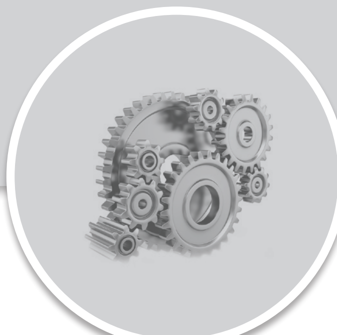
MECHANICAL ENGINEERING

Production Engineering



Comprehensive Theory
with Solved Examples *and* Practice Questions

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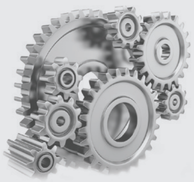

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1

Metal Casting

1.1 INTRODUCTION

Casting is the oldest and still most widely used process. Casting is a manufacturing process in which a **mould cavity** is created out of sand or some permanent material and **liquid metal** is poured and allowed to solidify into this cavity. The product is taken out after solidification either by breaking the mould or taking the mould apart. If the mould is broken after each cast then it is called **expendable mould**. If the same mould is used for a number of castings, it is called **permanent mould**.

1.1.1 Sand Casting process

- Sand casting uses ordinary silica sand as the primary mould material.
- The sand grains are mixed with small amounts of other materials, such as clay and water, to improve mouldability and cohesive strength, and are then packed around a pattern that has the shape of the desired casting.
- The pattern is removed before pouring of molten metal. To facilitate this, the mould is usually made in two or more pieces.
- An opening called as sprue hole is cut from the top of the mould through the sand and connected to a system of channels called runners.
- The molten metal is poured into the sprue hole, flows through the runners, and entering the mould cavity through an opening called as gate.
- Gravity flow is the most common means of introducing of metal into the mould.
- After solidification, the mould is broken and the finished casting is removed.
- The casting is then fettled by cutting off the ingate and the feeder head.

Advantages of casting

1. It can be used to produce intricate shapes because molten metal can easily flow into small sections in the mould cavity.
2. Both hard and soft, ductile and brittle materials can be casted easily.
3. Large size castings can be produced weighing upto 200 tonnes.
4. Sand casting is a cheap process.

Limitations

1. Dimensional accuracy and surface finish of sand casted products is very poor.
2. Sand casting is labourious and time consuming process.
3. Sand casting are prone to gas defects.
4. Casting do not have uniform mechanical properties due to non-uniform cooling.

1.2 TERMS ASSOCIATED WITH CASTING

- Flask:
  - (i) A moulding flask is one which holds the sand mould intact.
  - (ii) It is made up of **wood** for temporary applications or more generally of **metal** for long term use.
  - (iii) The top moulding flask is known as cope and the bottom one is known as drag. Sometimes, a third flask is placed in between cope and drag which is known as cheek.
- Pattern: It is the replica of final product to be made with some **allowances**. It is used to make mould cavity.
- Core: It is used for making **hollow cavities** in casting.

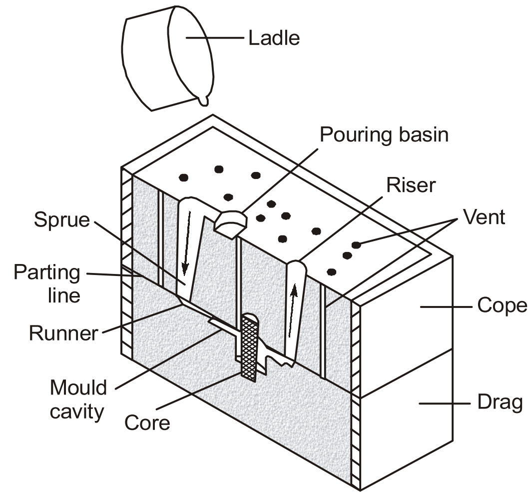


Figure: Cross section of a sand mould

- Pouring Basin: A small funnel shaped cavity at top of the mould into which the molten metal is poured.
- Sprue: The passage through which the molten metal from the pouring basin reaches the mould cavity.
- Runner: The passage way in the parting plane through which molten metal flow before it reaches the mould cavity.
- Gate: The actual entry point through which molten metal enters the mould cavity.
- Chaplet: Chaplets are used to support cores inside the mould cavity to take care of its own weight and overcome the metallostatic forces.
- Chills: Chills are metallic objects, which are placed in the mould to increase the **cooling rate** of casting to provide uniform or desired cooling rate.
- Riser: It is a reservoir of molten metal in the casting so that hot metal can flow back into the mould cavity when there is **a reduction in volume** of metal due to contraction.
- Parting line : It is the dividing line between two moulding flasks.
- Vent : Small openings created in the mould to facilitate the escape of air and gases.

