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MANUFACTURING ENGINEERING

For

MECHANICAL ENGINEERING

MANUFACTURING ENGINEERING

SYLLABUS

Engineering Materials: Structure and properties of engineering materials, phase diagrams, heat treatment, stress-strain diagrams for engineering materials.
Casting, Forming and Joining Processes: Different types of castings, design of patterns, moulds and cores; solidification and cooling; riser and gating design. Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes; principles of powder metallurgy. Principles of welding, brazing, soldering and adhesive bonding.
Machining and Machine Tool Operations: Mechanics of machining; basic machine tools; single and multi-point cutting tools, tool geometry and materials, tool life and wear; economics of machining; principles of non-traditional machining processes; principles of work holding, design of jigs and fixtures.
Metrology & Inspection: Limits, fits and tolerances; linear and angular measurements; comparators; gauge design; interferometry; form and finish measurement; alignment and testing methods; tolerance analysis in manufacturing and assembly.
Computer Integrated Manufacturing: Basic concepts of CAD/CAM and their integration tools.

ANALYSIS OF GATE PAPERS

Exam Year	1 Mark Ques.	2 Mark Ques.	Total	Exam Year	1 Mark Ques.	2 Mark Ques.	Total
2003	9	23	46	2014 Set-3	6	4	14
2004	4	20	44	2014 Set-4	6	4	14
2005	11	36	83	2015 Set-1	5	6	17
2006	4	20	44	2015 Set-2	3	6	15
2007	7	15	37	2015 Set-3	5	6	17
2008	2	22	46	2016 Set-1	6	5	16
2009	3	14	31	2016 Set-2	4	5	14
2010	6	7	20	2016 Set-3	5	7	19
2011	6	12	30	2017 Set-1	5	6	17
2012	5	8	21	2017 Set-2	4	5	14
2013	7	9	25				
2014 Set-1	6	2	10				
2014 Set-2	6	3	12				

CONTENTS

Topics **Page No**

1. METAL CASTING

1.1 Introduction 01
1.2 Pattern and Pattern Allowances 01
1.3 Moulding 02
1.4 Fluidity of Molten Metal 04
1.5 Gating System 04
1.6 Time Required To Filling the Mould 05
1.7 Aspiration Effect 06
1.8 Riser 06
1.9 Various Casting Processes 07
1.10 Casting Defects 09

2. WELDING

2.1 Introduction 12
2.2 Shielded Metal Arc Welding (SMAW) 13
2.3 Submerged Arc Welding 13
2.4 Gas Metal Arc Welding (MIG) 13
2.5 TIG Welding 14
2.6 Electroslag Welding 14
2.7 Solid State Welding 15
2.8 Thermit Welding 16
2.9 Resistance Welding 17
2.10 Electron Beam Welding 19
2.11 Brazing and Soldering 19
2.12 Gas Welding /Oxy- Acetylene Welding 19
2.13 Welding Defects 20

3. METAL FORMING

3.1 Introduction 22
3.2 Rolling 23
3.3 Extrusion 26
3.4 Wire Drawing 28
3.5 Forging 28
3.6 Sheet Metal Forming 30
3.7 Classification of Sheet Metal Forming & the Stress Induced 32

4. METAL CUTTING

4.1 Metal Cutting With Single Point Cutting Tool 33

4.2 Drilling and Related Processes 40
4.3 Grinding 42
4.4 Milling 43
4.5 Non –Traditional Machining Processes 45

5. POWDER METALLURGY

5.1 Introduction 48
5.2 Step Followed in Powder Metallurgy Technique 48
5.3 Advantages and Disadvantages of Powder Metallurgy 49

6. METROLOGY (LIMITS, FITS & TOLERANCE)

6.1 Important Terms 51
6.2 Fits 51
6.3 Grades of Tolerance 52
6.4 Fundamental Deviation 53
6.5 Direct and In-Direct Measurement 53

7. GATE QUESTIONS 55

8. ASSIGNMENT QUESTIONS 131

1 METAL CASTING

1.1 INTRODUCTION

In casting, metals or alloys are initially heated to melt them. The Molten Metal is then poured into a mould cavity, where it is allowed to solidity. After solidification, the product is taken out of the mould cavity and subjected to finishing operation as per requirement.

1.1.1 CASTING TERMINOLOGY

1) **Pattern:** A pattern is the replica of the part to be cast It is used to mould the sand mixture into the shape of the casting
2) **Flask:** The rigid metal or wood frame that holds the molding aggregate is called flask.
3) **Mould:** A mould refers to avoid created in a compact sand mass which, when filled with molten metal, will produce a casting. The mould cavity lies within the mould and holds the liquid material.
4) **Gating system:** Gating system is the network of channels used to deliver the molten metal into the mould cavity. It consists of pouring basin, sprue, runner and gate.
5) **Core:** Core is a sand mass which is inserted into the module to produce identical shaped regions such as holes or passage for water cooling or otherwise define the interior surface of the casting.
6) **Core prints:** Core prints are the projected parts added to the pattern which is used to locate the core within the mould.
7) **Chaplet:** Chaplets are used to support cores inside the mould cavity to take care of its own weight and overcome the metallostatic forces.
8) **Chills:** Chills are metallic object which are placed in the mould to increase the cooling rate of the castings to provide uniform or desired cooling rate.
9) **Riser:** It is a reservoir of molten metal provided 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 solidification.

1.2 PATTERN AND PATTERN ALLOWANCES

A pattern is a replica of the object to be made by the casting process with some modification. The main modifications are:
(i) The addition of pattern allowances
(ii) The provision of core prints

1.2.1 PATTERN ALLOWANCES

The dimensions of the pattern are different from the final dimensions of the casting required. This is known as pattern allowances. The pattern allowances can be classified into:

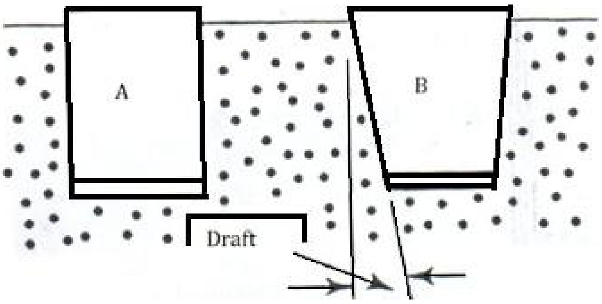
1) **Shrinkage Allowance:** The shrinkage allowance is provided to cater for the contraction of the casting .The overall contraction of the casting takes place in three stages:

a. Contraction of liquid when its temperature changes from pouring temperature to freezing temperature (liquid shrinkage).
b. Contraction due to phase change from liquid to solid at freezing temperature.
c. Contraction of solid from freezing temperature to room temperature (solid shrinkage).

