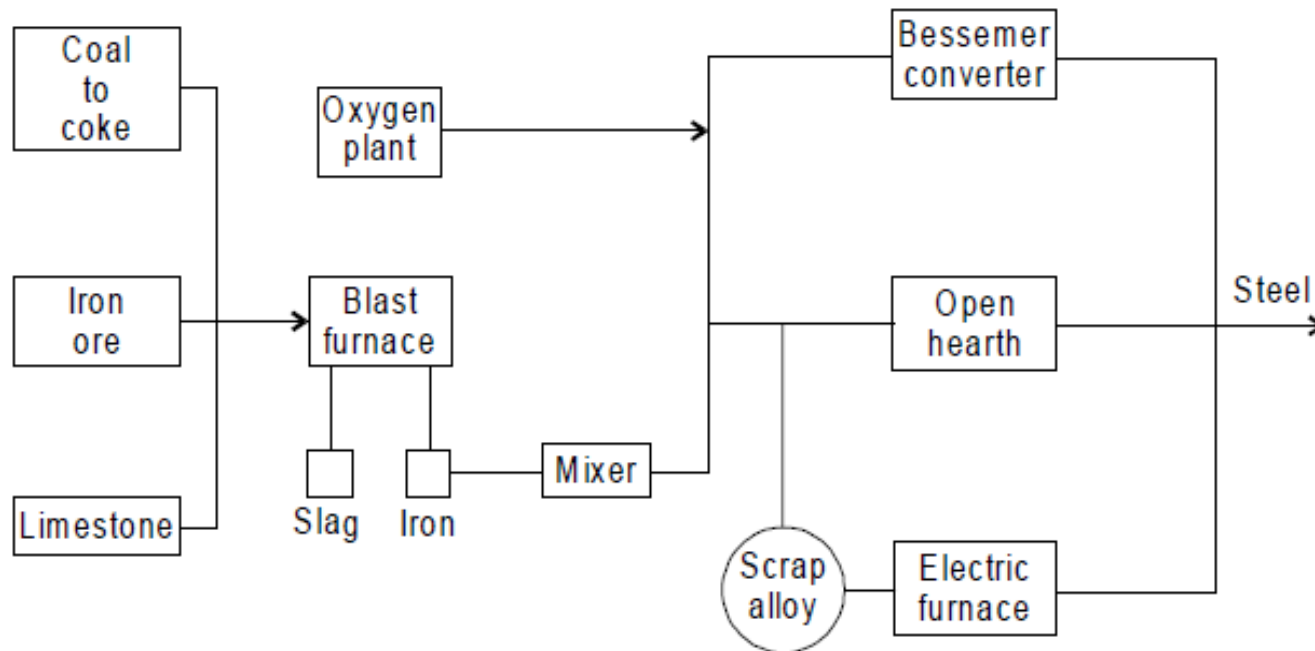
- (a) Electric furnaces**
- (b) Open hearth furnace**

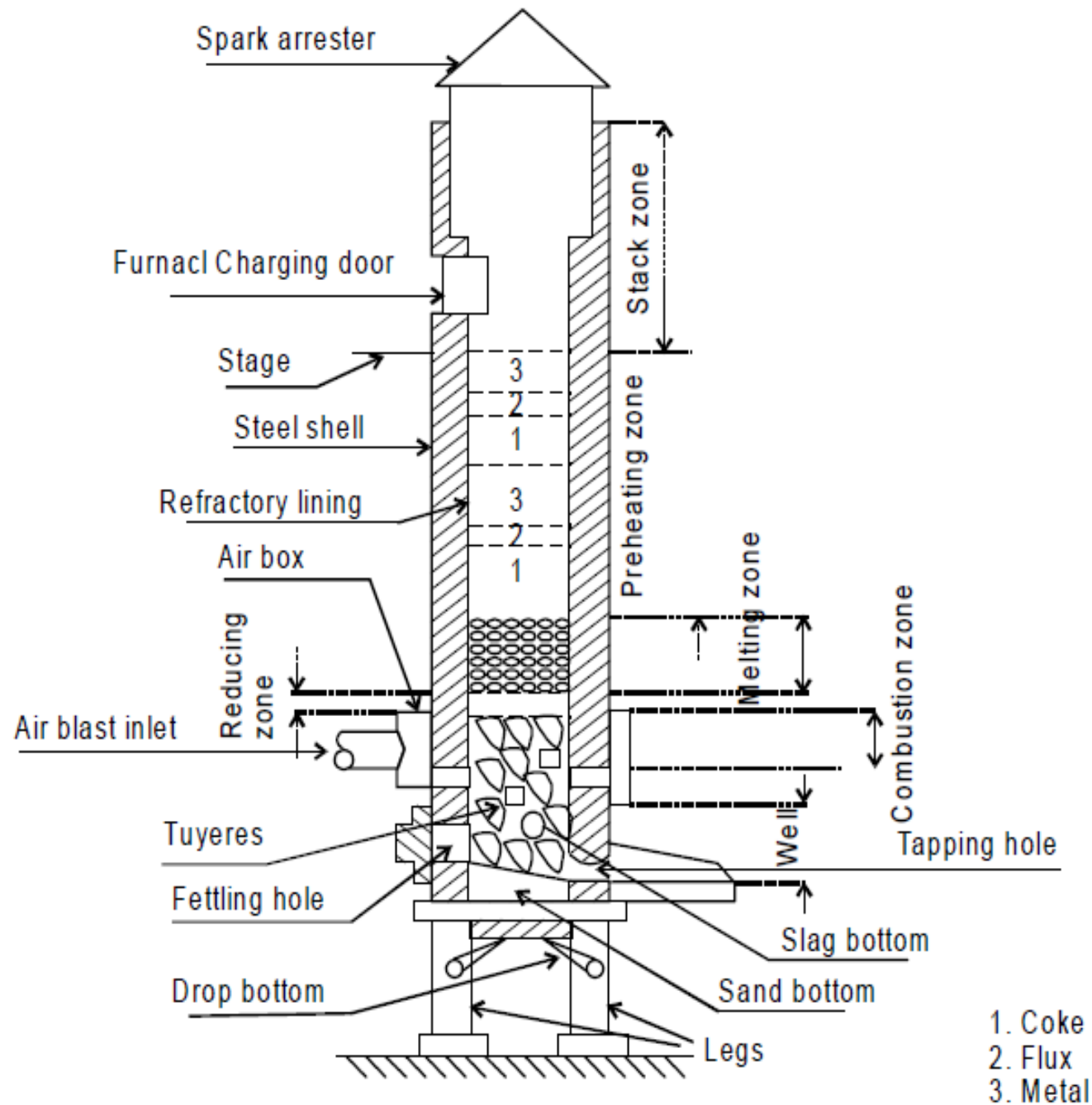
Non-ferrous Metals

- (a) Reverberatory furnaces (fuel fired) (Al, Cu)**
 - (i) Stationary**
 - (ii) Tilting**
- (b) Rotary furnaces**
 - (i) Fuel fired**
 - (ii) Electrically heated**
- (c) Induction furnaces (Cu, Al)**
 - (i) Low frequency**
 - (ii) High frequency.**
- (d) Electric Arc furnaces (Cu)**
- (e) Crucible furnaces (Al, Cu)**
 - (i) Pit type**
 - (ii) Tilting type**
 - (iii) Non-tilting or bale-out type**
- (iv) Electric resistance type (Cu)**
- (f) Pot furnaces (fuel fired) (Mg and Al)**
 - (i) Stationary**
 - (ii) Tilting**

CUPOLA FURNACE

- Cupola furnace is employed for melting scrap metal or pig iron for production of various cast irons.
- It is also used for production of nodular and malleable cast iron.
- It is available in good varying sizes.
- The main considerations in selection of cupolas are melting capacity, diameter of shell without lining or with lining, spark arrester.





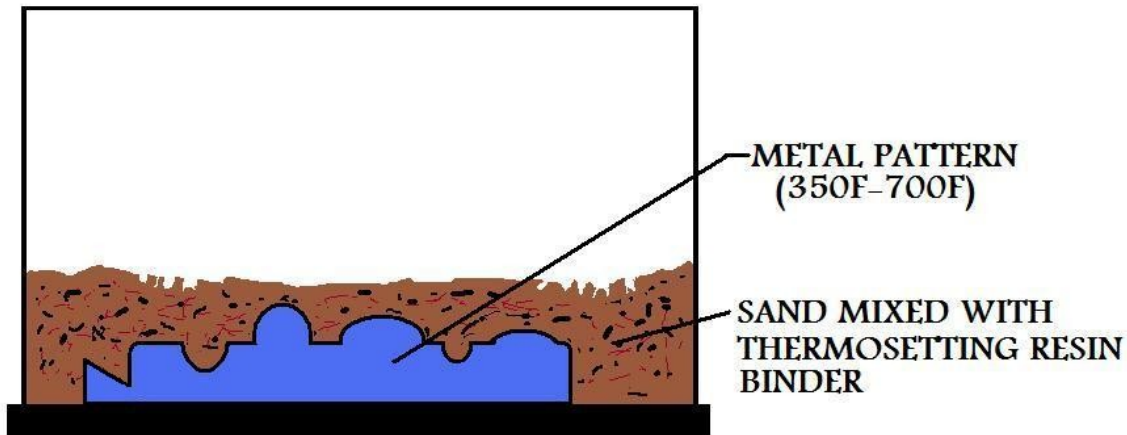
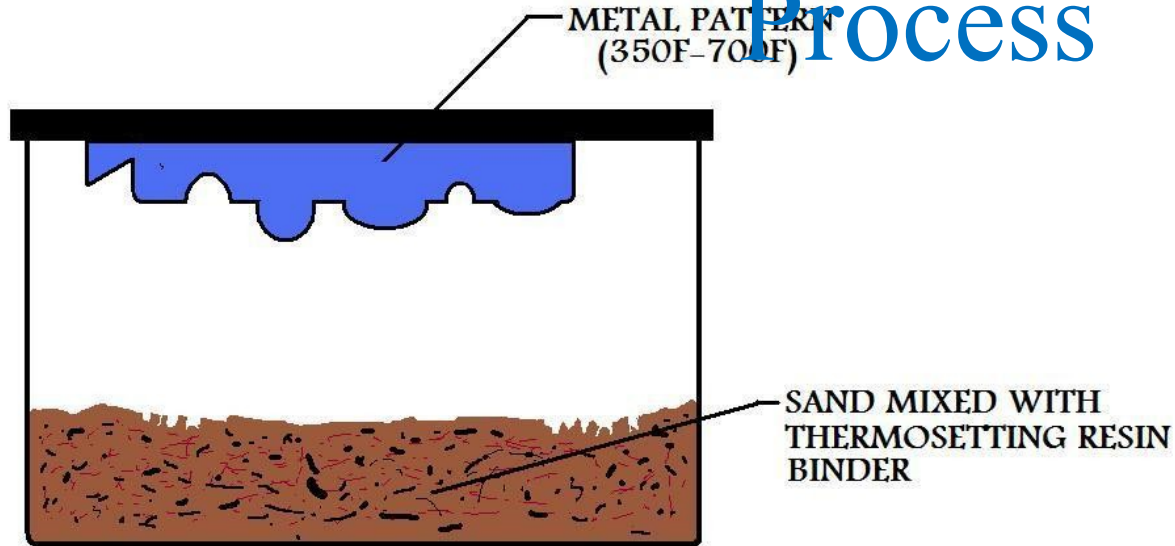