1.3 PATTERN

Patterns are objects which are similar in shape to that of final casting required. Some modifications in the form of allowances and core prints are done while deciding the size and features of a pattern. Also, some intricate details of final product may be omitted on pattern, specifically for those which are to be used with sand casting.

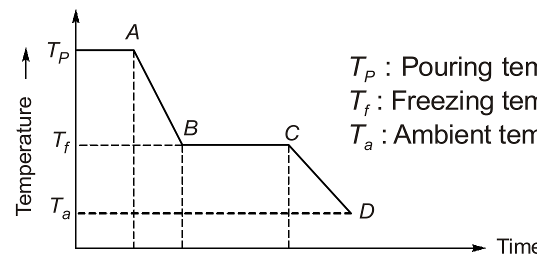
1.3.1 Pattern Allowances

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

1.3.2 Shrinkage Allowance

When the liquid metal is cooled from pouring to ambient temperature during solidification, it experiences a shrinkage or contraction due to its inherent nature.

The figure on the right shows the cooling curve for a pure metal. It describes the variation of temperature with time upon cooling.



T_P : Pouring temperature
T_f : Freezing temperature
T_a : Ambient temperature

Figure: Cooling curve

It can be observed from the cooling curve that cooling occurs in 3 stages i.e. from *A* to *B*, from *B* to *C* and then from *C* to *D*. On this basis, the shrinkage in liquid metal can be classfied as:

1. **Liquid shrinkage:** Shrinkage in liquid metal when it is cooled from pouring to freezing temperature.
2. **Solidification shrinkage:** Shrinkage in the liquid metal when it undergoes phase transformation at freezing temperature.
3. **Solid shrinkage:** Shrinkage in metal when it cools from freezing to ambient temperature.

Liquid and solidification shrinkage can be compensated with the help of riser since the metal is still in liquid state. But the solid shrinkage can only be compensated by changing the pattern dimensions in the form of pattern shrinkage allowance.

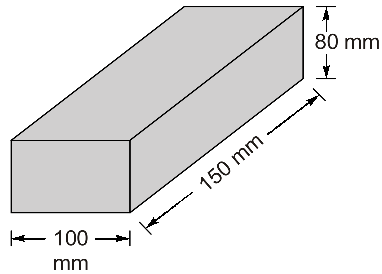
The shrinkage allowance is generally positive in nature i.e. it is provided as an extra length along dimensions of the pattern. For e.g. if the shrinkage allowance for a particular metal in mentioned as 'x' mm/m length then it means 1 m length of casting will require a corresponding dimension of $(1 + x \times 10^{-3})$ m length.

NOTE

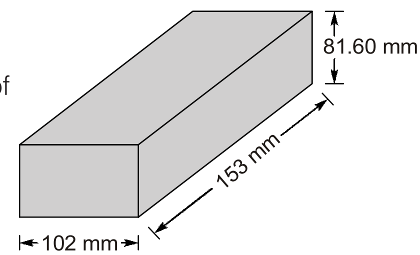
- There are some metals like Bismuth, Antimony, germanium and silicon which expand upon cooling. For such metals, we provide negative shrinkage allowance.
- Shrinkage allowances for some important materials:

Material	**Allowance**
Bismuth	Negligible
Cast iron	10 mm/metre length
Aluminium	12-15 mm/metre length
Steel	20 mm / metre length
Brass	23 mm / metre length
Zinc, Lead	25 mm / metre length

EXAMPLE : 1.1 Design a pattern for the casting shown below if it is to be produced by steel material by considering shrinkage of 20 mm/m.



Solution:



For 1 mm steel shrinkage allowance should be of 0.02 mm

∴ Allowance on length = 150 × 0.02 = 3.00 mm

Allowance on breadth = 100 × 0.02 = 2 mm

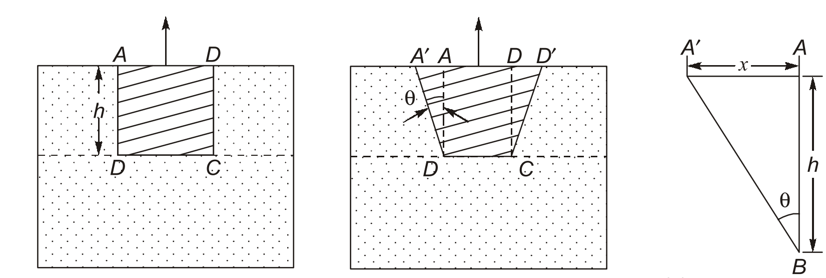
Allowance on width = 80 × 0.02 = 1.60 mm

∴ Length, breadth and width of pattern will be 153 mm 102 mm and 81.60 mm respectively.

1.3.3 Machining Allowance

Casting produces poor surface finish and tolerance. To get smooth surface finish in casting machining is required. Due to machining casting size is reduced and to overcome this, machining or finish allowance is provided on the pattern. It is expressed in terms of each surface of casting (mm/surface). It is positive in nature.