It is to be noted that first two stages of shrinkage are compensated by riser and last stage i.e. Solid shrinkage is compensated by providing allowances over the pattern.

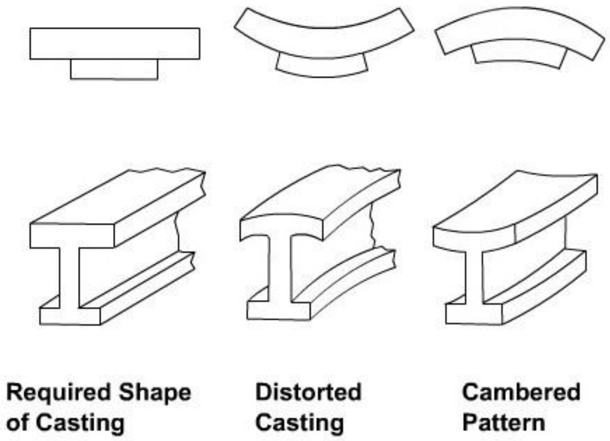
2) **Draft Allowance:** By draft we mean the taper provided by the patternmaker on

all vertical surfaces so that it can be removed from the sand without tearing away the sides of the mould and without excessive rapping by the moulder. A draft is thus given to provide light clearance for the pattern as it is lifted up.



3) **Machining Allowance:** Machining or finishing allowance is the extra material added to certain parts of the casting to enable their finishing or machining to the required size.

4) **Distortion Allowance:** Sometimes castings get distorted cooling due to their typical shape. For example, if the casting has the form of the letter U, it will tend to contract at the closed end causing the vertical legs to look slightly inclined and out of parallel, This can be prevented by making the legs of the U-pattern converge slightly (in –wards) so that the casting after distortion will have its sides parallel (fig). This allowance is considered only for castings that tend to get distorted and have an irregular shape.



5) **Shaking or rapping allowance:** When the pattern is rapped for easy withdrawal, the mould cavity gets slightly larger in size. This also causes the casting size to increase. To compensate for this growth, the pattern should initially be made slightly smaller than the required size.

1.3 MOULDING

1.3.1 TYPES OF MOULDING

1) **Green sand moulding:** Green sand is the moulding sand which has been freshly prepared from silica grains, clay and moisture. In a green sand mould, metal is poured immediately and the casting taken out.
Composition:
Sand: 70-80%
Clay: 18-30%
Water: 6-8%
Additives: 1-5%

2) **Dry sand moulding:** These are the green sand moulds which are completely dried by keeping in an oven. These moulds generally have higher strengths than green sand moulds and preferred because they are less likely to be damaged during handling

3) **Carbon Dioxide Moulding:** This method of moulding is widely used in making cores .The principle of working of the CO_2 process is based on the fact that if CO_2 gas is passed through a sand mix containing sodium silicate as the binder, immediate hardening of sand takes place as a result of the chemical action between sodium silicate and CO_2 The bonding strength obtained by the hardening action is sufficient to eliminate the need for any drying or baking of the mould & the metal can be immediately poured. The chemical reactions taking place are of complex nature, though the main reaction can be represented in simplified form as

$$Na_2O \times mSio_2 \times xH_2O + CO_2 \rightarrow Na_2CO_3 + mSio_2xH_2O$$

1.3.2 TYPES OF MOULDING SAND

1) **Facing sand:** This sand is used next to the pattern to obtain cleaner and smoother casting surfaces. Generally sea coal or coal dust (finely divided bituminous coal of 2 to 8%) is mixed with the system sand to improve the mould ability and surface finish. The sea coal being carbonaceous, will slowly burn due to the heat from the molten metal and give off small amounts of reducing gases. This creates a small gas pressure in the surroundings of the cavity such that molten metal is prevented from entering into the silica grains or fuse with them. This helps in generating good casting surface and also lets the moulding sand peel off from the casting during shake out.
2) **Backing sand:** This is normally the reconditioned foundry sand and is used for ramming the bulk of the moulding flask. The moulding flask is completely filled with backing sand after the pattern is covered with a thin layer of facing sand. It usually contains the burnt facing sand, moulding sand and clay.
3) **Parting sand:** This is the material, which is sprinkled on the pattern and to the parting surfaces of the mould halves before they are prepared to prevent the adherence of the moulding sand. This helps in easy withdrawal of the pattern and easier separation of the cope and drag flasks at parting surface. It is essentially a nonstick material such as washed silica grains.
4) **Mould Wash:** Purely carbonaceous materials such as sea coal, finely powdered graphite or proprietary compounds are also applied on to the mould cavity after the pattern is withdrawn. This is called the mould wash and is done by spraying, swabbing or painting. These are used essentially for the following reasons:
   1. To prevent metal penetration into the sand grains and thus ensure a good casting finish and
   2. To avoid mould –metal interaction and prevent sand fusion.

1.3.3 PROPERTIES OF MOULDING SAND

1) **Refractoriness:** It is the ability of the moulding material to withstand the high temperatures of the molten metal so that it does not cause fusion.
2) **Green strength:** The moulding sand that contains moisture is termed as green sand. The green sand should have enough strength so that constructed mould retains its shape.
3) **Dry strength:** When the moisture in the moulding sand is completely expelled, it is called dry sand. When molten metal is poured into a mould, the sand around the mould cavity is quickly converted into dry sand as the moisture in the sand immediately evaporates due to the heat in the molten metal. At this stage, it should retain the mould cavity and the same times withstand the metallostatic forces.
4) **Hot Strength:** After all the moisture is eliminated, the sand would reach a high temperature when the metal in the mould is still in the liquid state. The strength of the sand that is required to hold the shape of the mould cavity then is called hot strength.
5) **Permeability:** During the solidification of a casting large amounts of gases are to be expelled from the mould. The gases are those which have been absorbed by the metal in the furnace, air absorbed from the atmosphere and steam and other generated by the moulding and core sands. If these gases are not allowed to escape from the mould they would be trapped inside the casting and cause defects. The moulding sand should be sufficiently porous so that the gases are allowed to escape from the mould. This gas evolution

capability of the moulding sand is termed as permeability.