- **Special Casting Processes**

• Shell Mold Casting

- Shell mold casting or shell molding is a metal casting process in manufacturing industry in which the mold is a thin hardened shell of sand and thermosetting resin binder, backed up by some other material.
- Typical parts manufactured in industry using the shell mold casting process include cylinder heads, gears, bushings, connecting rods, camshafts and valve bodies.

Process



METAL PATTERN
(WITH SHELL)

LEFT OVER
SAND MIXED WITH
THERMOSETTING RESIN
BINDER

SHELL AND PATTERN ARE BAKED IN
OVEN TO HARDEN SHELL MOLD

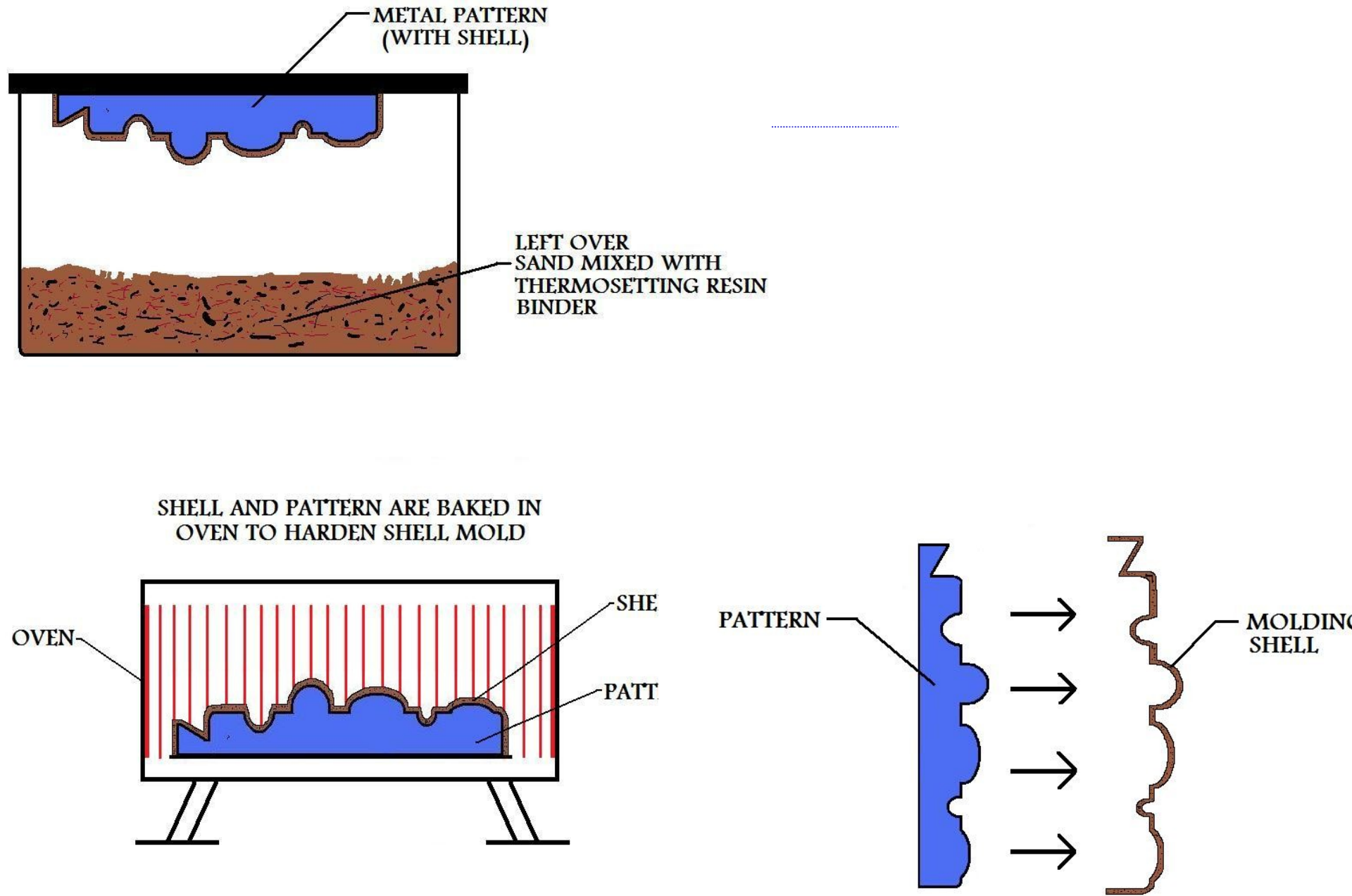
OVEN

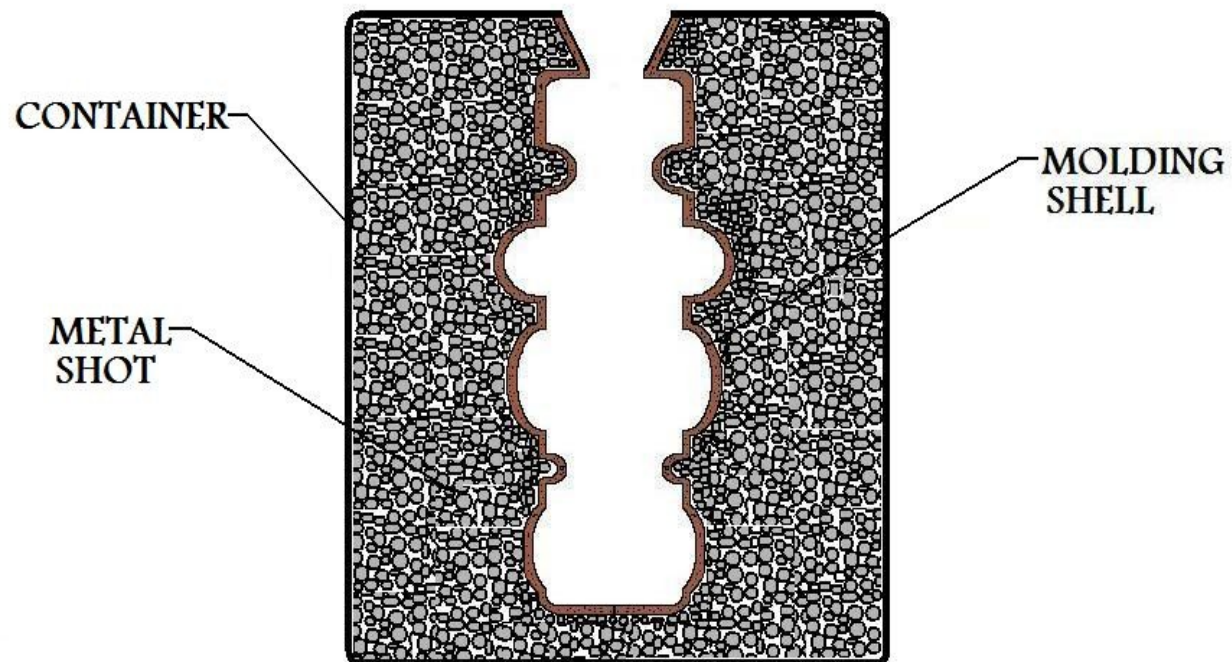
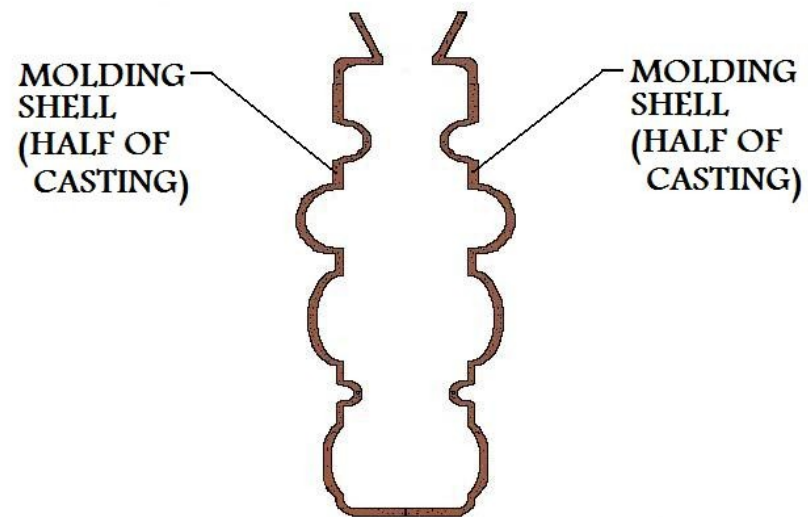
SHE

PATT

PATTERN

MOLDING
SHELL





Properties and Considerations of Manufacturing by Shell Mold Casting

- The internal surface of the shell mold is very smooth and rigid.
- Shell mold casting enables the manufacture of complex parts with thin sections and smaller projections than green sand mold casting.
- Manufacturing with the shell mold 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.
- manufacturing by shell casting may be economical for large batch production.