1.3.4 Draft or Taper Allowance



(a) Pattern in without mould taper (b) Pattern with taper (c) Taper angle θ

Figure: Draft allowance

Around 1/2 to 2° taper is provided over the vertical surfaces of pattern for easy removal from the sand mould as shown in figure. The value of taper angle can be calculated by geometry as

$$x = h \tan \theta$$

The draft allowance is added as extra material i.e. it is a positive allowance. The internal sections always require more draft allowance as compared to external sections as shown in figure. This is so because the amount and strength of sand mould material surrounded by internal sections of pattern is less. Small patterns may not require taper allowance at all.

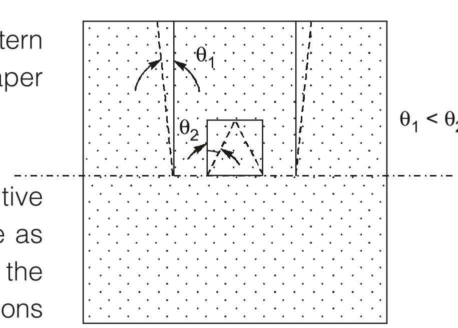


Figure: External surfaces require less taper

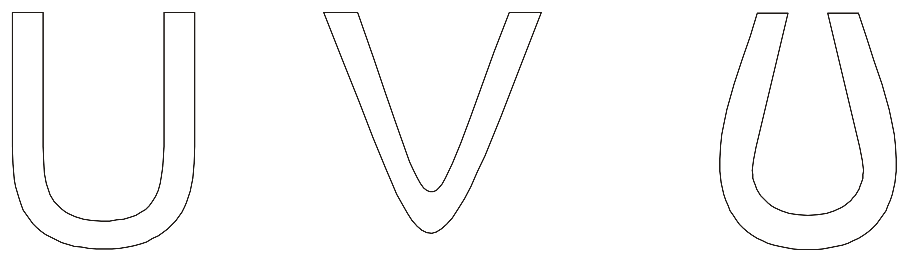
1.3.5 Rapping or Shake Allowance

For easy removal of the pattern from the mould, clearance is required between pattern and mould. This can be produced by shaking the pattern. Due to shaking size of cavity is increased. To overcome this, size of the pattern can be reduced in the form of shake allowance. It is a negative allowance.

NOTE: Ramming is a process of packing sand around the pattern and in flask by application of a little pressure with the help a wooden hammer.

1.3.6 Distortion or Camber allowance

Some typical shaped casted products like V-shape, U-shape and flat objects with very less thickness can distort, while cooling and solidification. In order to take care of this distortion, a distortion allowance is provided in the opposite direction on the pattern.

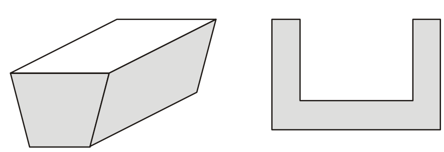


(a) Required product (b) Possible distortion while cooling (c) Pattern with distortion allowance

1.4 TYPES OF PATTERNS

1.4.1 Solid or Single Piece Pattern

For simple shaped castings, this pattern can be used. One of such a surface of such a pattern is flat.



(a) (b)

Figure: Examples of single piece pattern

1.4.2 Split Piece Pattern

This is used to produce complex shapes, pattern can be split into number of pieces. Pattern is split along the parting surface, the position of which is determined by shape of casting.

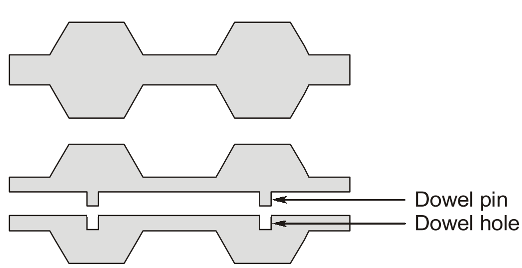


Figure: Split piece pattern

1.4.3 Loose Piece Pattern

- This pattern is used when the contour of the part is such that withdrawing the pattern made as a single piece is not possible.
- It is used when parts with internal webs, projections, undercuts, etc. are to be manufactured.

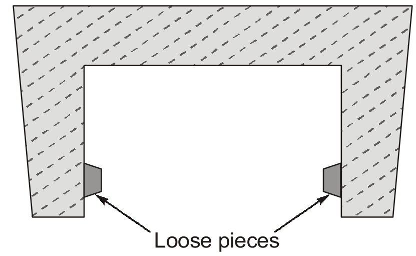


Figure: Loose piece pattern

1.4.4 Gated Pattern

The gate and runner is the integral part of the pattern. This would eliminate the hand cutting of the runner and gates and hence productivity is improved. It is used to produce small size objects in mass production.