6) **Collapsibility:** This is the ability of sand to decrease in volume under effect of compressive forces developed due to shrinkage of metal during solidification process. A lesser value of collapsibility in moulding sand results in cracks formation in the casting.

1.4 FLUIDITY OF MOLTEN METAL

Fluidity is the capability of the molten metal to fill the mould cavity. Fluidity depends on the molten metal properties and mould properties. Molten metal properties which affect the fluidity are the viscosity, heat content of the molten metal, surface tension etc. and mould properties which affect the fluidity are the permeability of the mould.

Fluidity is quantified by the Spiral Test. In this test spiral cavity is prepared and molten metal is poured in it. The length of the spiral cavity covered by the molten metal represents its fluidity.

Fluidity Spiral

1.5 GATING SYSTEM

Gating system refers to all those elements, which are connected with the flow of molten metal from the ladle to the mould cavity .The various elements of gating system are:

1. Pouring Basin
2. Sprue
3. Sprue Base Well
4. Runner
5. In gate

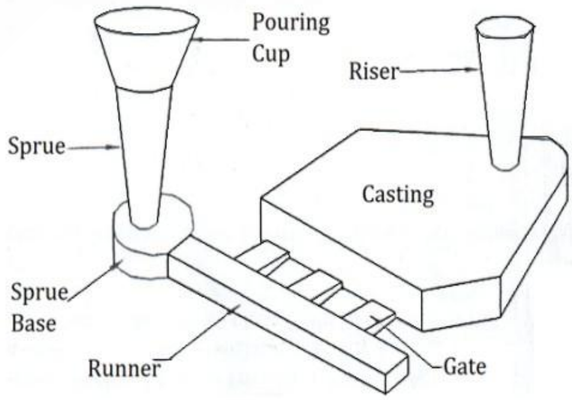
1.5.1 ELEMENTS OF GATING SYSTEM

1) **Pouring Basin:** The molten metal is not directly poured into the mould cavity because it may causemould erosion .The molten metal is poured into a pouring basin, which acts as a reservoir from which it moves smoothly into the sprue.

2) **Sprue:** Sprue is the channel through which the molten metal is brought into the parting plane where it enters the runners and gates ultimately reach the mould cavity.

If the sprue were to be straight cylindrical then the metal flow would not be full at the bottom, but some low-pressure area would be created around the metal in the sprue. Since the sand mould is permeable, atmospheric air would be breathed into this low-pressure area which would then be carried to the mould cavity. To eliminate this problem of air aspiration, the sprue is tapered to gradually reduce the cross section as it moves from top of the cope.

3) **Sprue Base Well:** This is a reservoir for metal at the bottom of the sprue provided to reduce the momentum of the molten metal.



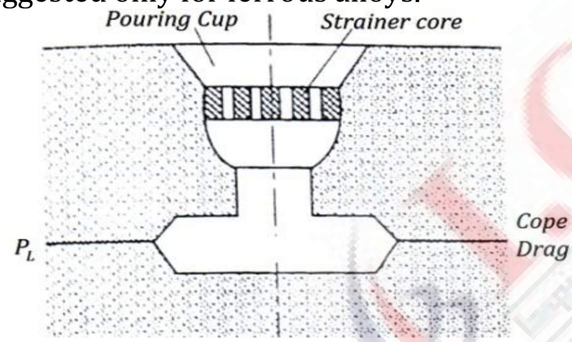
4) **Runner:** It is generally located in the horizontal plane (parting plane.) which connects the sprue to its in gates. Thus allowing the metal enter the mould cavity. The runners are normally made trapezoidal in cross section

5) **Gates or in-gates:** These are the openings through which the molten metal enters the mould cavity.

1.5.2 TYPE OF GATES

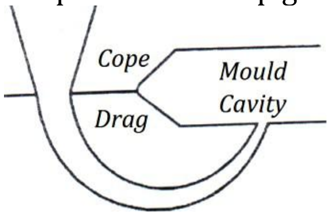
1.5.2.1 TOP GATE

This is the type of gating through which the molten metal enters the mould cavity from the top.
Since the first metal entering the gate reaches the bottom and the hotter metal is at the top, a favorable temperature gradient towards the gate is achieved. Also, the mould is filled very quickly. But as the metal falls directly into the mould cavity through a height, it is likely to have some mould erosion. Also because it cause turbulence in the mould cavity, it is prone to form dross and as such the top gate is not advisable for those materials, which are likely to form excessive dross. It is not suggested for nonferrous materials and is suggested only for ferrous alloys.



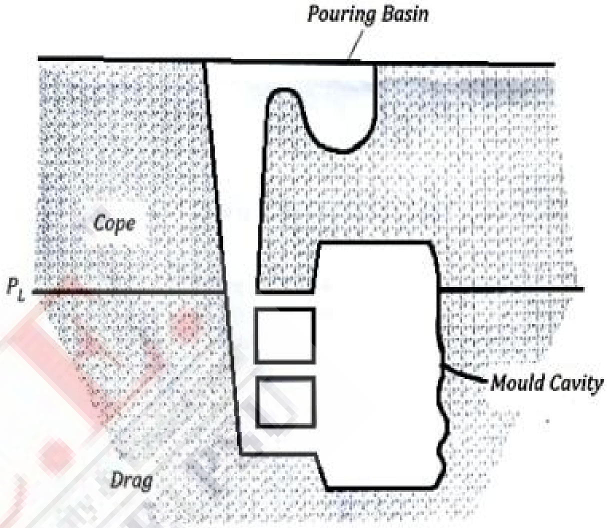
1.5.2.2 BOTTOM GATE

When molten metal enters the mould cavity slowly, it would not cause and mould erosion. Bottom gate is generally used for very deep moulds. It takes somewhat higher time for filling of the mould. These gates may cause unfavorable temperature gradients compared to the top gating.