Investment Casting

- Investment casting is one of the oldest manufacturing processes, dating back thousands of years, in which molten metal is poured into an expendable ceramic mold.
- The mold is formed by using a wax pattern - a disposable piece in the shape of the desired part. The pattern is surrounded, or "invested", into ceramic slurry that hardens into the mold.
- Investment casting is often referred to as "lost-wax casting" because the wax pattern is melted out of the mold after it has been formed.
- However, since the mold is destroyed during the process, parts with complex geometries and intricate details can be created

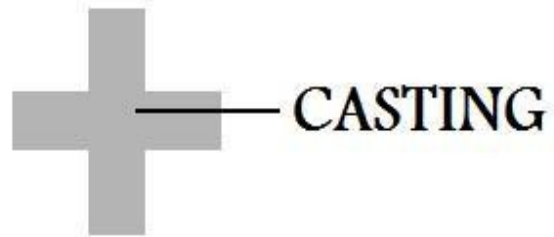
- Investment casting can make use of most metals, most commonly using aluminum alloys, bronze alloys, magnesium alloys, cast iron, stainless steel, and tool steel
- This process is beneficial for casting metals with high melting temperatures that can not be molded in plaster or metal.
- Parts that are typically made by investment casting include those with complex geometry such as turbine blades or firearm components.

- 
- Investment casting requires the use of a metal die, wax, ceramic slurry, furnace, molten metal, and any machines needed for sandblasting, cutting, or grinding. The process steps include the following:

Process

- ***Pattern creation*** - The wax patterns are typically injection molded into a metal die and are formed as one piece. Cores may be used to form any internal features on the pattern.
- ***Mold creation*** - This "pattern tree" is dipped into a slurry of fine ceramic particles, coated with more coarse particles, and then dried to form a ceramic shell around the patterns and gating system. This process is repeated until the shell is thick enough to withstand the molten metal it will encounter.

INVESTMENT CASTING
FINAL PRODUCT





- The shell is then placed into an oven and the wax is melted out leaving a hollow ceramic shell that acts as a one-piece mold, hence the name "lost wax" casting.
- *Pouring* - The mold is preheated in a furnace to approximately 1000°C (1832°F) and the molten metal is poured from a ladle into the gating system of the mold, filling the mold cavity..
- *Cooling* - After the mold has been filled, the molten metal is allowed to cool and solidify into the shape of the final casting. Cooling time depends on the thickness of the part, thickness of the mold, and the material used.

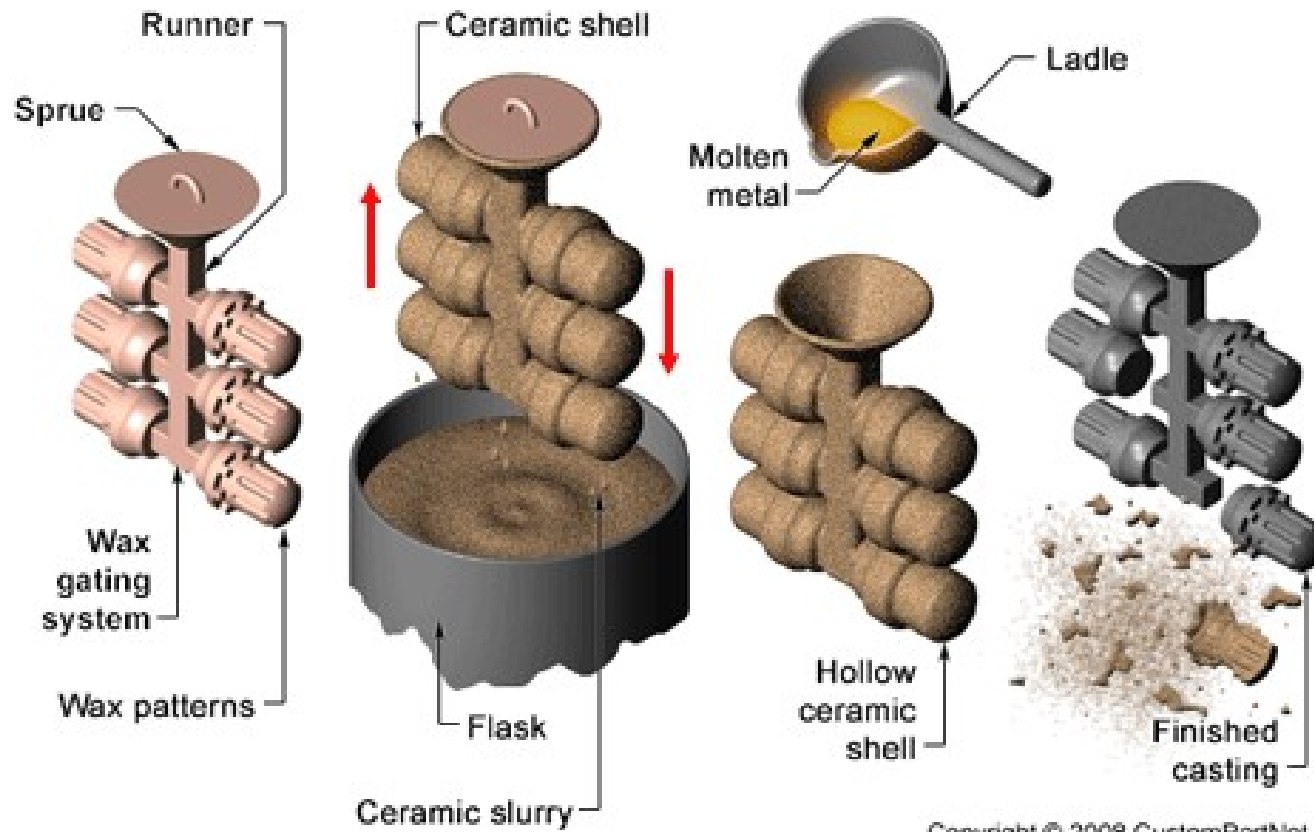
- 
- *Casting removal* - After the molten metal has cooled, the mold can be broken and the casting removed. The ceramic mold is typically broken using water jets, but several other methods exist. Once removed, the parts are separated from the gating system by either sawing or cold breaking (using liquid nitrogen).
 - *Finishing* - Often times, finishing operations such as grinding or sandblasting are used to smooth the part at the gates. Heat treatment is also sometimes used to harden the final part.

Pattern Tree

Shell-Making

Investment Casting

Casting



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Typical

Feasible

Shapes: Thin-walled: Complex Flat
Solid: Cylindrical Thin-walled: Cylindrical
Solid: Cubic Thin-walled: Cubic
Solid: Complex

Part size: Weight: 0.02 oz - 500 lb

Materials: Metals Cast Iron
Alloy Steel Lead
Carbon Steel Magnesium
Stainless Steel Tin
Aluminum Titanium
Copper Zinc
Nickel

Surface finish - Ra: 50 - 125 μin 16 - 300 μin

Tolerance: ± 0.005 in. ± 0.002 in.

Max wall thickness: 0.06 - 0.80 in. 0.025 - 5.0 in.

Quantity: 10 - 1000 1 - 1000000

Lead time: Weeks Days

Advantages: Can form complex shapes and fine details
Many material options
High strength parts
Very good surface finish and accuracy
Little need for secondary machining

Disadvantages: Time-consuming process
High labor cost
High tooling cost
Long lead time possible

Applications: Turbine blades, armament parts, pipe fittings, lock parts, handtools, jewelry

video

.....



Part to manufactured



● Properties And Considerations

- casting of extremely complex parts, with good surface finish.
- Very thin sections can be produced by this process , 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.
- 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.

Applications

- Investment casting is used in the **aerospace and power generation industries** to produce turbine blades with complex shapes or cooling systems.
- Blades produced by investment casting can include single-crystal (SX), directionally solidified (DS), or conventional equiaxed blades.
- Investment casting is also widely used by firearms manufacturers to **fabricate firearm receivers, triggers, hammers, and other precision parts at low cost.**
- Other industries that use standard investment-cast parts include **military, medical, commercial and automotive.**

- 
- **Centrifugal casting** or **rotocasting** is a casting technique that is typically used to cast thin-walled cylinders.
 - It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure.
 - Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use.

Process

- In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (300 to 3000 rpm) as the molten metal is poured.
- The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling.
- The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface.
- Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away.
- Casting machines may be either horizontal or vertical-axis. Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings.
- Most castings are solidified from the outside first. This may be used to encourage directional solidification of the casting, and thus give useful metallurgical properties to it. Often the inner and outer layers are discarded and only the intermediary *columnar zone* is used.
- Centrifugal casting was the invention of Alfred Krupp, who used it to manufacture cast steel tyres for railway wheels in 1852.



• **Features of centrifugal casting**

- Castings can be made in almost any length, thickness and diameter.
- Different wall thicknesses can be produced from the same size mold.
- Eliminates the need for cores.
- Resistant to atmospheric corrosion, a typical situation with pipes.
- Mechanical properties of centrifugal castings are excellent.
- Only cylindrical shapes can be produced with this process.
- Size limits are up to 3 m (10 feet) diameter and 15 m (50 feet) length.
- Wall thickness range from 2.5 mm to 125 mm (0.1 - 5.0 in).
- Tolerance limit: on the OD can be 2.5 mm (0.1 in) on the ID can be 3.8 mm (0.15 in).
- Surface finish ranges from 2.5 mm to 12.5 mm (0.1 - 0.5 in) rms.