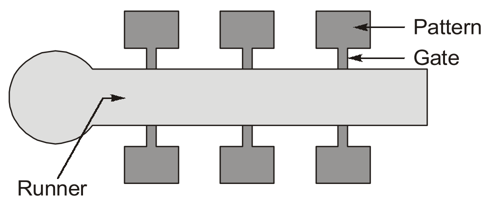


Figure: Gated Pattern

1.4.5 Match Plate Pattern

This pattern is made in two halves which are mounted on both sides of a single match plate (of wood or metal) conforming to the contour of the parting surface. The match plate is accurately placed between the cope and the drag flasks by means of locating pins. For small castings, several patterns can be mounted on the same match plate to increase the production rate.

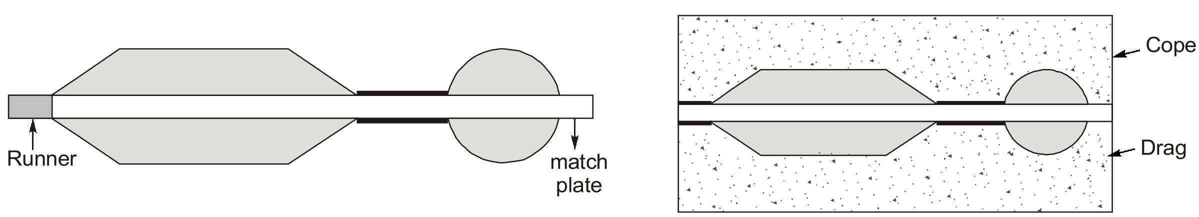


Figure: Match plate pattern

1.4.6 Cope and Drag Pattern

- It is similar to split pattern.
- In addition to splitting the pattern, the cope and drag halves of the pattern along with the gating and riser systems are attached separately to the metal or wooden plates along with the alignment pins.
- This type of pattern is used for castings which are heavy and inconvenient for handling and also for continuous production.
- It is used to produce big size casting.

1.4.7 Sweep Pattern

- It is used to generate surfaces of revolution in large castings, and to prepare moulds out of a paste-like material, Here "sweep" refers to the section that rotates about an edge to yield circular sections. It is generally made of wood.
- To produce 3 dimensional complex cavity using two dimensional plane pattern we can use sweep pattern.

- Two dimension plane pattern will be sweeped inside the mould cavity by 360° by fixing one of its end. Due to this, the cost of producing pattern will be reduced.

  e.g.: Cone, cylinder, large size bells etc..

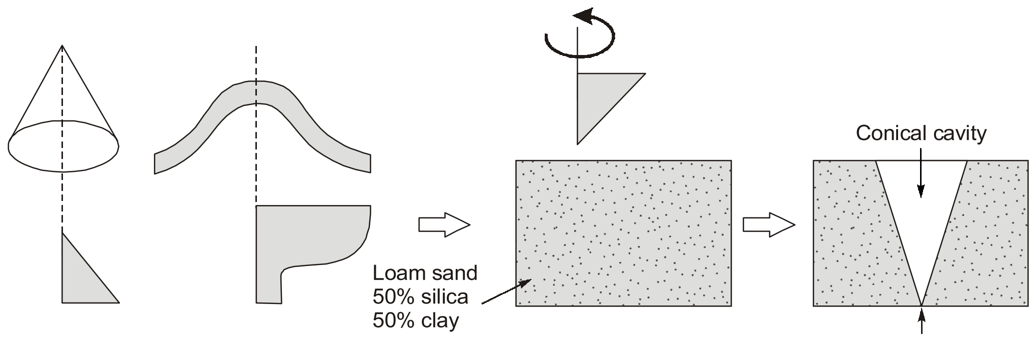


Figure: Use of sweep pattern for producing a conical cavity

1.4.8 Follow board Pattern

This type of pattern is adopted for those castings where there are some portions which are structurally weak and if not supported properly are likely to break under the force of ramming.

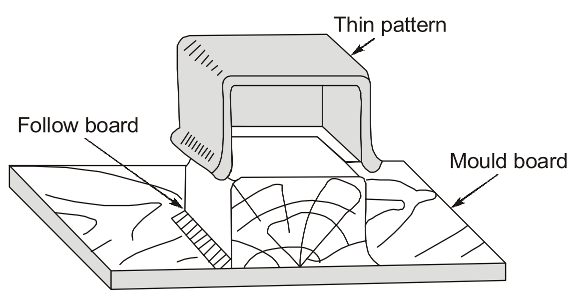


Figure: Follow-board pattern

1.4.9 Skeleton Pattern

- This type of pattern will be used to produce large size shells and cylinders. To produce such objects very large size pattern is required.
- To minimize the material consumption on preparing the pattern skeleton pattern is used.
- 3-dimensional skeleton is produced using small wooden pieces to get the required casting shape on skeleton wire mesh will be added.