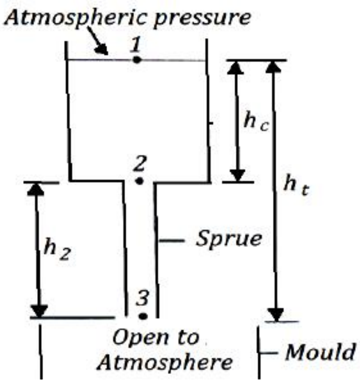
1.5.2.3 STEP GATE

Such gates are used for heavy and large castings. The molten metal enters mould cavity through a number of in gates which are arranged in vertical steps as shown in the figure.
The size of in gates are normally increased from top to bottom such that the metal enters the mould cavity from the bottom most gate and then progressively moves to the higher gates .This ensures a gradual filing of the mould without any mould erosion and produces a sound casting .



1.6 TIME REQUIRED TO FILLING THE MOULD

1) Top Gating system:



(i) Velocity of liquid metal at point 3

$$V_3 = v_g = \sqrt{2gh_t}$$

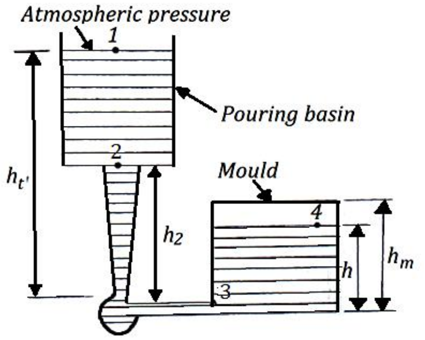
(ii) Time taken to fill the mould

$$t_f = \frac{v}{A_g V_3}$$

Where v = volume of liquid flowing

A_g = Area of gates / sprue at exit

2) Bottom Gating System:



Time required to fill

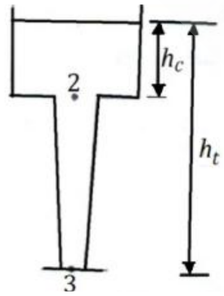
$$t_f = \frac{A_m}{A_g}\frac{1}{\sqrt{2g}}2\left(\sqrt{h_t} - \sqrt{h_t - h_m}\right)$$

Where A_m = Cross sectional area of mould/ casting

A_g = Cross sectional Area of gate.

1.7 ASPIRATION EFFECT

Since the moulds are made of sands, it becomes important that pressure in the liquid molten metal does not fall below the atmospheric pressure. If this happens the gases produced during the process may enter from the mould into the molten creating porosities in the casting which is called as aspiration effect. To avoid this aspiration effect the following ratio should obeyed:



$$\frac{A_3}{A_2} = \sqrt{\frac{h_c}{h_t}}$$

1.8 RISER

Riser is an important element of foundry. Riser performs following job in the casting

1) It acts as reservoir and provides molten metal during the liquid shrinkage and shrinkage during the phase change.
2) On seeing the riser, any one can say that whether the casting is full or not.
3) In the initial stages of pouring, riser allows the air, steam and gases to pass out of the mould.

1.8.1 TYPES OF RISER

There are basically two types of riser
(i) Open riser
(ii) Blind riser
When the top of the riser is exposed to atmosphere then it is called open riser and when the riser is not open to atmosphere and it is surrounded from all sides by the moulding sand then it is called blind riser.

1.8.2 DESIGN OF RISER

Design of riser involves the estimation of shape of riser, size of riser and location of riser. As shape of riser is concern, the best shape of riser is spherical but, on account of the difficulties in the production, cylindrical riser is most commonly used.
The riser should be such that the heat loss through it should be minimum and molten metal in the riser should be in molten state as long as possible for a given shape of riser; the dimensions of riser should, however be chosen so as to give a minimum surface area to volume ratio and the minimum volume should be required from the shrinkage consideration.
The optimum diameter of riser for given casting can be obtained by following rules.

1. **Chvorinov's law:**
   It state that solidification time of the casting $(t_s) = K\left(\frac{V}{S-A}\right)^2$
   Where
   V = Volume of the casting
   S.A = surface area of the casting
   K = Solidification constant

2) **Caine's Law:**
   Caine's Law state that cooling rate of the casting is proportional to ratio of it is surface area to volume ratio.

Cooling rate $Q \propto \frac{SA}{V}$

If this ratio is higher for the casting than riser than it can be estimated that casting will cool prior to riser.

Caine's law also gives the cooling characteristic of riser in terms of freezing ratio, which can be defined as the ratio of cooling rate of casting to cooling rate of riser

$$\text{Freezing ratio } (X) = \frac{\left(\frac{SA}{V}\right)_{casting}}{\left(\frac{SA}{V}\right)_{Riser}}$$

And in order to compensate shrinkage, riser should solidify at last and hence freezing ratio should be greater than unity. Cain's also developed an empirical relationship for freezing ratio should be greater than unity.

Caine's also developed a empirical relationship for freezing ratio as follows:

$$\text{Freezing Ratio } (X) = \frac{\left(\frac{SA}{V}\right)_{casting}}{\left(\frac{SA}{V}\right)_{Riser}}$$