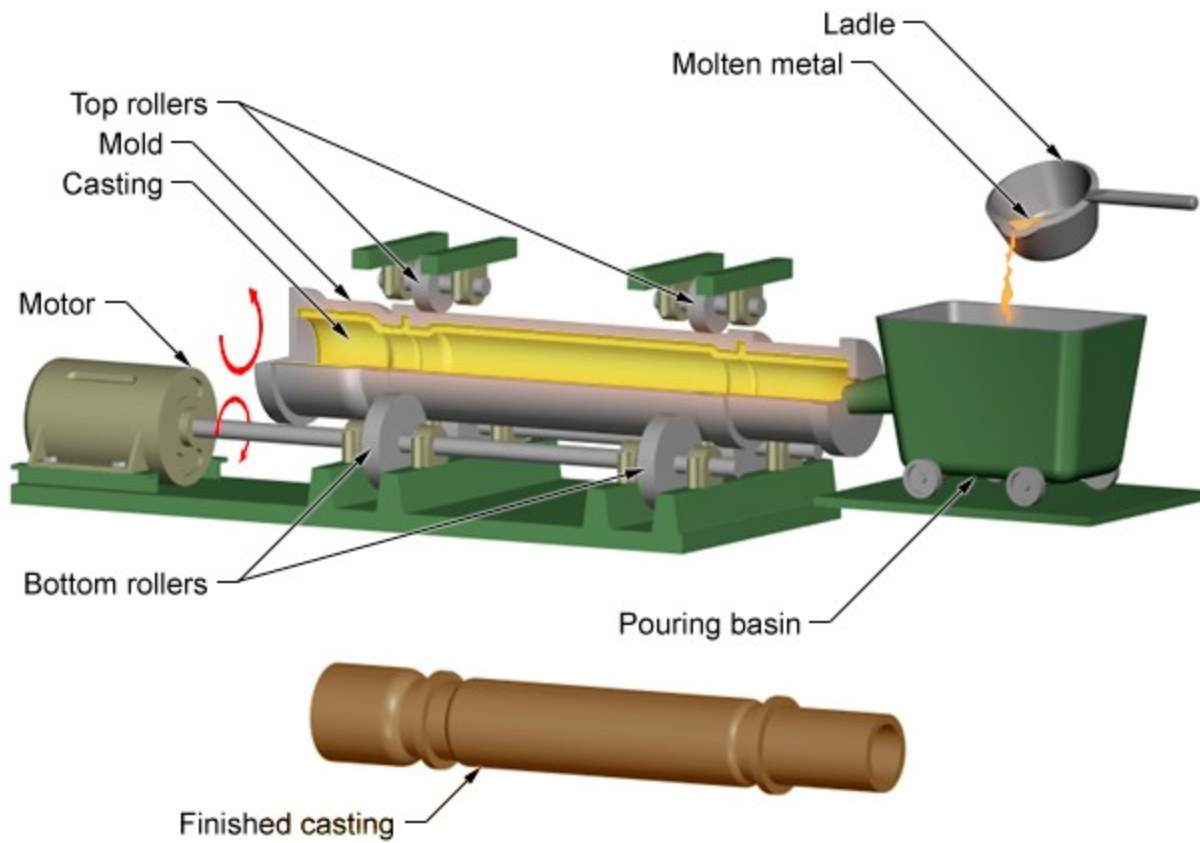
Benefits

- **Cylinders and shapes with rotational symmetry are most commonly cast by this technique. "Tall" castings are always more difficult than short castings. In the centrifugal casting technique the radius of the rotation, along which the centrifugal force acts, replaces the vertical axis.**
- **The casting machine may be rotated to place this in any convenient orientation, relative to gravity's vertical. Horizontal and vertical axis machines are both used, simply to place the casting's longest dimension conveniently horizontal.**
- **Thin-walled cylinders are difficult to cast by other means, but centrifugal casting is particularly suited to them.**
- **Centrifugal casting is also applied to the casting of disk and cylindrical shaped objects such as railway carriage wheels or machine fittings where the grain, flow, and balance are important to the durability and utility of the finished product.**
- **Providing that the shape is relatively constant in radius.**
- **noncircular shapes may also be cast.**

Materials

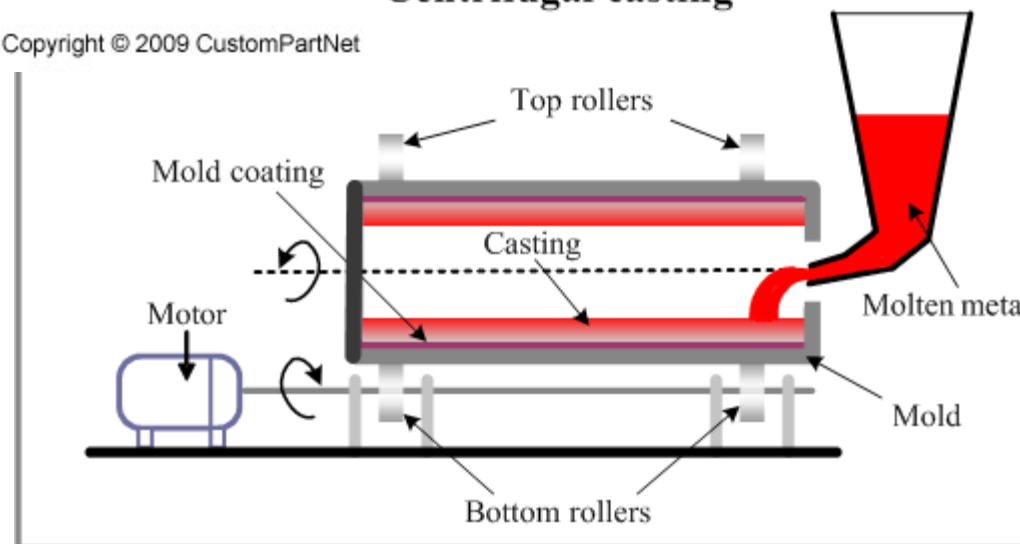
- Typical materials that can be cast with this process are iron,
- steel,
- stainless steels,
- glass, and
- alloys of aluminum,
- copper and nickel.

- 
- Typical parts made by this process are
 - **pipes,**
 - **boilers,**
 - **pressure vessels ,**
 - **flywheels,**
 - **cylinder liners and**
 - **other parts that are axi-symmetric.**
 - It is notably used to cast cylinder liners and sleeve valves for piston engines, parts which could not be reliably manufactured otherwise.



Centrifugal casting

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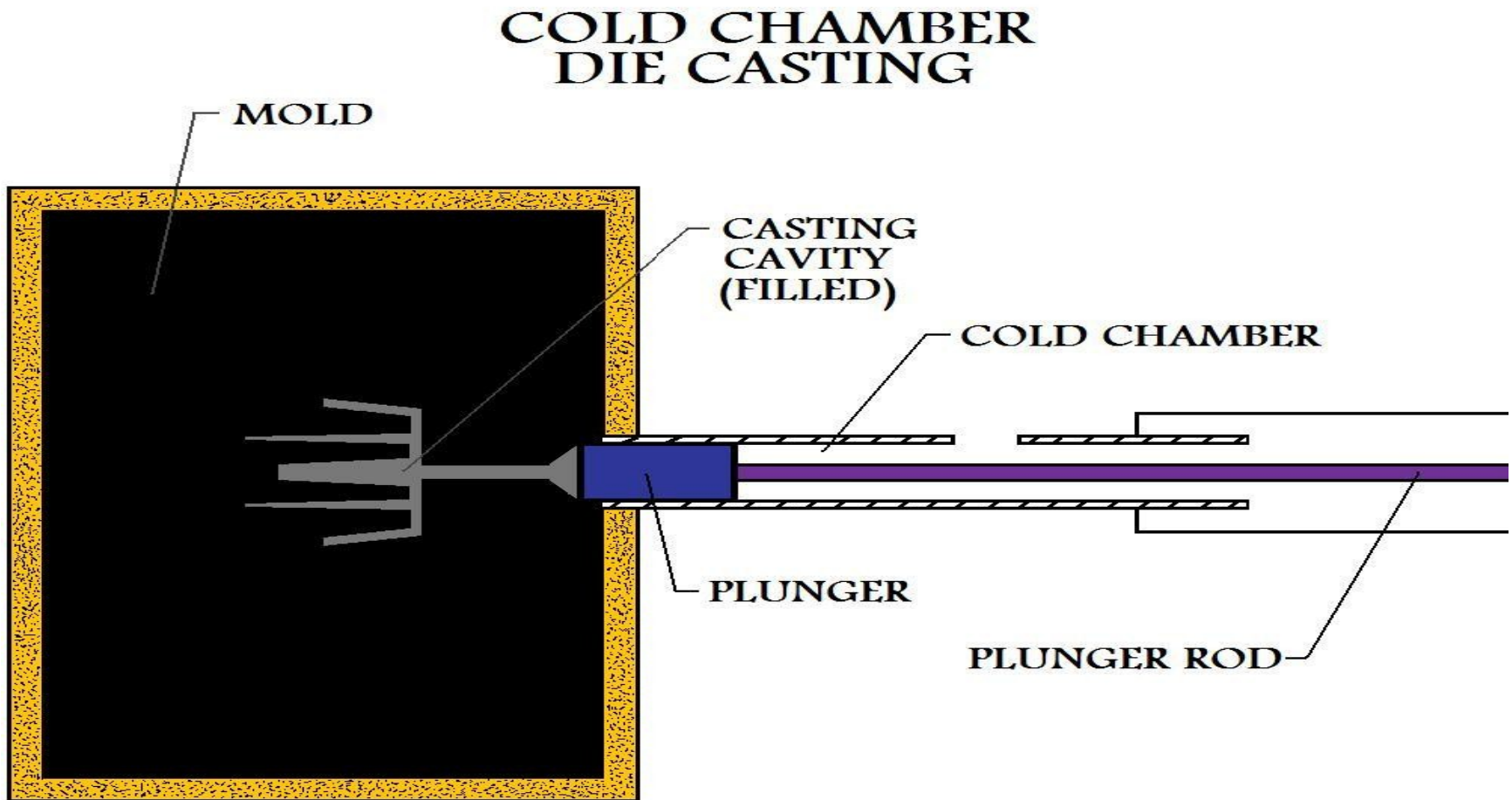
Video

CENTRIFUGAL CASTING

• Cold chamber die casting

- Cold chamber die casting is the second of the two major branches of the die casting manufacturing process.

Cold chamber die casting





- Pressures of 3000psi to 50000psi (20MPa to 350MPa) may be used in manufacturing industry to fill the mold cavities with molten material during cold chamber die casting manufacture.
- Castings manufactured by cold chamber die casting have all the advantages characteristic of the die casting process, such as intricate detail, thin walls, and superior mechanical properties.
- The significant initial investment into this manufacturing process makes it suitable for high production applications.