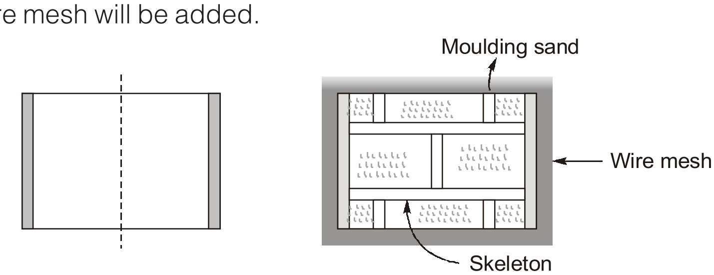


Figure: Skeleton Pattern

NOTE: The selection of pattern material and type depends on the size and shape of casting, dimensional accuracy, quantity to be produced and the moulding process.

OBJECTIVE BRAIN TEASERS

Q.1 Match List-I (Moulding process) with List-II (Binding agent) and select the correct answer.

List-I
A. Green sand
B. Cores sand
C. Shell moulding
D. Carbon dioxide process

List-II
1. Silicate
2. Organic
3. Clay
4. Plaster of Paris
5. Plastic

Codes:

	A	B	C	D
(a)	3	2	5	1
(b)	3	2	4	1
(c)	2	3	5	4
(d)	2	3	4	5

Q.2 Which of the following are characteristics of lost-foam process?
(a) It has design flexibility.
(b) It cannot be easily automated.
(c) The casting requires minimal finishing and cleaning.
(d) The flow velocity of molten metal in mould depends upon degration of the polymer.
[MSQ]

Q.3 Match **List-I** (Produce) with **List-II** (Process of manufacture) and select the correct answer.

List-I
A. Automobile piston in aluminium alloy.
B. Engine crankshaft in spheroidal graphite iron
C. Carburettor housing in aluminium alloy.
D. Cast titanium blades

List-II
1. Pressure die casting
2. Gravity die casting
3. Sand casting
4. Precision investment casting.
5. Shell moulding

Codes:

	A	B	C	D
(a)	3	2	1	5
(b)	3	2	5	1
(c)	2	1	3	4
(d)	4	1	2	3

Q.4 Match **List-I** with **List-II** and select the correct answer.

List-I
A. Die casting
B. Centrifugal casting
C. Centrifuging
D. Continues casting

List-II
1. Molten metal is forced into the die under pressure
2. Axis of rotation does not coincide with axis of mould
3. Metal solidifies when mould is rotating
4. Continuously pouring molten metal into mould
5. Plastic

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	4	3	2	1
(c)	1	2	3	4
(d)	4	2	3	1

Q.5 An expendable pattern is used in
(a) Slush casting
(b) Squeeze casting
(c) Centrifugal casting
(d) investment casting

Q.6 Which one of the following processes consist of central sprue to feed metal into cavities through a number of radial gates?
(a) Centrifuging
(b) Semi-centrifugal casting
(c) True centrifugal casting
(d) Precision casting

Q.7 Which of the following materials are used for making patterns in investment casting method?

1. Wax
2. Rubber
3. wood
4. Plastic

Select the correct answer.

(a) only 1 and 3
(b) only 2 and 3
(c) only 1, 2 and 4
(d) only 2, 3 and 4

Q.8 Which one of the following would produce strongest components?

(a) Die casting
(b) Hot rolling
(c) Cold rolling
(d) Forging

Q.9 In hot chamber method a die casting

(a) only low melting point metals can be used.
(b) high melting point metals can be cast.
(c) Die is kept hot by electrical heating
(d) Die is kept cold by circulating water.

Q.10 Ornamental objects, statues, toys etc are cast by

(a) Die casting
(b) Pressed casting
(c) Centrifugal casting
(d) Slush casting

Q.11 Consider the following statements about casting process:

1. Casting is labour intensive process.
2. Forging products are interior to casting in respect of strength.
3. Pattern and part to be made are exact in shape and size.
4. Cores are used for making runner and gate.

Which of the above statement/s is/are correct?

(a) 1, 2 and 3
(b) 1 and 3 only
(c) 3 and 4 only
(d) 1 only

Q.12 which of the following statements regarding patterns is correct?

(a) Liquid shrinkage is compensated by pattern.
(b) The shrinkage allowance depends on the coefficient of thermal expansion (α).
(c) In gated pattern, runners are part of it.
(d) Chaplets are used to support check.

[MSQ]

Q.13 Statement (I) : Urea formaldehyde binders for core mix are suitable for metals like Al, Mg.

Statement (II): Urea formaldehyde binders burn out faster and collapse at lower temperature.

