METAL CASTING
&
WELDING

Prepared by
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MANUFACTURING PROCESS			
Course Code	**BME302**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2*:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 8-10 Lab slots	Total Marks	100
Credits	04	Exam Hours	03
* One additional hour may be considered wherever required			

Course objectives:

•To provide knowledge of various casting process in manufacturing.
•To provide in-depth knowledge on metallurgical aspects during solidification of metal and alloys, also to provide detailed information about the moulding processes.
•To acquaint with the basic knowledge on fundamentals of metal forming processes and also tostudy various metal forming processes.
•To impart knowledge of various joining process used in manufacturing.
•To impart knowledge about behaviour of materials during welding, and the effect of process
•parameters in welding

Teaching-Learning Process (General Instructions)

These are sample Strategies; that teachers can use to accelerate the attainment of the various course outcomes.

1.Lecturer method (L) does not mean only traditional lecture method, but different type ofteaching methods may be adopted to develop the outcomes.
2.Arrange visits to nearby power plants, receiving station and substations to give briefinformation about the electrical power generation.
3.Show Video/animation films to explain functioning of various machines
4.Encourage collaborative (Group Learning) Learning in the class
5.Ask at least three HOTS (Higher order Thinking) questions in the class, which promotes criticalthinking
6.Adopt Problem Based Learning (PBL), which fosters students Analytical skills, develop thinkingskills such as the ability to evaluate, generalize, and analyze information rather than simplyrecall it.
7.Topics will be introduced in a multiple representation.
8.Show the different ways to solve the same problem and encourage the students to come up withtheir own creative ways to solve them.
9.Discuss how every concept can be applied to the real world - and when that's possible, it helpsimprove the students' understanding.
10.Individual teacher can device the innovative pedagogy to improve the teaching-learning.

MODULE-1	8 HOURS

Introduction & basic materials used in foundry: *Introduction: Definition, Classification of manufacturing processes. Metals cast in the foundry-classification, factors that determine the selection of a casting alloy. Introduction to casting process & steps involved – (Brief Introduction)- Not for SEE*
Patterns: Definition, classification, materials used for pattern, various pattern allowances and their importance.
Sand moulding: Types of base sand, requirement of base sand. Binder, Additive's definition, need and types; preparation of sand moulds. Molding machines- Jolt type, squeeze type and Sand slinger.
Study of important moulding process: Green sand, core sand, dry sand, sweep mould, CO2mould, shell mould, investment mould, plaster mould, cement bonded mould.
Cores: Definition, need, types. Method of making cores,
Concept of gating (top, bottom, parting line, horn gate) and risers (open, blind) Functions and types.

Teaching - Learning Process	Understanding, Remembering Chalk & Talk Method / Power point presentation/ You tube videos
MODULE-2	**8HOURS** 14

Melting furnaces: Classification of furnaces, Gas fired pit furnace, Resistance furnace, Coreless induction furnace, electric arc furnace, constructional features & working principle of cupola furnace.
Casting using metal moulds: Gravity die casting, pressure die casting, centrifugal casting, squeeze casting, slush casting, thixocasting, and continuous casting processes. Casting defects, their causes and remedies.

Teaching-Learning Process	. Understanding, Remembering Chalk & Talk Method / Power point presentation/ You tube videos
MODULE-3	**8 HOURS**

METAL FORMING PROCESSES
Introduction of metal forming process*:* Mechanical behaviour of metals in elastic and plastic deformation, stress-strain relationships, Yield criteria, Application to tensile testing, train rate and temperature in metal working; Hot deformation, Cold working and annealing.
Metal Working Processes*:* Fundamentals of metal working, Analysis of bulk forming processes like forging, rolling, extrusion, wire drawing by slab method,
Other sheet metal processes*:* Sheet metal forming processes (Die and punch assembly, Blanking, piercing, bending etc., Compound and Progressive die), High Energy rate forming processes.