Advantages

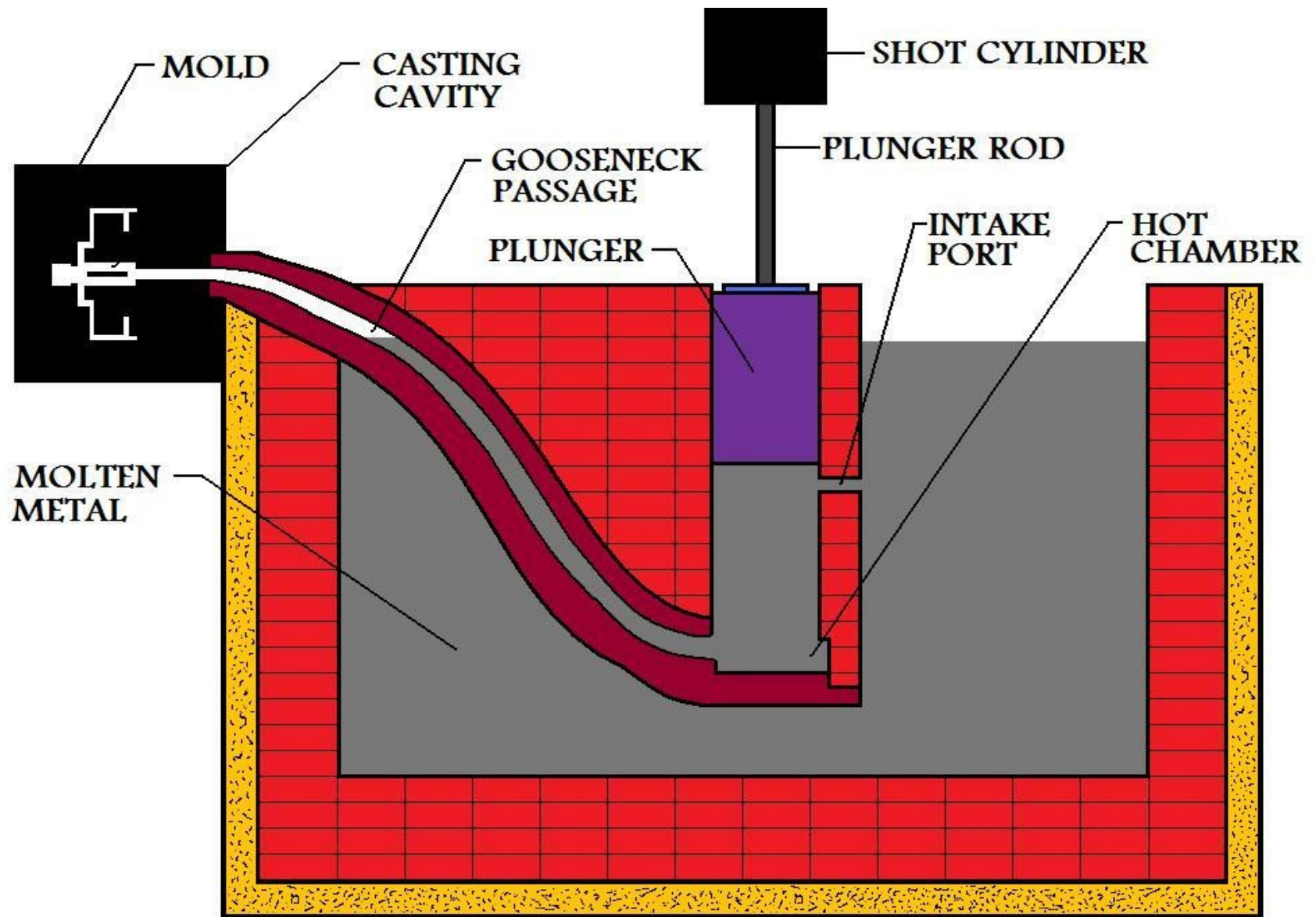
- Excellent dimensional accuracy (dependent on casting material, but typically 0.1 mm for the first 2.5 cm (0.005 inch for the first inch) and 0.02 mm for each additional centimeter (0.002 inch for each additional inch).
- Smooth cast surfaces (Ra 1–2.5 micrometres or 0.04–0.10 thou rms).
- Thinner walls can be cast as compared to sand and permanent mold casting (approximately 0.75 mm or 0.030 in).
- Inserts can be cast-in (such as threaded inserts, heating elements, and high strength bearing surfaces).
- Reduces or eliminates secondary machining operations.
- Rapid production rates.
- Casting tensile strength as high as 415 megapascals (60 ksi).
- Casting of low fluidity metals.

Disadvantages

- The main disadvantage to die casting is the **very high capital cost**.
- Therefore to make die casting an economic process a large production volume is needed.
- Other disadvantages include: the process is limited to high-fluidity metals and casting weights must be between 30 grams and 10 kg
- In the standard die casting process the final casting will have a small amount of porosity.
- This prevents any heat treating or welding, because the heat causes the gas in the pores to expand, which causes micro-cracks inside the part and exfoliation of the surface.

Hot chamber die casting

- Die casting process is the use of high pressure to force molten metal through a mold called a die.
- Many of the superior qualities of castings manufactured by die casting, can be attributed to the use of pressure to ensure the flow of metal through the die.
- In hot chamber die casting manufacture, the supply of molten metal is attached to the die casting machine and is an integral part of the casting apparatus for this manufacturing operation
- The pressure exerted on the liquid metal to fill the die in hot chamber die casting manufacture usually varies from about 700psi to 5000psi (5MPa to 35 MPa).
- The pressure is held long enough for the casting to solidify.



HOT CHAMBER DIE CASTING

- 
- Hot chamber die casting has the advantage of a very high rate of productivity.
 - During industrial manufacture by this process one of the disadvantages is that the setup requires that critical parts of the mechanical apparatus, (such as the plunger), must be continuously submersed in molten material.
 - Continuous submersion in a high enough temperature material will cause thermal related damage to these components rendering them inoperative.
 - For this reason, usually only lower melting point alloys of lead, tin, and zinc are used to manufacture metal castings with the hot chamber die casting process.

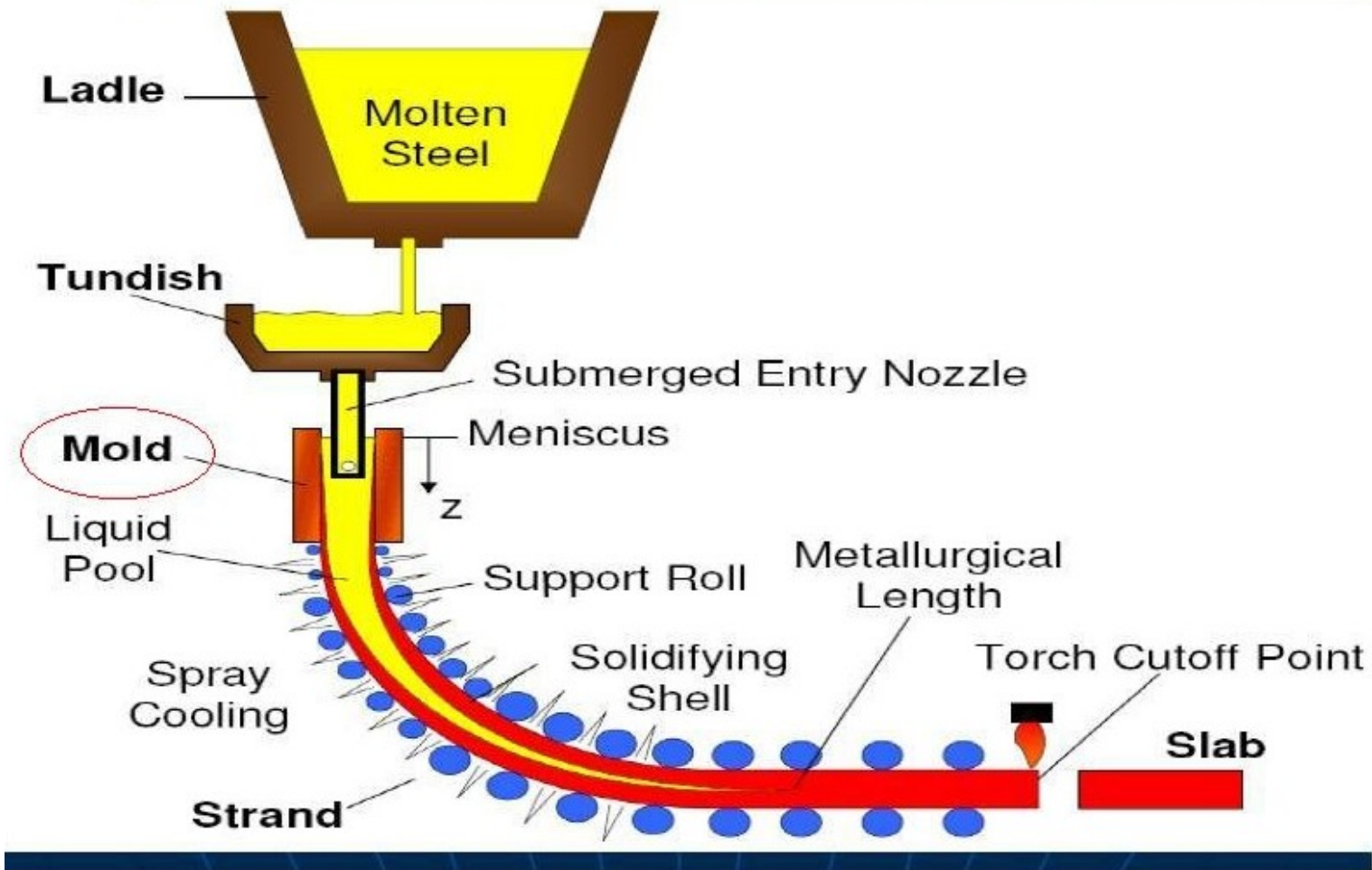
Hot chamber die casting

- It is very possible to manufacture castings from lower melting point alloys using the cold-chamber method.

Continuous casting

- **Continuous casting**, also referred to as strand casting, is a process used in manufacturing industry to cast a continuous length of metal.
- Continuous casting can produce long strands from aluminum and copper, also the process has been developed for the production of steel.