(a) Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are true but Statement (II) is not a correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

Q.14 Consider the following statements:

1. Proper core venting is required especially if the cores are surrounded largely by molten metal.
2. The cores containing binders will produce gases, steam because of the heat generated due to molten metal.
3. Gases from core should be vented out through core prints so that defects can be avoided.
4. Large cores are sometimes made hollow.

Which of the above statements are correct?

(a) 1, 2 and 3
(b) 2, 3 and 4
(c) 1, 2 and 4
(d) All of the above

Q.15 A disk 30 cm in diameter and 4 cm thick is to be casted of pure aluminium in an open mold operation. The melting temperature of aluminium = 660°C and the pouring temperature will be 800°C. Assume that the amount of aluminium heated will be 7% more than needed to fill the mold cavity. Compute the amount of heat in kJ that must be added to the metal to heat it to the pouring temperature, starting from a room temperature of 25°C. The heat of fusion of aluminum = 389.3 J/g, density = 2.7 cm^3 and specific heat C = 0.88 J/g-°C. Assume the specific heat has the same value for solid and molten aluminum.

Q.16 The flow rate of liquid metal into the down sprue of a mold = 1 *l*/s. The cross-sectional area at the top of the sprue = 810 mm^2 and its length = 180 mm. What area in square cm should be used at the base of the sprue to avoid aspiration of the molten metal?

Q.17 A cylindrical side riser must be designed for a sand-casting mold. The casting itself is a steel rectangular plate with dimensions 7.5 cm × 12.5 cm × 2.0 cm. Previous observations have indicated that the solidification time for this casting dimensions of the riser so that its solidification time is 2.8 min.

Q.18 In a horizontal centrifugal casting a molten metal having density, ρ = 6000 kg/m^3 is poured. The required rotational speed needed for sound casting is 20% excess of what required to just hold the molten metal at upper wall of horizontal rotating mould of radius 50 cm. The rotational speed needed is _______ rpm.

Q.19 The casting defect 'Misrun' is due to
1. Low pouring temperature.
2. Slow pouring.
3. Thinner cross-section of mould cavity.
4. Less fluidity of molten material.
5. Absence of skim bob.

Select the correct answer using codes given below
(a) 1, 2 and 4
(b) 1, 2, 3 and 4
(c) 1, 2 and 3
(d) All of the above

Q.20 Which of the following properties not influence the fluidity of molten metal?
(a) Surface tension
(b) Melting point of metal
(c) Inclusions
(d) Degree of superheat

Q.21 Consider the following statements about solidification of molten metal:
1. Pure metal solidifies at a range of temperature.
2. The solidification front moves from wall towards centre.
3. Metals which shrinks while cooling are generally don't shrink during solidification.
4. In pure metals the solidification front moves as a plane without forming a mushy zone.

Which of the above statements are correct?
(a) 1, 3 and 4
(b) 1 and 2 only
(c) 2 and 4 only
(d) 1, 2 and 4

Q.22 Match **List-I** (Cooling rates) with **List-II** (Resultant structure of alloys) and select the correct answer.

List-I
P. Slow cooling rates
Q. High cooling rates
R. Very high cooling rates

List-II
1. Fine dendritic structure
2. Amorphous structure
3. Coarse dendritic structure

Codes:

	P	Q	R
(a)	3	1	2
(b)	2	1	3
(c)	3	2	1
(d)	1	2	3

Q.23 Which of the following supports the core and avoid and avoid them from shifting?
(a) Core prints
(b) Chaplets
(c) Cope
(d) Both (a) and (b)

■■■■

ANSWER KEY

1. (a) 2. (a, c, d) 3. (a) 4. (a)
5. (d) 6. (a) 7. (c) 8. (d) 9. (a)
10. (d) 11. (d) 12. (a, d) 13. (a) 14. (d)
15. (8750.78) 16. (4.44) 17. (4.976)
18. (50.74) 19. (b) 20. (b) 21. (c)
22. (a) 23. (d)

HINTS & EXPLANATIONS

2. (c)
It can be easily automated.

11. (d)
- Forging products are superior.
- Pattern is made little larger then part after adding allowances.
- Cores are used for making hollow cavities inside the casting.

12. (d)
- Solid shrinkage is compensated by pattern.
- Chaplets are used to support core.