Teaching - Learning Process	Understanding, Remembering Chalk & Talk Method / Power point presentation/ You tube videos
MODULE-4	**8 HOURS**

JOINING PROCESSES
Operating principle, basic equipment, merits and applications of: Fusion welding processes: Gas welding - Types – Flame characteristics; Manual metal arc welding – Gas Tungsten arc welding - Gas metal arc welding – Submerged arc welding

Teaching - Learning Process	Understanding, Remembering Chalk & Talk Method / Power point presentation/ You tube videos
MODULE 5	**8 HOURS**
Weldability and thermal aspects: Concept of weldability of materials; Thermal Effects in Welding (Distortion, shrinkage and residual stresses in welded structures); Welding defects and remedies. ***Allied processes***: Soldering, Brazing and adhesive bonding **Advance welding processes:** Resistance welding processes, friction stir welding (FSW).	
Teaching-Learnin g Process	Understanding, Remembering Chalk & Talk Method / Power point presentation/ You tube videos

PRACTICAL COMPONENT OF IPCC

Course objectives:

• Impart fundamental understanding of various casting, welding and forming processes
• To provide in-depth knowledge on metallurgical aspects during solidification of metal and alloys
• Discuss design methodology and process parameters involve in obtaining defect free component

Sl.NO	Experiments
1	Preparation of sand specimens and conduction of the following tests: Compression, Shear and Tensile tests on Universal Sand Testing Machine.
2	To determine permeability number of green sand, core sand and raw sand.
3	To determine AFS fineness no. and distribution coefficient of given sand sample.
4	Studying the effect of the clay and moisture content on sand mould properties
5	Use of Arc welding tools and welding equipment Preparation of welded joints using Arc Welding equipment L-Joint, T-Joint, Butt joint, V-Joint, Lap joints on M.S. flats
6	Foundry Practice: Use of foundry tools and other equipment for Preparation of molding sand mixture. Preparation of green sand molds kept ready for pouring in the following cases: 1. Using two molding boxes (hand cut molds). 2. Using patterns (Single piece pattern and Split pattern).
7	Preparation of green sand molds kept ready for pouring in the following cases: 1. Incorporating core in the mold.(Core boxes).
8	Forging Operations: Use of forging tools and other forging equipment. Preparing minimum three forged models involving upsetting, drawing and bending operations.
Demo experiments for CIE	
9	Demonstration of forging model using Power Hammer.
10	To study the defects of Cast and Welded components using Non-destructive tests like: a) Ultrasonic flaw detection b) Magnetic crack detection c) Dye penetration testing

11	Mould preparation of varieties of patterns, including demonstration
12	Demonstration of material flow and solidification simulation using Auto-Cast software

Course outcomes (Course Skill Set):

At the end of the course, the student will be able to:

CO1: Describe the casting process and prepare different types of cast products. Acquire knowledge on Pattern, Core, Gating, Riser system and to use Jolt, Squeeze, and Sand Slinger Moulding machines.

CO2: Compare the Gas fired pit, Resistance, Coreless, Electrical and Cupola Metal Furnaces. Compare the Gravity, Pressure die, Centrifugal, Squeeze, slush and Continuous Metal mold castings.

CO3: Understand the Solidification process and Casting of Non-Ferrous Metals.

CO4: Describe the Metal Arc, TIG, MIG, Submerged and Atomic Hydrogen Welding processes etc. used in manufacturing.

CO5: Describe the methods of different joining processes and thermal effects in joining process

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of the IPCC (maximum marks 50)

• IPCC means practical portion integrated with the theory of the course.

• CIE marks for the theory component are **25 marks** and that for the practical component is **25 marks**.

• 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests, each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.

• Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.

• The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

CIE for the practical component of the IPCC

• **15 marks** for the conduction of the experiment and preparation of laboratory record, and **10 marks**

for the test to be conducted after the completion of all the laboratory sessions.

• On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.

• The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to **15 marks**.

• The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be conducted for 50 marks and scaled down to **10 marks.**

• Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.

• The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours**)

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to 50 Marks

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component.

CIE for the practical component of IPCC

- **On completion of every experiment/program in the laboratory, the students shall be evaluated and marks shall be awarded on the same day. The15 marks are for conducting the experiment and preparation of the laboratory record, the other 05 marks shall be for the test conducted at the end of the semester.**
- **The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to 15 marks.**
- **The laboratory test (duration 03 hours) at the end of the 15th week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 05 marks.**

Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for 20 marks.

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SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (duration 03 hours)

3. **The question paper will have ten questions. Each question is set for 20 marks.**
4. **There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub- questions), should have a mix of topics under that module.**
5. **The students have to answer 5 full questions, selecting one full question from each module.**

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper shall include questions from the practical component).