Where $y = \frac{V_{Riser}}{V_{casting}}$

and a, b, and c are the constant whose values are depends on types of material

For steel a = 0.1, b = 0.03, c = 1

For grey cast Iron a=0.33, b=0.030, c =1

For aluminum a = 0.10, b = 0.06,c = 1.08

1.9 VARIOUS CASTING PROCESSES

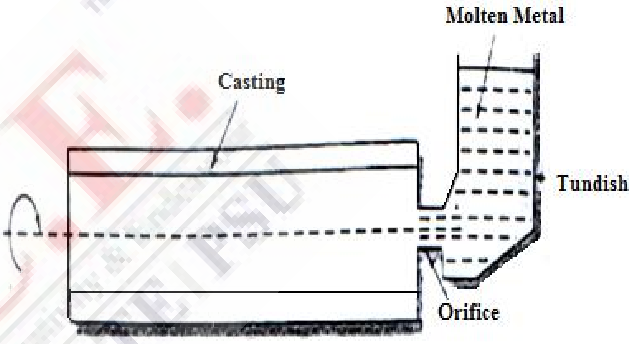
1.9.1 CENTRIFUGAL CASTING

This is a process where the mould is rotated rapidly about is central axis as the metal is poured into it. Because of the centrifugal force , a continuous pressure will be acting on the metal as it solidifies. The slag oxides and other inclusions being lighter, gets separated from the metal and segregates towards the centre. There are three main types of centrifugal casting processes .They are

1. True centrifugal casting ,
2. Semi –centrifugal casting , and
3. Centrifuging

1.9.2 TRUE CENTRIFUGAL CASTING

This is normally used for the making of hollow pipes, tubes, hollows bushes ,etc, which are axi-symmetric with a concentric hole .Since the metal is always pushed outward because of the centrifugal force, no core needs to be used for making the concentric hole.



As no gates, riser and centre core is used; the casting yield is nearly 100 percent. The wall thickness of cylindrical job is governed by the quantity of metal that is poured into the rotated mould. The selection of proper rotational speed is very important because at lower speed raining of molten metal takes place and molten metal will not take the required shape and at higher speed the defects like' hot tear ' may be produces on the surface of the casting.

Advantages:

1) The mechanical properties of centrifugally cast products are better compared to other process, because the inclusions such as slag and oxides get segregated towards the center and can be easily removed by machining.
2) No cores are required for making concentric holes in the case of true centrifugal casting.
3) There is no need for gates and runners, which increase the casting yield, reaching almost 100%

Limitations:

1) Only certain shape which are axi-symmetric and having concentric holes are suitable for true centrifugal casting
2) The equipment is expensive and thus is suitable only for large scale production.

1.9.3 SEMI –CENTRIFUGAL CASTING

Semi centrifugal casting is used for jobs which are more complicated than these possible in true centrifugal casting. But are axi-symmetric in nature. It is not necessary that these should have a central hole, which is to be obtained with the help of a core. The moulds made of sand or metal are rotated about a vertical axis and the metal enters the mould through the central pouring basin.

1.9.4 CENTRIFUGING

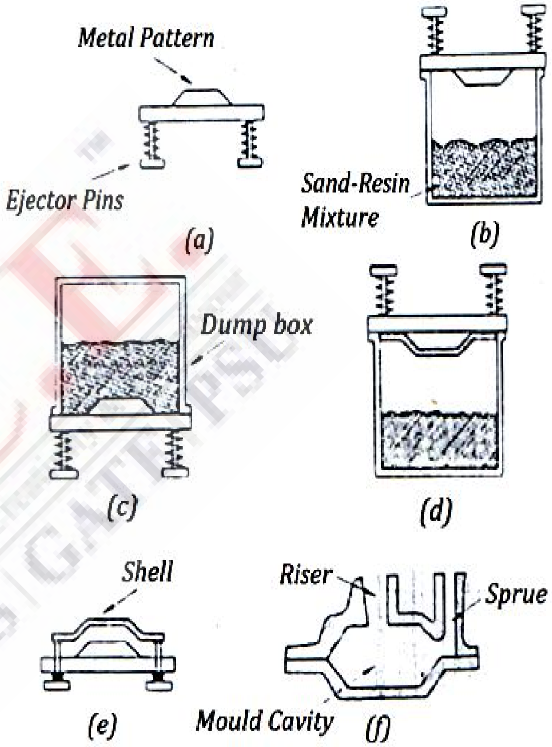
The centrifuging process is used in order to obtain higher metal pressures during solidification when casting shapes are not axis symmetrical. This is suitable only for small jobs of any shape. A number of such small jobs are joined together by means of radial runners with a central sprue on a revolving table. The Jobs are uniformly placed on the table around the periphery so that their masses are properly balanced.

1.9.5 SLUSH CASTING

Hollow casting with thin walls can be made by permanent mold casting using this principle, process called slush casting. The molten metal is poured into the metal mould and after desired thickness of solidified skin is obtained, the mould is in inverted or slung and the remaining liquid metal is poured out. The mould halves are then opened and the casting is removed.
Slush casting is suitable for small productions runs and is generally used for making ornamental and decorative objects (such as lamp bases and stems) and toys from low melting point metals such as zinc, tin and lead alloys.

1.9.6 SHELL MOULDING

Shell mould casting is a variation of sand casting, here the mould is made of a mixture of dried silica sand and phenolic resin, formed into this mould shells which are clamped together for pouring purposes. The different steps involved in shell moulding are:



Step1: Heating a metal pattern to 200 - 250°C (fig a) and then the metal Pattern is turned down and clamped over the open end of the dump box (fig b) filled with sand –resin mixture.

Step2: The dump box is inverted (fig c) so that the dry sand-resin mixture falls on the metal pattern. The sand resin mixture when comes in contact with the heated pattern, softens and fuses to from a soft and uniform shell on the surface of the pattern. Heat first causes resin to become sticky; then additional heat hardens it.

Step3: The dump box is turned over again (fig d) and excess sand –resin mixture falls back leaving a shell adhering closely to the Pattern.

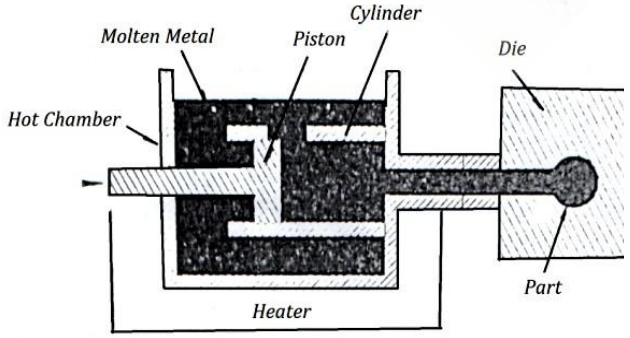
Step4: Pattern and shell are then heated in an oven at 300°C for one minute and then shell is removed from the pattern with the help of ejector pins (from e).
Step5: A complete mould is made in two or more pieces that are assembled together (fig f) and then the molten metal is poured into the cavity.