13. (a)
Urea formaldehyde binders burn out faster and collapse at lower temperature as compared to phenol formaldehyde binders. Thus urea formaldehyde binders are suitable for use at lower temperature metals like Al, Mg, thin sections of brass, bronze.
Phenol formaldehyde binders are employed for thick sections of CI, steel castings,

15. (8750.78)
Mass of disk,

$$\rho V = 2.7 \times \left(\frac{\pi}{4} \times 30^2 \times 4\right)$$

$$= 7634 \text{ gm}$$

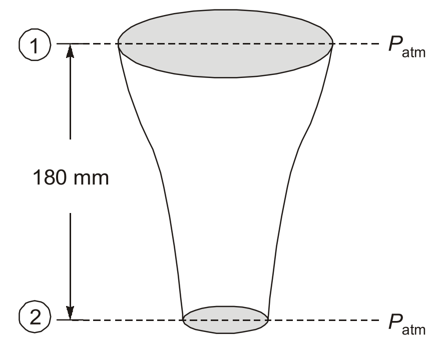
Amount of aluminium heated = 7634 × 1.07
= 8168.38 gm

$$\text{Heat required} = m\left[C \times (T_m - T_\infty) + L + C \times (T_p - T_m)\right]$$

$$q = 8168.38 \times [0.88 \times (660 - 25) + 389.3 + 0.88 \times (800 - 600)]$$

$$q = 8750785.5 \text{ J or } 8750.78 \text{ kJ}$$

16. (4.44)



$$q = 1 \times 10^{-3} \text{ m}^3/\text{s}$$

The pressure at bottom should be atleast greater than or equal to P_{atm}.
Using Bernoulli's equation

$$P_{atm} + \frac{V_1^2}{2g} + h_1 = P_{atm} + \frac{V_2^2}{2g} + h_2$$

$$V_1 = \frac{q}{A_1} = \frac{10^{-3}}{810 \times 10^{-6}} = 1.234 \text{ m/s}$$

$$\therefore \quad V_2^2 = V_1^2 + 2gh_1$$

$$= (1.234)^2 + 2g \times 0.18$$

$$V_2 = 2.248 \text{ m/s}$$

Area at bottom,

$$A_2 = \frac{10^{-3}}{2.248} = 444 \text{ mm}^2$$

17. (4.976)

$$\left(\frac{V}{A}\right)_{casting} = \frac{7.5 \times 12.5 \times 2}{2(7.5 \times 12.5 + 12.5 \times 2 + 2 \times 7.5)}$$

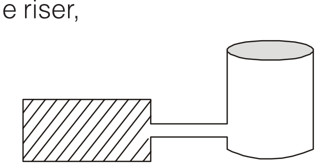
$$\left(\frac{V}{A}\right)_{casting} = 0.701$$

Using Chvorinov's rule,

$$t_f = K\left(\frac{V}{A}\right)^2$$

$$\Rightarrow \quad K = \frac{2}{(0.701)^2} = 4.07 \text{ min/cm}^2$$

For side riser,



$$\left(\frac{V}{A}\right)_R = \frac{\frac{\pi}{4}d^2 \times d}{2 \times \frac{\pi}{4}d^2 + \pi d^2} = \frac{d}{6}$$

$$t_f = K\left(\frac{V}{A}\right)_R^2$$

$$\Rightarrow \qquad \frac{V}{A} = \sqrt{\frac{t_f}{K}} = \sqrt{\frac{2.8}{4.07}}$$

$d = 4.976$ cm

$h = d = 4.976$ cm

18. (50.74)

The minimum speed required to hold molten metal at upper wall is

$$\frac{mv^2}{R} = mg$$

$$v = \sqrt{gR} = \sqrt{9.81 \times 0.5} = 2.214 \text{ m/s}$$

We know, $v = \dfrac{\pi DN}{60}$

$\therefore \quad N = \dfrac{V \times 60}{\pi \times D} = \dfrac{2.214 \times 60}{\pi \times 1}$

$N = 42.284$ rpm

Required rotational speed (20% excess) = 1.2 × 42.284 = 50.74 rpm

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CONVENTIONAL BRAIN TEASERS

Q.1 Three metal pieces being cast have the same volume but different shapes, one is sphere, one is a cube and other a cylinder with its height equal to its diameter. Which piece will solidify the fastest and which one the slowest?

Solution:

Let volume of each casting be 1 unit.

We know, $t_s = K\left(\dfrac{V}{SA}\right)^2$ [k : Constant]

For sphere, $V_{\text{sphere}} = \dfrac{4}{3}\pi r^3$

$$1 = \frac{4}{3}\pi r^3$$

$$r^3 = \frac{3}{4\pi}; \qquad r = \left(\frac{3}{4\pi}\right)^{1/3}$$

$$\text{Surface Area} = 4\pi r^2 = 4 \times \pi \times \left(\frac{3}{4\pi}\right)^{2/3} = 4.83$$

Cube, Volume $= a^3$

$1 = a^3 \Rightarrow a = 1$

Surface Area $= 6a^2 = 6 \times 1 = 6$

Cylinder, Volume $= \pi r^2 h$

$$r^3 = \frac{1}{2\pi}$$

$$r = \left(\frac{1}{2\pi}\right)^{1/3}$$

Surface area $= 2\pi rh + 2\pi r^2 = 2\pi r^2 + 2\pi r^2 = 4\pi r^2 = 4\times\pi\times\left(\frac{1}{2\pi}\right)^{2/3} = 5.85$

Solidification times,

$$t_s \propto \frac{1}{(\text{Surface area})^2}$$

$$t_{\text{sphere}} = \frac{1}{(4.83)^2} = 0.0428$$

$$t_{\text{cube}} = \frac{1}{6^2} = 0.0277$$

$$t_{\text{cyclinder}} = \frac{1}{5.85^2} = 0.0291$$

Hence, cube casting will solidify fastest and sphere slowest.

