Manufacturing - The process of converting raw materials, components, or parts into finished product.
What is Manufacturing

- From Latin → *manu factus*, means “made by hand.”
- Making of goods & services for sale.
- Manufacturing involves making products from raw materials by various processes, machinery, and operations.

- Raw Materials
  - Clay

- Manufacturing Processes

- Finished Products
  - ceramic cutting tool or electrical insulator
Casting Terminology

- Sprue
- Pouring Basin
- Riser
- Vents
- Cope
- Drag
- Runner
- Ingate
- Casting
Flask:

- The moulding flask is used to hold the sand mould.
- The sand mould has desire cavity of object which to be casted.
- The sand is rammed into the flask to create sand mould in which metal is poured to get desire shape.
- It is created into minimum two pieces which allows removal of pattern easily
**Cope:**
The upper part of moulding flask is known as cope.

**Drag:**
The lower part of moulding flask is known as drag.

**Cheeks:**
When the moulding flask made into more than two parts, the intermediate parts are known as cheeks. These are used in complex casting.
Molten metal is poured into feed hole

cope

Check

Drag

Molding Sand
Pattern

Pattern is replica of object to be created. It is made by either wood, wax or other suitable material. It is placed into moulding flask and sand rammed over it which forms an object cavity into sand.
DRAW SPIKE:

- It is a tapered steel rod having a loop or ring at its one end and a sharp point at the other.

- It may have screw threads on the end to engage metal pattern for it withdrawal from the mold.

- It is used for driven into pattern which is embedded in the molding sand and raps the pattern to get separated from the pattern and finally draws out it from the mold cavity.
Pouring basin

It is a funnel shape cavity at the top of the mould. The metal is poured into pouring basin from where it is supplied at different parts of mould.
Runner

Runner is a horizontal passage of molten metal. It connects sprue to getting system. Normally it is situated at lower half of mould.
Riser:

• Riser is used as reservoir of molten metal when pouring of molten metal has stopped.

• When the cavity is filled by molten metal, the pouring is stopped which allows solidifying object.

• During solidification, volumetric shrinkage takes place which reduces the desire size and shape of object.

• The riser is provided into the mould which supplies the molten metal to remove effect of volumetric shrinkage during solidification.

• These are further divided into top riser, blind riser, side riser etc
Sprue:
• It is a passage which connects pouring basin to the runner. It controls the flow of molten metal from pouring basin. It is tapered in shape.

Ingate:
• It is the entry point through which molten metal enters into the actual mould cavity.
Core:

- Core is used to cast hollow cavity.
- It is also a sand structure and placed at right place into mould cavity where hollow part is to be created.
- The metal poured into mould cavity does not fill the part at which core is placed thus form a hollow cavity.
Chaplets:
These are supporting components of core. These used to support and hold the core into mould cavity. These protect the core from various forces encounter in casting.
Chills:
Chills are generally solid metal pieces which are placed into cavity to increase cooling rate. Mainly it is used to create direction solidification of molten metal. They have high thermal conductivity.
**Vents:**
These are small passages made in mould which allow the gases to escape during solidification.

![Vent wire](image.png)
Pattern

Pattern is replica of object to be created.

It is made by either wood, wax or other suitable material.

It is placed into moulding flask and sand rammed over it which forms an object cavity into sand.
Pattern Allowances:

A pattern is always made larger than the required size of the casting considering the various allowances. These are the allowances which are usually provided in a pattern.
shrinkage or contraction allowance:

The various metals used for casting contract after solidification in the mould. Since the contraction is different for different materials, therefore it will also differ with the form or type of metal.

There are three types of shrinkage.

1. Liquid Shrinkage
2. Solidification Shrinkage
3. Solid Shrinkage

The liquid shrinkage and solidification shrinkage are compensated by suitable riser but solid shrinkage does not compensated by it so the pattern is made slightly larger to compensate shrinkage.
Draft allowance

• It is a taper which is given to all the vertical walls of the pattern for easy and clean withdraw of the pattern from the sand without damaging the mould cavity.

• It may be expressed in millimeters on a side or in degrees. The amount of taper varies with the type of patterns.

• The wooden patterns require more taper than metal patterns because of the greater frictional resistance of the wooden surfaces.
Draft Allowance

Distorted Casting

Taper Casting
Finish or machining allowance

The allowance is provided on the pattern if the casting is to be machined. This allowance is given in addition to shrinkage allowance.

(a) Before machining

(b) After machining
Distortion or camber allowance

This allowance is provided on patterns used for casting of such design in which the contraction is not uniform throughout.
Rapping or shaking allowance

- When the pattern is removed from casting, it will slightly increase the dimension of casting. So to compensate this change, the pattern is made slightly smaller from casting. This change in dimension is known as rapping allowance.