- **The minimum marks to be secured in CIE to appear for SEE shall be the 12 (40% of maximum marks-30) in the theory component and 08 (40% of maximum marks -20) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included. The maximum of 04/05 questions to be set from the practical component of IPCC, the total marks of all questions should not be more than the 20 marks.**
- **SEE will be conducted for 100 marks and students shall secure 35% of the maximum marks to qualify in the SEE.**

Marks secured will be scaled down to 50.

Suggested Learning Resources:

Books

1. Ghosh, A. and Mallik, A. K., (2017), Manufacturing Science, East-West Press.
2. Parmar R. S., (2007), Welding Processes and Technology, Khanna Publishers.
3. Little R. L. – 'Welding and Welding Technology' – Tata McGraw Hill Publishing Company Limited, New Delhi – 1989
4. Grong O. – 'Metallurgical Modelling of Welding' – The Institute of Materials – 1997 – 2nd Edition
5. Kou S. – 'Welding Metallurgy' – John Wiley Publications, New York – 2003 – 2nd Edition.

6. Serope Kalpakjian and Steven R. Schmid – 'Manufacturing Engineering and Technology' – Prentice Hall – 2013 – 7th Edition
7. Principles of foundry technology, 4th edition, P L Jain, Tata McGraw Hill, 2006.
8. Advanced Welding Processes technology and process control, John Norrish, Wood Head Publishing, 2006.

Web links and Video Lectures (e-Resources):

- (Link:http://www.springer.com/us/book/9781447151784http://nptel.ac.in/courses/112
- 105127/)
- http://www.astm.org/DIGITAL_LIBRARY/MNL/SOURCE_PAGES/MNL11.htm
- http://www.astm.org/DIGITAL_LIBRARY/JOURNALS/COMPTECH/PAGES/CTR10654J.htm
- MOOCs: http://nptel.ac.in/courses/112105126/

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

Metal Casting: Design pattern/core for a given component drawing and develop a sand mould with optimum gating and riser system for ferrous and non-ferrous materials. Melting and casting, inspection for macroscopic casting defects.

- Welding: TIG and MIG welding processes – design weld joints – welding practice –weld quality inspection.
- Metal Forming: Press working operation – hydraulic and mechanical press -load calculation: blanking, bending and drawing operations – sheet metal layout design.

MODULE -1

Introduction & basic materials used in foundry: *Introduction: Definition, Classification of manufacturing processes. Metals cast in the foundry-classification, factors that determine the selection of a casting alloy. Introduction to casting process & steps involved – (Brief Introduction)- Not for SEE*

Patterns: Definition, classification, materials used for pattern, various pattern allowances and their importance.

Sand moulding: Types of base sand, requirement of base sand. Binder, Additive's definition, need and types; preparation of sand moulds. Molding machines- Jolt type, squeeze type and Sand slinger.

Study of important moulding process: Green sand, core sand, dry sand, sweep mould, CO2mould, shell mould, investment mould, plaster mould, cement bonded mould.

Cores: Definition, need, types. Method of making cores,

Concept of gating (top, bottom, parting line, horn gate) and risers (open, blind) Functions and types.

Introduction :

Manufacturing process basically deals with the conversion of raw materials to end or useful material. Casting Process is one of them.

All useful items are referred to as end product or finished product or component. These end products are made by using a number of raw materials. The raw materials are subjected to a number of operations referred to as processing. The end product has the necessary shape size etc. and meets the specified requirements. The steps involved in the conversion of raw materials are called processing and the mechanism of getting the end product from the raw material is referred to as manufacturing.

CLASSIFICATION OF MANUFACTURING PROCESS

The various processes available for manufacturing a product can be put into any one of the four categories mentioned below:

(1) Casting
(2) Forming
(3) Machining
(4) Joining.

Casting : Casting is a manufacturing process in which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

Forming : Forming processes are particular manufacturing processes which make use of suitable stresses (like compression, tension, shear or combined stresses) which cause plastic deformation of the materials to produce required shapes. During forming processes no material is removed, i.e. they are deformed and displaced. Ex: Forging, Extrusion, Rollig etc.

Machining: Machining is the broad term used to describe removal of material from a work piece, it covers several processes, which we usually divide into the following categories: Cutting, generally involving single-point or multipoint cutting tools, each with a clearly defined geometry. Abrasive processes, such as grinding. Ex: Drilling, Turning, Thread Cutting etc.