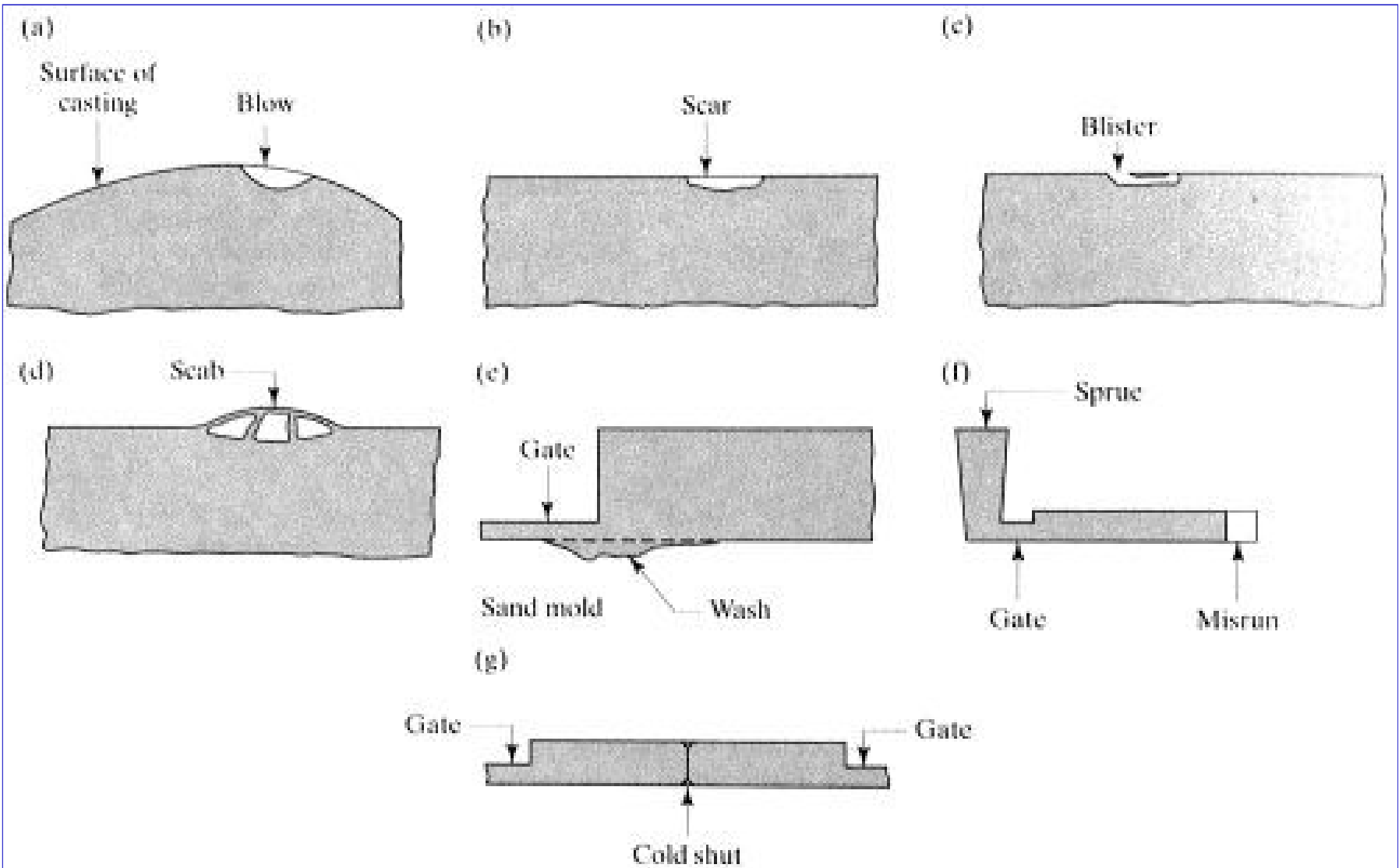
Continuous Casting

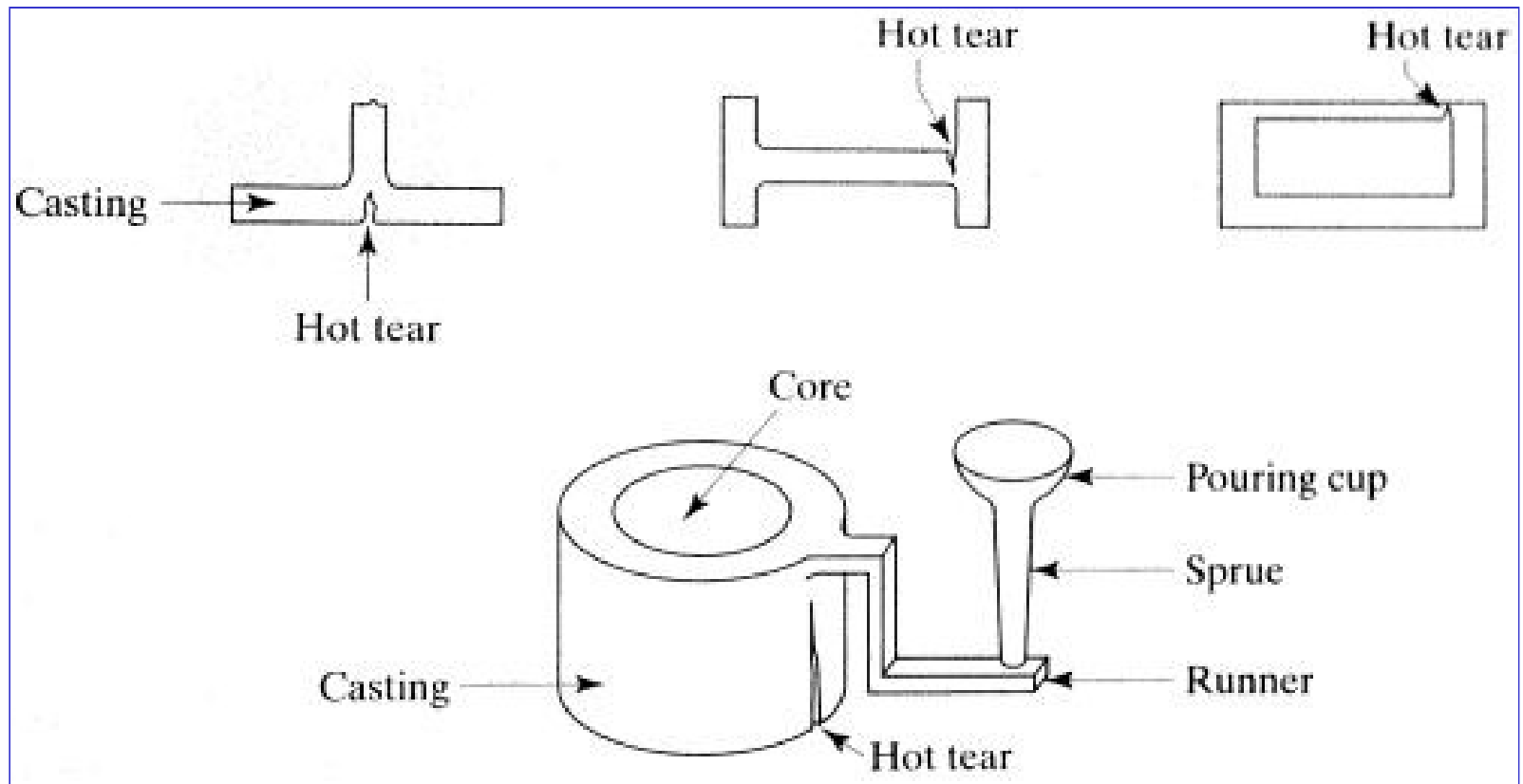


Different Casting Processes

Process	Advantages	Disadvantages	Examples
Sand	many metals, sizes, shapes, cheap	poor finish & tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, few shapes	pipes, boilers, flywheels