1.9.7 DIE-CASTING

Die-casting involves the preparation of components by injecting molten meal at high pressure into a metallic die. Die-casting is closely related to permanent mould casting, in that both the processes use reusable metallic dies.
In die-casting as metal is forced under pressure, any narrow sections, complex, shapes and fine surface details can easily be produced.
Die-casting are of two types
1. Hot chamber die-casting
2. Cold chamber die-casting

1.9.8 HOT CHAMBER PROCESS DIE-CASTING

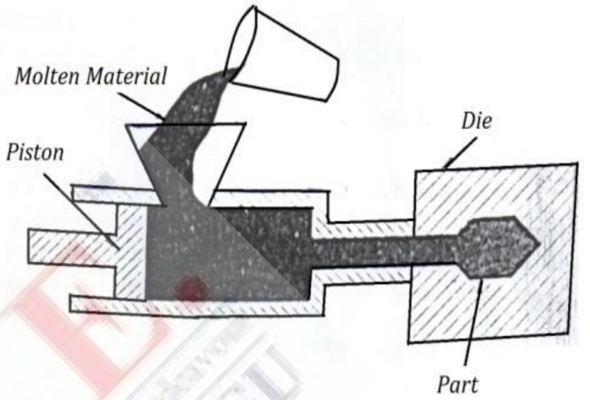
The hot chamber die-casting process is shown in Fig. When the piston is in the extreme left position, molten material in the hot chamber around the cylinder fills the cylinder.



As the piston moves forward, the die cavity is filled under pressure. When the die is filled, piston is returned and again cylinder is filled. The metal is solidified quickly and casting is removed from the die. This process is suitable for the materials having low melting temperature.

1.9.9 COLD CHAMBER DIE-CASTING

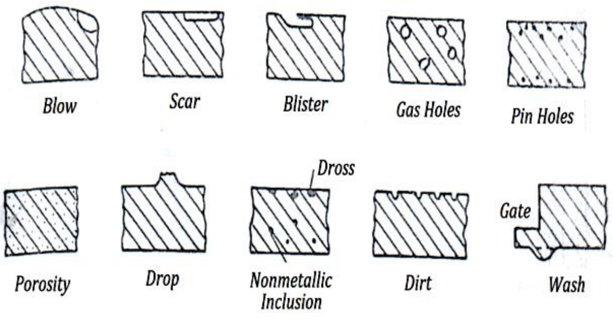
The set up for cold chamber die-casting is fig. The process is very much similar to the hot chamber die-casting method. The molten material is fed into the cold cylinder chamber from where it is forced into the die cavity .Cold chamber die-casting method is generally slower than the hot chamber die- casting method.

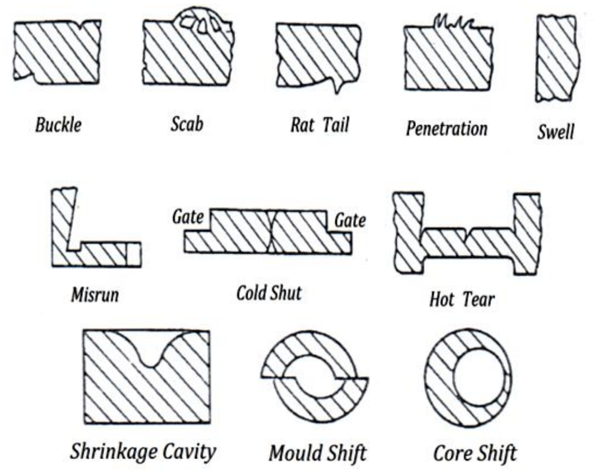


Cold chamber die-casting process differs from the hot chamber die-casting in the following respects:

1. Melting unit is not an integral part of the cold chamber die-casting machine. Molten metal is brought and poured into the die-casting machine with the help of ladles.
2. Molten metal poured into chamber of cold chamber die-casting machine is at the lower temperature as compared to the hot chamber –die- casting machine.
3. Pressure requirements in the case of cold chamber die- casting machine is higher than that of hot chamber die-casting machine.

1.10 CASTING DEFECTS





1. **Blow:** It is a fairly large, well- rounded cavity produced by the gases which displace the molten metal at the cope surface of a casting. Blow usually occur on a convex casting surface and can be avoided by having a proper venting and an adequate permeability. A controlled content of moisture and volatile constituents in the sand- mix also help in avoiding the below holes.
2. **Scar:** A shallow below, usually found on a flat casting surface, is referred to as a scar.
3. **Blister:** This is a scar covered by the thin layers of a metal.
4. **Gas holes:** These refer to the entrapped gas bubbles having a nearly spherical shape, and occur when an excessive amount of gases is dissolved in the liquid metal.
5. **Pin holes:** These are nothing but tiny blow holes, and occur either at or just below the casting surface. Normally, these are found in large numbers and are almost uniformly distributed in the entries casting surface.
6. **Porosity:** This indicates very small holes uniformly dispersed throughout a casting. It arises when there is a decrease in gas solubility during solidification.
7. **Drop:** An irregularly shaped projection of the cope surface of a casting is called a drop. This is caused by dropping of sand from the cope or other overhanging projections into the mould. An adequate strength of the sand and the use of gaggers can help in avoiding the drops.
8. **Inclusion:** It refers to nonmetallic particle in the metal matrix. It becomes highly undesirable when segregated.
9. **Dross:** Lighter impurities appearing on the top surface of a casting are called dross. It can be taken care of at the pouring stage by using items such as a strainer and a skim bob.
10. **Dirt:** Sometimes and particles drooping out of cope get embedded on the top surface of casting. When removed, these leave small angular holes, known as dirt's. Defects such as drop and dirt suggest that a well-designed Pattern should have as little apart as possible in the cope. Also, the most critical surface should be placed in the drag.
11. **Wash:** A low projection on the drag surface of a casting commencing near the gate is called a wash. This is caused by the erosion of sand due to the high velocity jet of liquid metal in bottom gating.
12. **Buckle:** This refers to a long, fairly shallow, broad, vee-shaped depression occurring in the surface of a flat casting of a high temperature metal .At this high temperature, an expansion of the thin layer of sand at the mould face takes places before the liquid metal at the mould face solidifies. As this expansion is obstructed by the flask, the mould face tends to bulge out, forming the vee shape, a proper amount of volatile additives in the sand –mix is therefore essential to make room for this expansion and to avoid the buckles.
13. **Scab:** This refers to the rough, this layer of a metal, protruding above the casting surface, on top of a thin layer of sand. The layer is held on to the casting by a metal stringer through the sand. A scab results when the up heaved sand is separated from the mould surface and the liquid metal flows into the space

between the mould and the displaced sand.