Joining : Joining processes involve assembling or joining two or more parts together to form a single component of the desired shape and size. They are further classified into two categories based on the type of joint:

i. Temporary joining process: In these processes, the joint obtained is temporary. The assembled parts can be separated easily without damage to them. Example Bolt and nut, soldering, brazing, adhesive bonding etc.

ii. Permanent joining process : In these processes, the joint obtained will be such that, the connected parts have to be broken in order to separate them. Example Welding and riveting.

METAL CAST IN THE FOUNDRIES-CLASSIFICATION

In casting process components are produced by pouring molten metal into a contoured cavity followed by cooling to a solid mass. The cooled solid mass represents the configuration of the cavity and is the required shape of the component. The components thus produced are referred to as castings.

The cavity corresponding to the shape of the component is called as the mould. The mould may be made of refractory grains or metal. The mould made out of refractory grains is called as sand moulds and that made out of metal is called metal moulds. The cooling of liquid metal to solid metal is termed phase transformation. The place where this activity is carried out is referred to as foundry.

CLASSIFICATION OF FOUNDRIES

a) **Based on the type of metal being cast**

   Ferrous foundry: Deals with iron based metal. Here the foundry produces only ferrous alloy castings ex: Cast irons, steel, ductile iron.

   Non-ferrous foundry: The foundry produces only non-ferrous alloy castings ex: Al-alloys, Cu-alloys, and Mg-alloys etc. Here metal other than Iron is processed.

b) **Based on the nature of foundry**

   Jobbing foundry: Produces small quantity of castings as and when orders are received by different customers. Here castings are produced against job orders. There is no set pattern of production.

   Captive foundry: Produces castings to its own requirement. Only castings required for internal needs are produced.

   Mechanized foundry: Produces large number of castings of repetitive nature using equipment and machinery. Very good control over the product quality is assured.

c) **Based on the total tonnage of castings produced**

   Small sized foundry: Produces small sized castings up to few hundred kilograms single piece ex: 20-50T/Month production.

   Medium sized foundry: Produces medium sized castings up to thousand kilograms ex: 50-100T/Month Production.

   Large sized foundry: Produces heavy castings weighing several tons, ex:1000/T Month Production.

d) **Based on the type of mould used**

   Sand casting foundries: Here sand is used for making the mould. Each mould is used for one casting only. Small to very huge castings can be produced.

   Die casting foundries or Permanent mould casting foundries: Here metal is used for making the mould- cast iron, steel, copper are used for making the moulds. These moulds can be used repeatedly for producing several thousands of castings. Hence the name permanent mould castings assigned to these. Size of the castings is limited to few hundred kilograms.

FACTORS THAT DETERMINE THE SELECTION OF A CASTING ALLOY

Selecting the casting process is an important element in the design cycle, even though in some cases, it is a decision that can be left to the foundry. More often than not, the process to be used falls out logically from the product's size, shape and technical requirements. Among the more important factors that influence the choice of casting method are:

1. The number of castings to be made
2. The size and/or weight of the casting
3. The shape and intricacy of the product
4. The amount and quality of finish machining needed
5. The required surface finish
6. The prescribed level of internal soundness (pressure tightness) and/or the type and level of inspection to be performed
7. The permissible variation in dimensional accuracy for a single part, and part-to-part consistency through the production
8. The casting characteristics of the alloy specified.

Other considerations, such as code requirements, can also play a role in selecting the casting process, but it is primarily the number and size of castings required, along with the alloy chosen, that determine how a casting will be made.

INTRODUCTION TO CASTING PROCESS

Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mould cavity and allows it to solidify. The solidified object is taken out from the mould either by breaking or taking the mould apart. The solidified object is called casting and the technique followed in method is known as casting process. The casting process was discovered probably around 3500 BC in Mesopotamia. In many parts of world during that period, copper axes (wood cutting tools) and other flat objects were made in open moulds using baked clay. These moulds were essentially made in single piece. The Bronze Age 2000 BC brought forward more refinement into casting process. For the first time, the core for making hollow sockets in the cast objects was invented. The core was made of baked sand. Also the lost wax process was extensively used for making ornaments using the casting process. Casting technology was greatly improved by Chinese from around 1500 BC. For this there is evidence of the casting activity found in China. For making highly intricate jobs, a lot of time in making the perfect mould to the last detail so hardly any finishing work was required on the casting made from the moulds. Indus valley civilization was also known for their extensive use of casting of copper and bronze for ornaments, weapons, tools and utensils. But there was not much of improvement in the casting technology. From various objects that were excavated from the Indus valley sites, they appear to have been familiar with all the known casting methods such as open mould and piece mould.