Casting Design: Typical casting defects





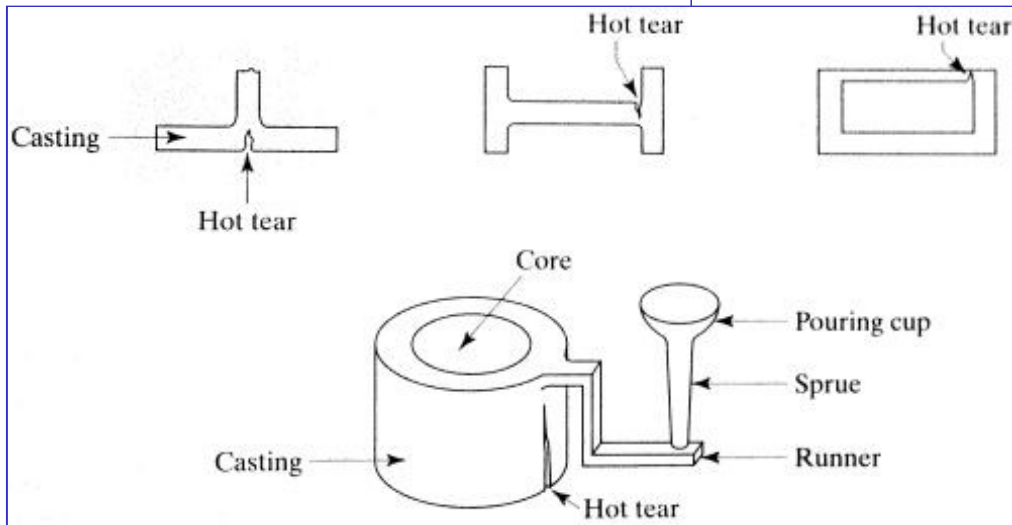
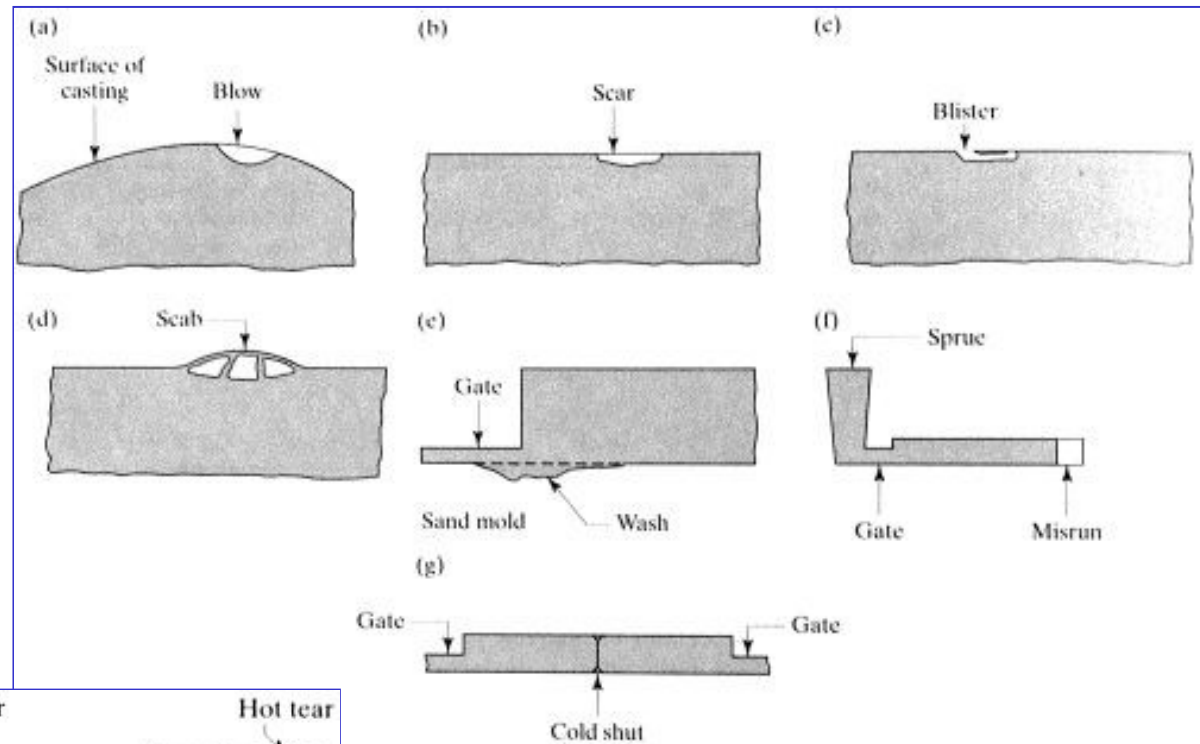


Inclusions	1. Faulty gating. 2. Faulty pouring. 3. Inferior molding or core sand. 4. Soft ramming of mold. 5. Rough handling of mold and core.	1. Modify gating system 2. Improve pouring to minimize turbulence. 3. Use of superior sand of good strength. 4. Provide hard, ramming.
Fusion	1. Low refractoriness in molding sand 2. Faulty gating. 3. Too high pouring temperature of metal. 4. Poor facing sand.	1. Improve refractoriness of sand. 2. Modify gating system. 3. Use lower pouring temperature. 4. Improve quality of facing sand.

Inspection of Casting

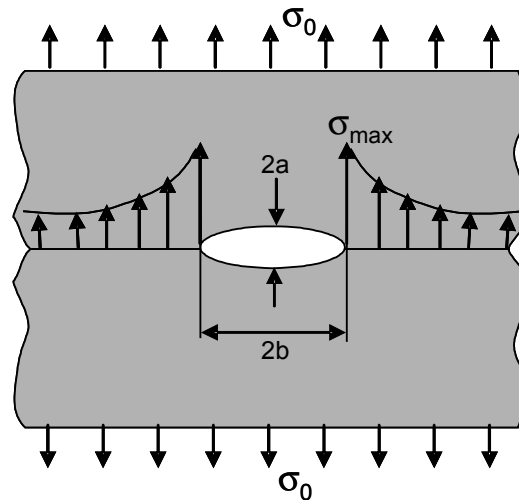
- **Visual Inspection**
- **Dimensional inspection**
- **Sound test**
- **Impact test**
- **Pressure test**
- **Magnetic particle testing**
- **Penetrant test**
- **Ultrasonic test**

Casting Design: Typical casting defects



Casting Design: Defects and Associated Problems

- Surface defects: finish, stress concentration
- Interior holes, inclusions: stress concentrations

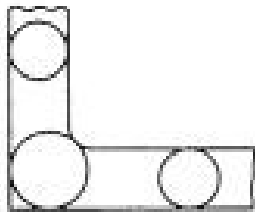


$$\sigma_{\max} = \sigma_0(1 + 2b/a)$$

Casting Design: guidelines

- (a) avoid sharp corners
- (b) use fillets to blend section changes smoothly
- (c) avoid rapid changes in cross-section areas

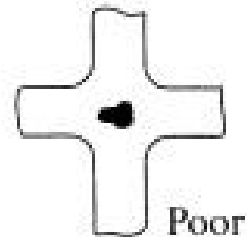
(a)



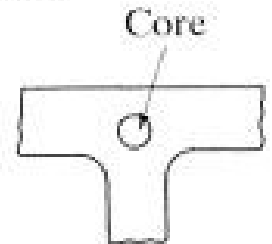
(c)



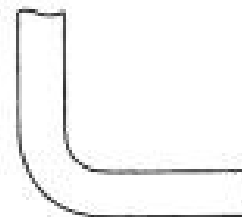
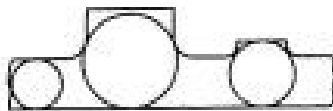
(d)



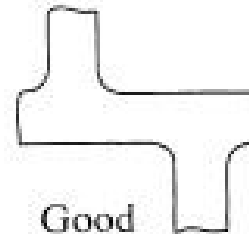
(e)



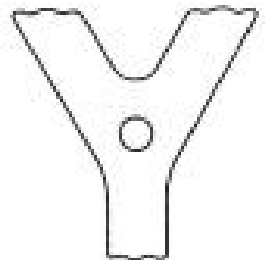
(b)



Good

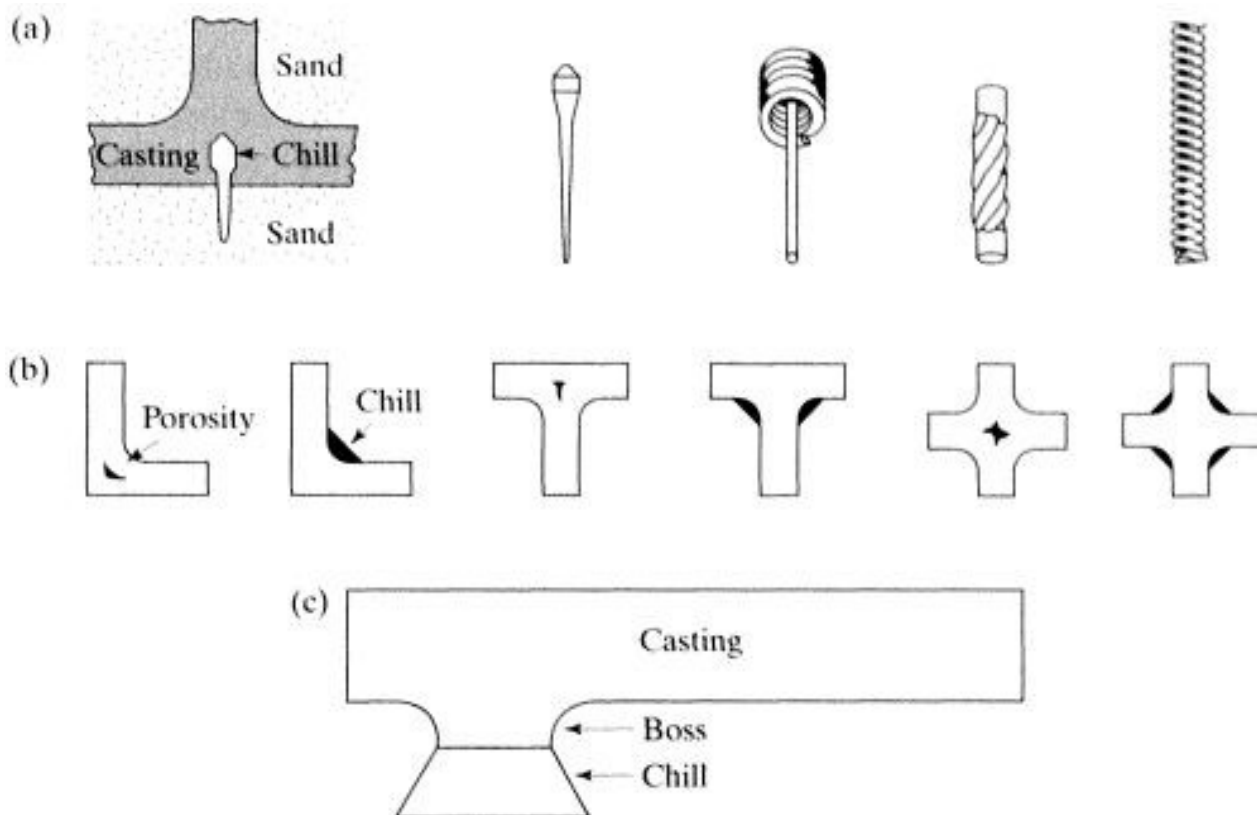


Good



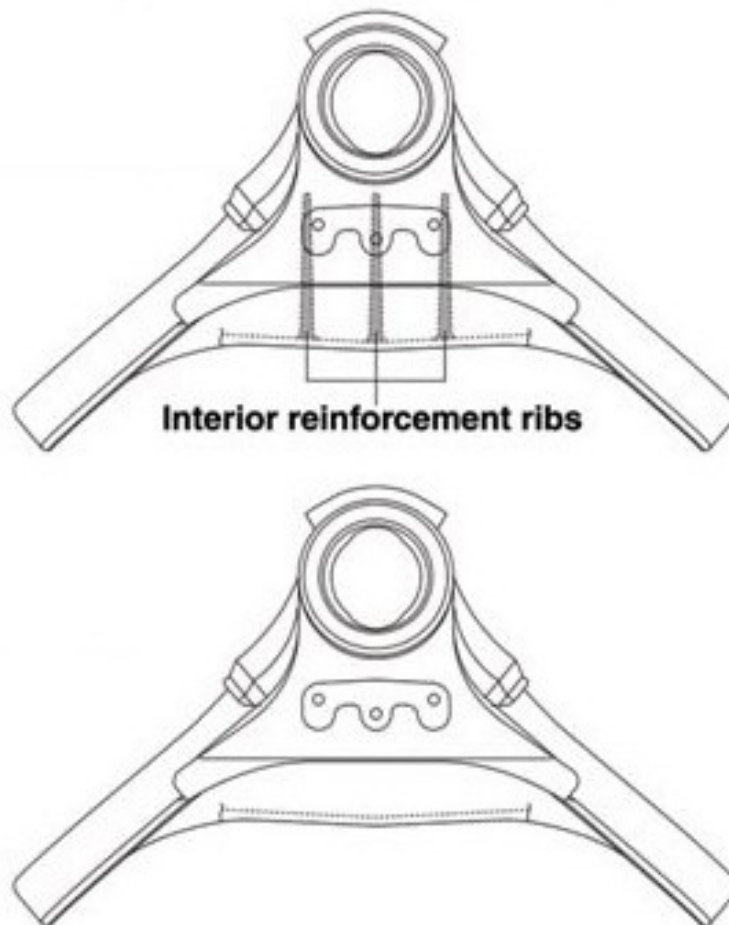
Casting Design: guidelines

- (c1) avoid rapid changes in cross-section areas
- (c2) if unavoidable, design mold to ensure
 - easy metal flow
 - uniform, rapid cooling (use chills, fluid-cooled tubes)