- This allowance is provided in the pattern to compensate for the rapping of mould because the pattern is to be rapped before removing it from the mould.
Heat is removed from a molten metal of mass 2 kg at a constant rate of 10 kW till it is completely solidified. The cooling curve is shown in the figure.

Assuming uniform temperature throughout the volume of the metal during solidification, the latent heat of fusion of the metal (in kJ/kg) is _____.

GATE-2016
Gray cast iron blocks of size 100 mm × 50 mm × 10 mm with a central spherical cavity of diameter 4 mm are sand cast. The shrinkage allowance for the pattern is 3%. The ratio of the volume of the pattern to volume of the casting is _______
Types of patterns:

The following factors affect the choice of a pattern.
(i) Number of Castings to be produced.
(ii) Size and complexity of the shape and size of casting
(iii) Type of molding and castings method to be used.
(iv) Machining operation
(v) Characteristics of castings
Different types of patterns:

The common types of patterns are:

1) Single piece pattern
2) Split piece pattern
3) Loose piece pattern
4) Gated pattern
5) Match pattern
6) Sweep pattern
7) Cope and drag pattern
8) Skeleton pattern
9) Shell pattern
10) Follow board pattern
Solid/single Piece Pattern:

It is simplest type of pattern which is made in single piece. It is used for simple objects. It is either placed into cope or in drag according to the simplicity of operation. It is used to cast stuffing box of steam engines.
Split Piece Pattern:

- These patterns are made into two or more pieces.
- The first half of pattern placed into cope and other half into drag.
- It is used for complex objects where removal of single piece pattern from mould is impossible.
- When pattern is made in more than three parts cheeks are also used for easy removal.
Loose Piece Pattern

- If the objects are having internal projections or undercuts, loose piece pattern can be used.

- After removing the main part of the pattern. Loose piece can be removed from the mould.
Gated Pattern:

These are simply more than one loose pieces which are attached with a common gating system. These are used for mass production. It is used to produce small size cavities into one mould.
Match Plate Pattern

- To produce complex shape of the object in mass production, number of patterns can be split along the parting line and they will be added on the both side of match plate along the gating element.

- Used for mass production of complex shape.
Match Plate Pattern

When there is requirement of large scale production of a small size casting, match plate pattern is a viable alternative. match plate pattern requires less time to adjust the location of the pattern in cope and drag. the cope and drag portion of pattern is mounted on a the opposite of wood or metal plate. Both the drag and cope can be prepared simultaneously by the use of the match plate pattern.
Sweep Pattern:

These patterns are used for large rotational symmetrical casting. A sweep is a section of large symmetrical object which is rotated along an edge into sand which makes a large symmetrical mould. These patterns make easy pattern making work of large objects.
Follow Board Pattern:

Follow board is a wooden board which is used to support pattern during moulding. It acts as sit for pattern.
Core print

- Core print is an open space provided in the mold for locating, positioning and supporting the core.

- The core can't not be suspended inside the cavity without any support. So the space in the mold is needed.

- The core print is prepared with the help of projections on the pattern.

- But the problem is, while removing the pattern, the mold will get damaged due to the presence of projections on the pattern.

- Hence split pattern is used for casting process in which the core is used
During pouring, buoyancy of molten metal tends to displace the core, which can cause casting to be defective.

Force tending to lift the core = weight of displaced liquid less the weight of core itself

\[ F_b = W_m - W_c \]

Where \( F_b \) = buoyancy force; \( W_m \) = weight of molten metal displaced and \( W_c \) = weight of core
Constitutes of molding sand

- Water: 2-8%
- Silica: 70-85%
- Clay: 10-25%
- Additives: 1-6%
Properties of Molding Sand

1. Porosity
2. Flowability
3. Collapsibility
4. Adhesiveness
5. Cohesiveness or strength
6. Refractoriness
(i) Refractoriness:
Ability to withstand high temperature for molten metal so that it does not cause fusing. Sand with poor refractoriness may burn at high temperature.
Permeability is a property of foundry sand with respect to how well the sand can vent, i.e., how well gases pass through the sand. And in other words, permeability is the property by which we can know the ability of material to transmit fluid/gases.

Permeability number

\[ PN = \frac{(V \times H)}{P \times A \times T} \]

where

- \( V \) = volume of air (2000 cm\(^3\)) passing through the specimen
- \( H \) = Height of the specimen
- \( A \) = Cross sectional area of specimen
- \( P \) = Pressure of air in gm/cm\(^2\)
- \( T \) = Time in minutes
Flowability

- The ability of moulding sand to behave like a fluid when it is rammed is called flowability.