STEPS INVOLOVED IN SAND CASTING:

Here sand mixture is used for producing the mould cavity. By pouring molten metal into the mould followed by cooling casting is produced. Sand mixtures consist of base sand, binder and other ingredients. Mould cavity is produced by ramming sand mixture around a pattern. By removing the pattern mould cavity is obtained. Molten metal is poured into the mould cavity and allowed to solidify. The solidified metal is removed from the sand and this will represent the given shape of the component. This shaped object is referred to as casting. Since casting is produced from the sand mould it is referred as sand casting. Majority of the castings produced in practice are sand castings. Sand casting process offers advantages like very high flexibility, easy to adopt, easy to handle, low process cost, reusability etc. All types of metal can be used in the process. There are different types of sand mixtures used for producing the sand moulds. A sand mould is used to produce one casting only.

There are six steps in this process:

1. Pattern Making
2. Mould Preparation.
3. Core Making.
4. Melting & Pouring.
5. Cleaning & Inspection.

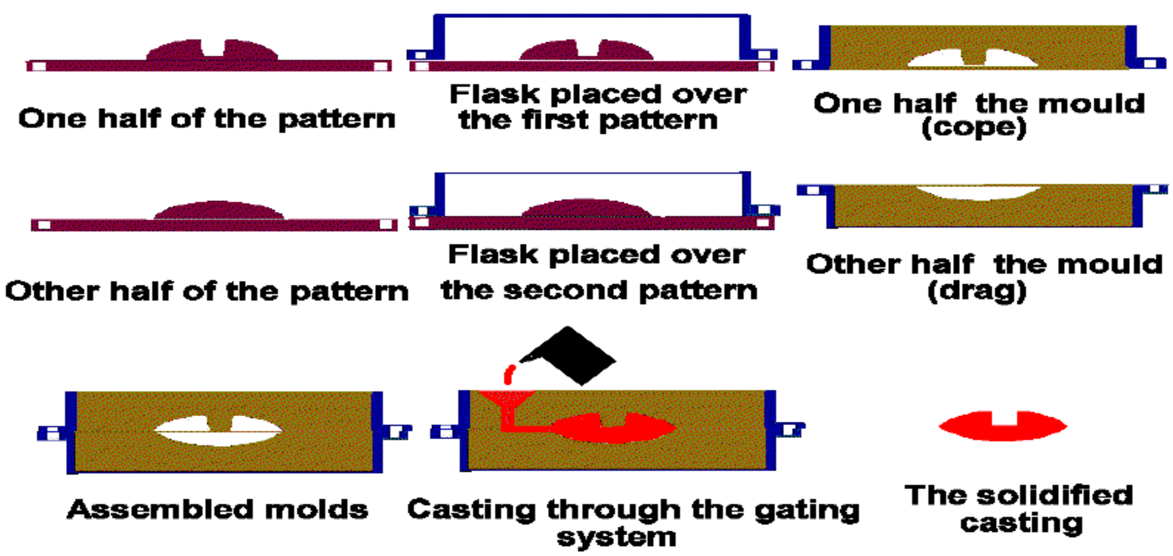


Fig.1 Steps involved in sand casting process.

TERMS INVOLVED IN CASTING

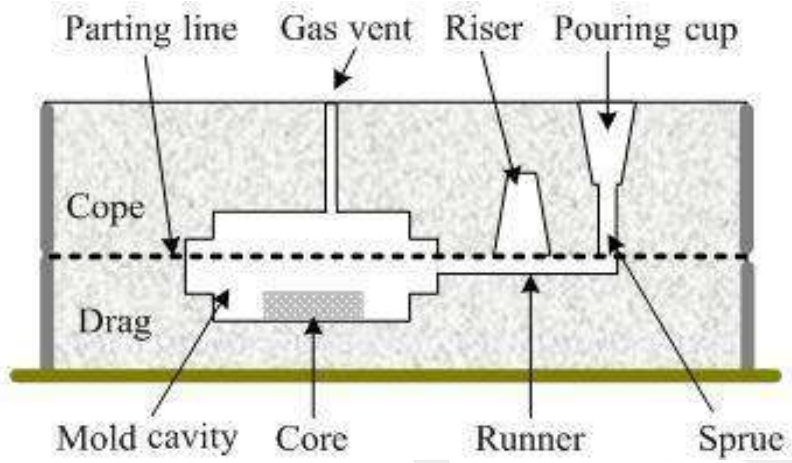


Fig 2 Typical mould for sand casting.