Q.2 Chvorinov and Caine gave rules for solidification time and freezing ratio for a riser. Using these rules find size of a cylindrical riser of height to diameter ratio as one for a steel casting of size 300 × 300 × 100 mm^3, when casting is fed horizontally and riser is a side one, thickness of casting is 100 mm.
For steel, $a = 0.10$, $b = 0.03$, $c = 1.00$

Solution:

Given: $h = d$, $a = 0.10$, $b = 0.03$ and $c = 1.00$

$$\text{Volume of casting} = 300 \times 300 \times 100 = 9 \times 10^6 \text{ mm}^3$$

$$\text{Surface area of casting} = 2(300 \times 300) + 4(300 \times 100)$$
$$= 18 \times 10^4 + 12 \times 10^4$$
$$= 30 \times 10^4 \text{ mm}^2$$

$$\text{Volume of riser} = \frac{\pi}{4}d^2 \times h = \frac{\pi}{4}d^3 \qquad [\because d = h]$$

$$\text{Surface area of riser} = \left(\frac{\pi}{4}d^2\right)2 + \pi dh = \frac{3}{2}\pi d^2 \qquad [\because d = h]$$

$$\text{For freezing ratio, } X = \frac{\left(\frac{V}{A}\right)_{riser}}{\left(\frac{V}{A}\right)_{casting}} = \frac{\left(\frac{\frac{\pi}{4}d^3}{\frac{3}{2}\pi d^2}\right)}{\left(\frac{9\times10^6}{30\times10^4}\right)}$$

$$X = \frac{\left(\frac{d}{6}\right)}{30} = \frac{d}{180} \qquad \text{...(i)}$$

From Caine's curve,

$$X = \frac{a}{Y-b} + c \qquad \text{...(ii)}$$

where,
$$Y = \frac{V_{riser}}{V_{casting}} = \frac{\frac{\pi}{4}d^3}{9\times 10^6} \qquad \text{...(iii)}$$

Now, putting values of a, b, c, X and Y in equation (ii), we get

$$\frac{d}{180} = \frac{0.10}{\frac{\left(\frac{\pi}{4}d^3\right)}{9\times 10^6} - 0.03} + 1$$

$$\Rightarrow \quad \frac{d}{180} = \frac{0.10}{\left(\frac{\pi d^3}{36\times 10^6} - 0.03\right)} + 1$$

$$\Rightarrow \quad \frac{d-180}{180} = \frac{0.10}{(8.72\times 10^{-8})d^3 - 0.03}$$

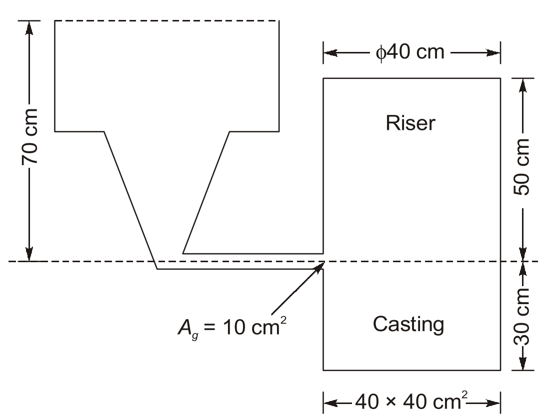
$$\Rightarrow \quad d^4(8.72\times 10^{-8}) - 180\times 8.72\times 10^{-8} d^3 - 0.03d + 180(0.03) = 18$$

$$\Rightarrow \quad d^4 - 180d^3 - \left(\frac{0.03}{8.72\times 10^{-8}}\right)d + \frac{180\times 0.03}{8.72\times 10^{-8}} - \frac{18}{8.72\times 10^{-8}} = 0$$

$$\Rightarrow \quad d^4 - 180d^3 - 344036.7d - 144495412.8 = 0$$

$$\Rightarrow \quad d = 204.9689$$

Q.3 Gating design for a casting is as shown in figure has cuboidal casting with 40 × 40 cm^2 area and cylindrical riser with diameter 40 cm. Determine the total time to fill the cavity.



Solution:

Given: Area of gate (A_g) = 10 cm^2, Height of sprue (h_t) = 70 cm, Height of riser (h_m) = 50 cm, Height of casting (h_B) = 30 cm, Area of the casting (A_c) = 40 × 40 cm^2, Diameter of riser (d_r) = 40 cm