Casting Design: guidelines

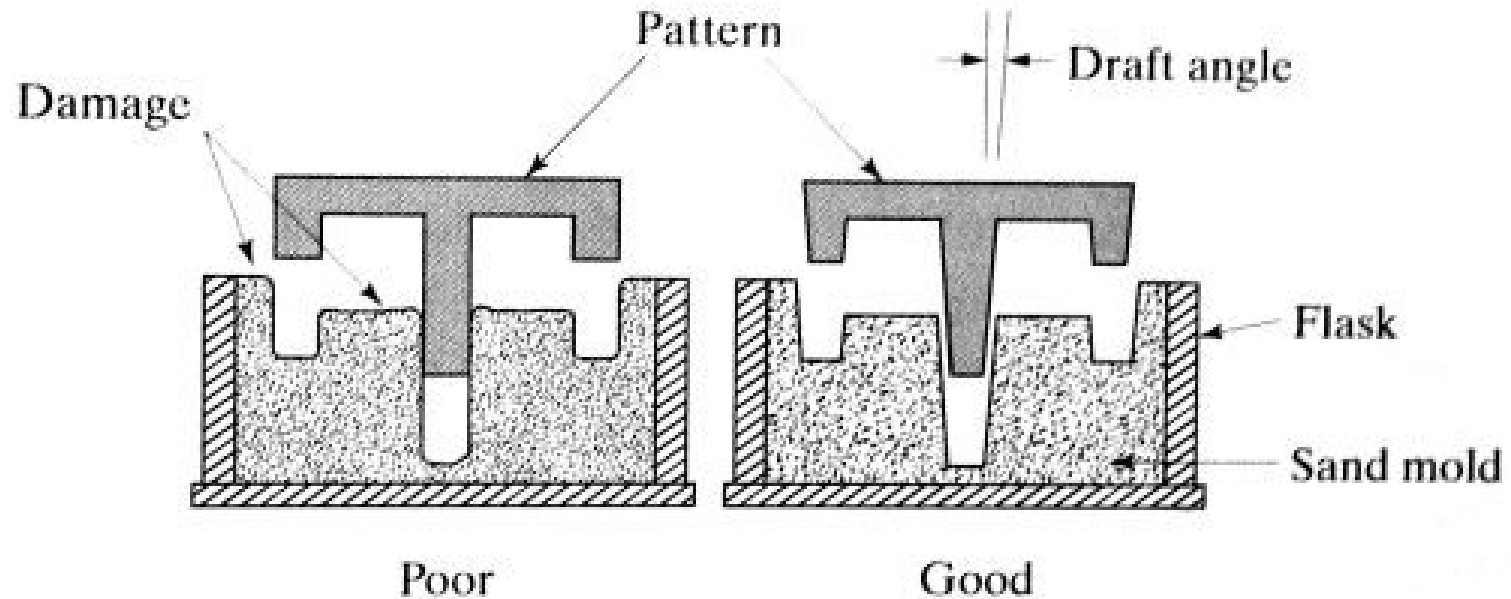
- (d) avoid large, flat areas
 - warpage due to residual stresses (why?)



Casting Design: guidelines

(e) provide drafts and tapers

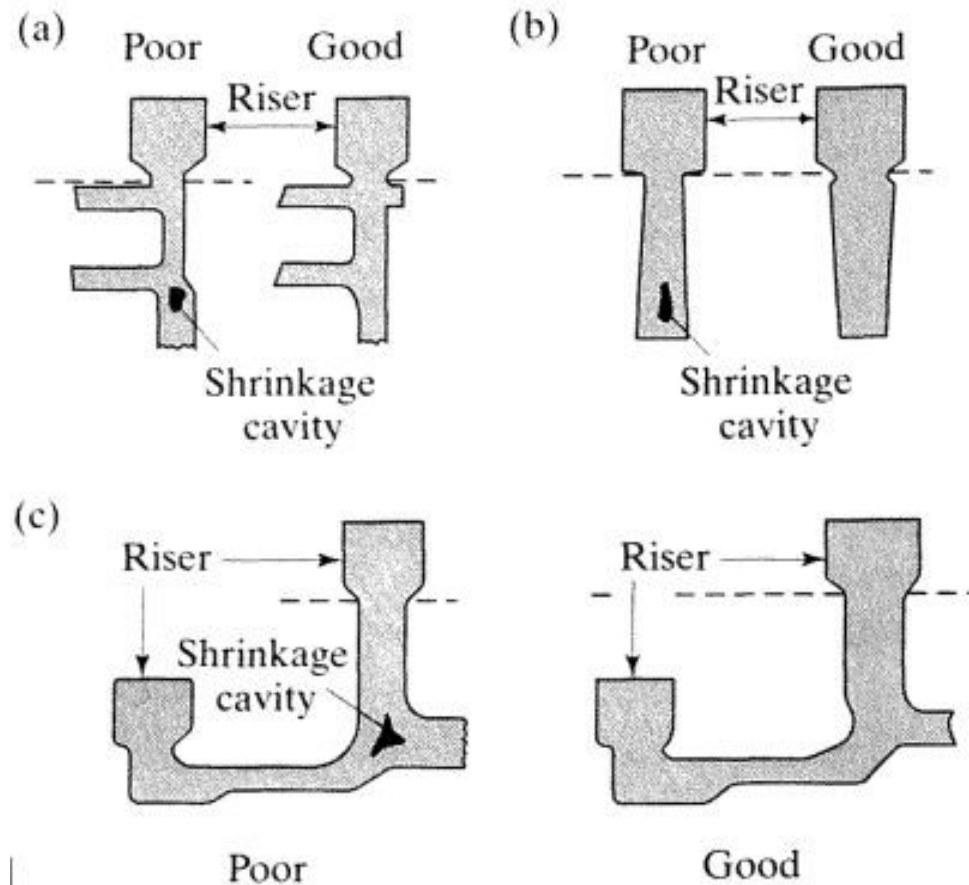
- easy removal, avoid damage
- along what direction should we taper ?



Casting Design: guidelines

(f) account for shrinkage

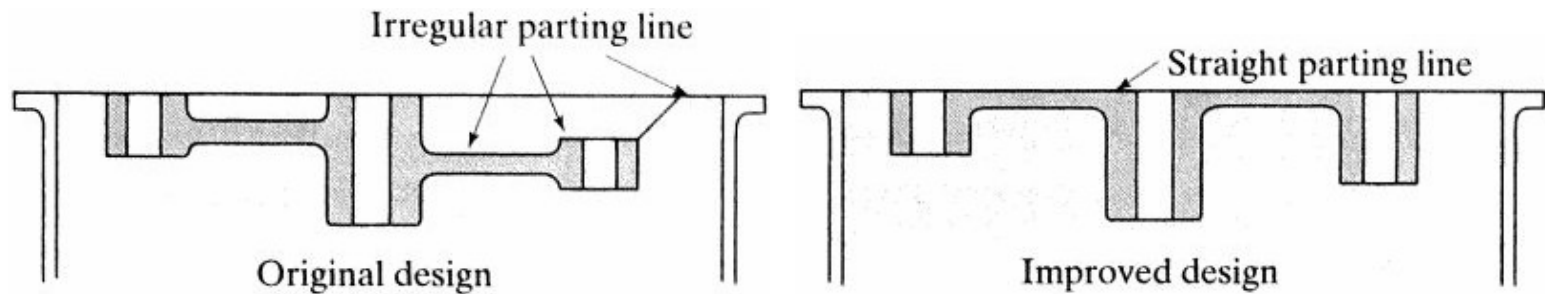
- geometry
- shrinkage cavities

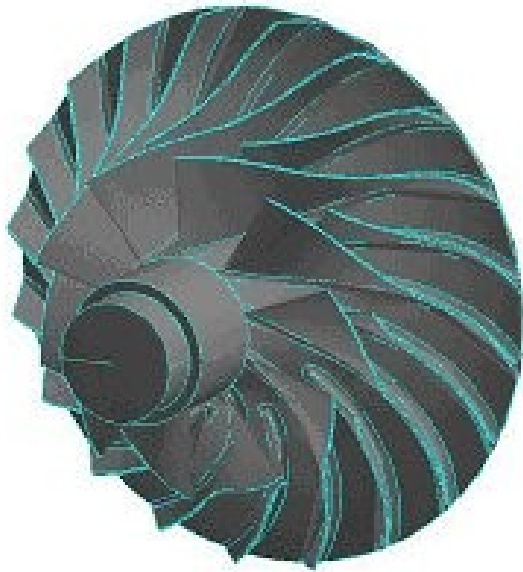


Casting Design: guidelines

(g) proper design of parting line

- “flattest” parting line is best





Impellers





THANK YOU