14. **Rat tail:** It is a long, shallow, angular depression normally found in a thin casting. The reason for its formation is the same as that for a buckle. The reason for its formation is the same as that for a buckle. Here, instead of the expanding sand up heaving, the compressed layer fails by one layer, gliding over the other.
15. **Penetrations:** If the mould surface is too soft and porous, the liquid metal may flow between the sand particles up to a distance, into the mould. This causes rough, porous projections and this defect is called penetration. The fusion of sand on a casting surface produces a rough, glossy appearance.
16. **Swell:** This defect is found on the vertical surface of casting if the moulding sand is deformed by the by the hydrostatic pressure caused by the high moisture content in the sand.
17. **Misrun:** Many a time, the liquid metal may, due to insufficient superheat, start freezing before reaching the farthest point of the mould cavity. The defect that thus results is termed as a misrun.
18. **Cold shut: For** a casting with gates at its two sides, the misrun may show up at the centre of the casting .When this happens, the defect is called a cold shut.
19. **Hot Tear:** A crack that develops in a casting due to high residual stress is called a hot tear.
20. **Shrinkage cavity:** An improper riser may give rise to a defect called shrinkage cavity, as already detailed.
21. **Shift:** A misalignment between two halves of a mould or of a core may give rise to a defective casting, as shown in Fig. Accordingly, the defect is called mould shift or a core shift.

GATE QUESTIONS

Topics **Page No**

Topics	Page No
1. ENGINEERING MATERIALS	56
2. METAL CASTING	61
3. METAL FORMING	75
4. SHEET METAL OPERATIONS	82
5. JOINING/WELDING	87
6. MACHINING AND MACHINE TOOL OPERATION	96
7. METROLOGY AND INSPECTION	112
8. CIMS	120
9. NONCONVENTIONAL MACHINING (EDM, HIGH ENERGY SAFE FORMING)	125

1 ENGINEERING MATERIALS

Q.1 During heat treatment of steel, the hardness of various structures in increasing order is
a) Martensite, fine pearlite, coarse pearlite, spherodite
b) Fine pearlite, Martensite, spherodite, coarse pearlite
c) Martensite, coarse pearlite, fine pearlite, spherodite
d) Spherodite, coarse pearlite, fine pearlite, martensite
[GATE-2003]

Q.2 Cold working of steel is defined as working
a) At its recrystallisation temperature
b) Above its recrystallisation temperature
c) Below its recrystallisation temperature
d) At two thirds of the melting temperature of the metal
[GATE-2003]

Q.3 Hardness of steel greatly improves with
a) Annealing b) cyaniding
c) Normalizing d) tempering
[GATE-2003]

Q.4 The percentage of carbon in gray cast iron is in the range of
a) 0.25% to 0.75%
b)1.25% to 1.75%
c) 3% to 4%
d) 8% to 10%
[GATE-2004]

Q.5 From the lists given below choose the most appropriate set of heat treatment process and the corresponding process characteristics
Process
P. Tempering
Q. Austempering
R. Martempering
Characteristics
1. Austenite is converted into bainite
2. Austenite is converted into martensite
3. Cementite is converted into globular structure
4. Both hardness and brittleness are reduced
5. Carbon is absorbed into the metal
a) P-3, Q-1, R-5 b) P-4, Q-3, R-2
c) P-4, Q-1, R-2 d) P-1, Q-5, R-4
[GATE-2004]

Q.6 When the temperature of a solid metal increases,
a) Strength of the metal decreases but ductility increases
b) Both strength and ductility of the metal decreases
c) Both strength and ductility of the metal increases
d) Strength of the metal increases but ductility decreases
[GATE-2005]

Q.7 The main purpose of spheroidising treatment is to improve
a) Hardenability of low carbon steels
b) Machinability of low carbon steels
c) Hardeability of high carbon steels
d) Machinability of high carbon steels
[GATE-2006]

Q.8 The ultimate tensile strength of a material is 400 MPa and the elongation up to maximum load is 35%. If the material obeys power law of hardening, then the true stress-true strain relation (stress in MPa) in the plastic deformation range is
a) $\sigma = 540\varepsilon^{0.30}$ b) $\sigma = 775\varepsilon^{0.30}$
c) $\sigma = 540\varepsilon^{0.35}$ d) $\sigma = 775\varepsilon^{0.35}$
[GATE-2006]

EXPLANATIONS

Q.1 (d)

Structure	**Rockwell harsness**
Coarse pearlite	RC15
Fine pearlite	RC25
Martensite	RC65

Q.2 (c)
Cold forming or cold working can be defined as the plastic deformation of metals and alloys below the recrystallization temperature of the metal/alloy.

Q.3 (b)

Q.4 (c)
Gray cast iron is the most widely used of all cast irons. In fact, it is common to speak of gray cast iron just as cast iron.
It contains 3 to 4 % C and 2.5 % Si.

Q.5 (c)

Process	**Characteristics**
P. Tempering	4. Both hardness and brittleness are reduced
Q. Austempering	1. Austenite is converted into bainite
R. Martempering	2. Austenite is converted into martensite

So, correct pairs are P-4, Q-1, R-2

Q.6 (a)

Q.7 (d)
Spheroidizing may be defined as any heat treatment process that produces a rounded or globular form of carbide.
High carbon steels are spheroidized to improve machinability, especially in continuous cutting operations.