- Due to this property the sand can easily occupy the space in molding box and take up its shape.

- This allows the sand to compress to a compact density and let it pack around the pattern.

- The sand should be of high flowability, so that it can be easily compacted for uniform density and to obtain a good impression of the pattern in the mould.

- The flowability of the sand can be increases as we increases the clay and water content in the sand.
Collapsibility

- The ability of the moulding sand to collapse after solidification of the molten metal is called collapsibility.

- After the solidification of molten metal, the sand should get collapse for free contraction of the metal.

- If free contraction of the metal will happen than if eliminates naturally the tearing or cracking of the contracting metal
Adhesiveness.

The ability of the sand particles to get stick with another body is called adhesiveness.
Cohesiveness

The ability of the sand particles to stick with each other is called cohesiveness
Strength

- The sand should have sufficient strength so that it can easily capable to retain its shape during conveying, turning or closing and pouring.

- If it is not of appropriate strength than it will not be able to hold its shape and the mould may damage during pouring of molten metal.

- Low strength sand leads to pouring casting defects in metals.
The sand strength can be of two type

(i) Green strength: The strength of sand possessed by it in its moist state is called green strength. The mould with adequate green strength retains its shape and do not collapse even when the pattern is removed from the moulding box.

(ii) Dry strength: The strength possessed by the sand in its dry or baked state is called dry strength. Enough dry strength allows the sand to withstand erosive forces due to molten metal and helps to retain its shape.
The term gating system refers to all passageways through which the molten metal passes to enter the mold cavity.

The gating system is composed of:
- Pouring basin
- Sprue
- Runner
- Gates
- Risers
Requirements needed in gating system to achieve a defect free casting

❖ The mould should be completely filled in the smallest time possible without having to rise metal temperature.

❖ The metal should flow smoothly into the mould.

❖ The unwanted material – slag – should not be allowed to enter the mould cavity.

❖ The metal entry into the mould cavity should be controlled.
Metal flow should be maintained to avoid erosion.

Be ensure that enough molten metal reaches the mould cavity.

The gating system should be economical and easy to implement and remove after casting solidification.

The casting yield should be maximized.
Factors controlling the functioning of gating system

- Type of pouring equipment, such as ladles, pouring basin etc
- Temperature/ Fluidity of molten metal.
- Rate of liquid metal pouring.
- Type and size of sprue.
- Type and size of runner.
- Size, number and location of gates connecting runner and casting.
- Position of mould during pouring and solidification.
A pouring basin makes it easier for the ladle or crucible operator to direct the flow of metal from crucible to sprue.

Helps maintaining the required rate of liquid metal flow.

Reduces turbulence at the sprue entrance.
A sprue feeds metal to runner which in turn reaches the casting through gates.

A sprue is tapered with its bigger end at top to receive the liquid metal. The smaller end is connected to runner.
Design of sprue
Mass flow rate = \( C \)
\( A \times V = \) constant

Applying continuity equation between point 2 and 3 we get

\[
\frac{A_2}{A_3} = \frac{V_3}{V_2} = \sqrt{\frac{2gh_t}{2gh_c}} = \sqrt{\frac{h_t}{h_c}}
\]

\[
\frac{h_t}{h_c} = \left(\frac{A_2}{A_3}\right)^2
\]
❖ As the liquid metal passes down the sprue it loses its pressure head but gains velocity.

❖ To reduce turbulence and promote Laminar Flow, from the Pouring Basin, the flow begins a near vertical incline that is acted upon by gravity and with an accelerative gravity force.
Actual shape of sprue is Parabola.

But in order to avoid manufacturing difficulty we use tapered cylinder shape.
The pressure in the liquid metal stream should not become less than (or should not fall below) the atmospheric pressure. If it falls

- Gases produced due to baking of organic compounds in the mould enter the metal stream and result in porous castings
- It is called the **Aspiration effect**
A sprue in a sand mould has a top diameter of 20 mm and height of 200 mm. The velocity of the molten metal at the entry of the sprue is 0.5 m/s. and neglect all losses. If the mould is well ventilated, the velocity (upto 3 decimal points accuracy) of the molten metal at the bottom of the sprue is _____ m/s. [GATE-17-set-1]
Schematic diagram of pouring basin and sprue of a gating system is shown in the Figure. Depth of molten metal in the pouring basin is 100 mm and the height of the sprue is 1500 mm.

Considering the cross-section of the sprue is circular, the ratio $d_1 : d_2$ to avoid aspiration is

\[ \text{GATE-PI-17} \]

(A) $3 : 2$

(B) $5 : 6$

(C) $15 : 16$

(D) $1 : 2$
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