Q.8 (b)
$\epsilon = \ln(1+\epsilon_0)$
$= \ln(1+0.35) = 0.3$
But at UTS $n = \epsilon$
Hence $n = \epsilon = 0.3$
Also $\sigma = \sigma_0(1+\epsilon_0)$
$= 400(1+0.35)$
$= 540$MPa
Now, $\sigma = K\epsilon^n$
$540 = K(0.3)^{0.3}$
$\Rightarrow K = 774.97$
Hence $\sigma = 775\epsilon^{0.3}$
Where, σ = true stress
ϵ = true strain

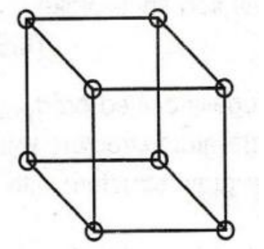
Q.9 (d)

Column I	**Column II**
P. Charpy test	4. Toughness
Q. Knoop test	2.Micro hardness
R. Spiral test	1. Fluidity
S. Cupping test	3. Formability

So, correct pairs are P-4, Q-2,R-1,S-3

Q.10 (b)
The carbon alloy having less than 2% carbon are called "steels" and those containing over 2% carbon are called cast irons.
Now, steel may further be classified into two groups.
i) Steels having less than 0.83% carbon are called "hypo eutectoid steels"
ii) Those having more than 0.83% carbon are called "hyper-eutectoid steels"

Q.11 (b)



Simple Cubic

ASSIGNMENT QUESTIONS

Q.1 With increase in side cutting edge angle the surface finish of a component?
a) improves
b) deteriorate
c) remains Same
d) none of the above

Q.2 The nose radius is ASA tool signature is indicated in
a) the first position
b) the middle
c) the last position
d) the last but one position

Q.3 Angle between the face and flank of the single point cutting tool is known as
a) Rake angle b)Clearance angle
c) Lip angle d) Point angle

Q.4 The angle between the face of the tool and the plane parallel to the base of the cutting tool is called
a) Rake angle
b) Cutting edge angle
c) Clearance angle
d) Lip angle

Q.5 For cutting of brass with single-point cutting tool on a lathe, tool should have
a) negative rake angle
b) positive rake angle
c) zero rake angle
d) zero side relief angle

Q.6 Which among the following is slowest speed operation in lathe?
a) Turning b)Thread cutting
c) Taper turning d) Knurling

Q.7 When machining a hard and brittle metal like cast iron, the type of chips produced is
a) continuous chips
b) discontinuous chips
c) fine chips
d) continuous chips with built-up edge

Q.8 Single point thread cutting tool should ideally have
a) zero rake b)positive rake
c) negative rake d) normal rake

Q.9 The relationship for cutting tool life is
a) $VT^n = C$ b) $V^2T^{\frac{1}{n}} = C$
c) $\frac{V}{T^n} = C$ d) $\frac{T^n}{V} = C$

Q.10 The function of chip-breaker in a cutting tool is
a) to get long chips
b) to break the chips into short segments
c) to remove chips from the bed
d) none of the above

Q.11 In metal cutting operation, the approximate ratio of heat distributed among chip, tool and work in that order is
a) 80:10:10 b) 33:33:33
c) 20:60:10 d) 10:10:80

Q.12 In Taylor's tool life equation is VT^n = constant.
What is the value of n for ceramic tools?
a) 0.15 to 0.25 b) 0.4 to 0.55
c) 0.6 to 0.75 d) 0.8 to 0.9

Q.13 In relation $VT^n = C$, the value of n for ceramic tools
a) 0.15 to 0.25 b) 0.4 to 0.55
c) 0.6 to 0. 75 d) 0.8 to 0.9

Q.14 Cutting tool material18-4-1 HSS has which one of the following composition

EXPLANATIONS

Q.1 (a)

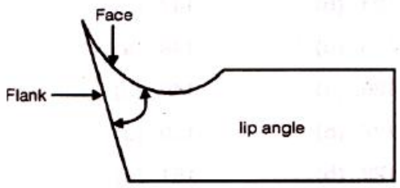
Q.2 (c)

Tool signature in ASA system

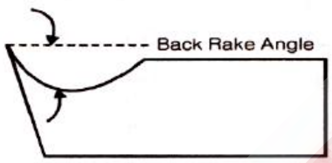
$\alpha_b - \alpha_s - \gamma_e - \gamma_s - C_e - C_s - R$

In thus nose radius comes in last position.

Q.3 (c)



Q.4 (a)



Q.5 (c)

For machining high strength material, tool stability is the major criteria for example in machining brass and other Copper alloys 0° rake angles are used.

If the tool material is brittle like ceramics and carbides negative back rake angles are provided.

Q.6 (b)

Q.7 (b)

Discontinuous chips are formed when machining brittle material at low speed.

Q.8 (b)

It is true form-cutting procedure, no rake should be ground on the tool, and the top of the tool must be horizontal and be set exactly in line with the axis of rotation of the work; otherwise, the resulting thread profile will not be correct. An obvious disadvantage of this method is that the absence of side and back rake angle results in poor cutting (except on cast iron or brass). The surface finish on steel usually will be poor.

Q.9 (a)

The relation between cutting speed and cutting tool life is expressed by Taylor's tool life equation

$VT^n = C$

Where V = Cutting speed (m/min)

T = Tool life (min)

n = Taylor's tool life exponent

C = Taylor's constant

Q.10 (b)

A continuous type of chip is quite troublesome, they should be broken into comparatively small pieces for the ease of handling and to prevent it from becoming a work hazard, hence chip breakers are used to reduce the chips into small pieces as they are formed.

Q.11 (a)

Maximum heat is carried away be chip. i.e., 80% of the total heat generated is carried away by the chip

Q.12 (c)

In Taylor's tool life equation is

n = 0.08 – 0.20 → for H. S. S.

n = 0.20 – 0.60 → for Carbides

n = 0.50 – 0.60 → for Ceramics

Q.13 (c)

In Taylor's too! life equation is

n = 0.08 — 0.20 → for H.S.S.

n = 0.20 — 0.60 → for Carbides

n = 0.60 — 0.80 →for Ceramics

Q.14 (a)