a) **Mould box (flask)** : It is usually a metallic frame used for making and holding a sand mould. The mould box has two parts: the upper part called 'cope', and the lower part called 'drag'. ·

b) **Parting line** : It is the zone of separation between cope and drag portions of the mould in sand casting.

c) **Sprue**: It is a vertical passage through which the molten metal will enter the gate, and then into the mould cavity.

d) **Pouring basin**: The enlarged portion of the sprue at its top into which the molten metal is poured.

e) **Gate/ingate**: It is a short passageway which carries the molten metal from the runner/ sprue into the mould cavity.

h) **Riser**: A riser or feed head is a vertical passage that stores the molten metal and supplies (feed) the same to the casting as it solidifies.

i) **Mould cavity**: The space in a mould that is filled with molten metal to form the casting upon solidification.

j) **Core**: A core is a pre-formed (shaped) mass of sand placed in the mould cavity to form hollow cavities in castings.

k) **Core print**: It is a projection attached to the pattern to help for support and correct location of core in the mould cavity.

ADVANTAGES AND DISADVANTAGES OF CASTING

Advantages

(i) Fine and dense grained structure is achieved in the casting.
(ii) No blow holes exist in castings produced by this method.
(iii) The process is economical for mass production.

(iv) Because of rapid rate of cooling, the castings possess fine grain structure.
(v) Close dimensional tolerance or job accuracy is possible to achieve on the cast product.
(vi) Good surface finish and surface details are obtained.
(vii) Casting defects observed in sand castings are eliminated.
(viii) Fast rate of production can be attained.
(ix) The process requires less labor.

Disadvantages

(i) The cost of metallic mould is higher than the sand mould. The process is impractical for large castings.
(ii) The surface of casting becomes hard due to chilling effect.
(iii) Refractoriness of the high melting point alloys.

PATTERN

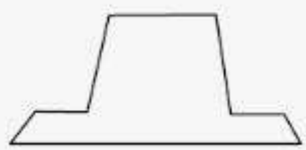
DEFINITION: A pattern is a model or the replica of the object (to be casted). It is embedded in moulding sand and suitable ramming of moulding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mould) in moulding sand. Thus it is a mould forming tool. Pattern can be said as a model or the replica of the object to be cast except for the various al1owances a pattern exactly resembles the casting to be made. It may be defined as a model or form around which sand is packed to give rise to a cavity known as mould cavity in which when molten metal is poured, the result is the cast object. When this mould cavity is filled with molten metal, molten metal solidifies and produces a casting (product). So the pattern is the replica of the casting.

TYPES OF PATTERN

The types of the pattern and the description of each are given as under.
1. One piece or solid pattern
2. Two piece or split pattern
3. Cope and drag pattern
4. Three-piece or multi- piece pattern
5. Loose piece pattern
6. Match plate pattern
7. Follow board pattern
8. Gated pattern
9. Sweep pattern
10. Skeleton pattern

1. **Single-piece or solid pattern**

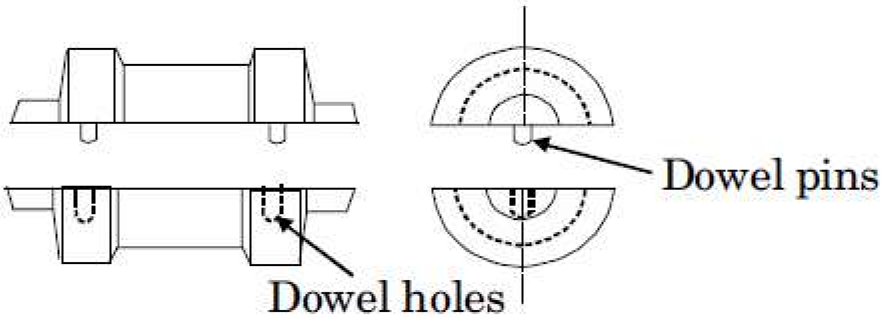
Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern. Typical single piece pattern is shown in Figure below



Single piee pattern

2. Two-piece or split pattern

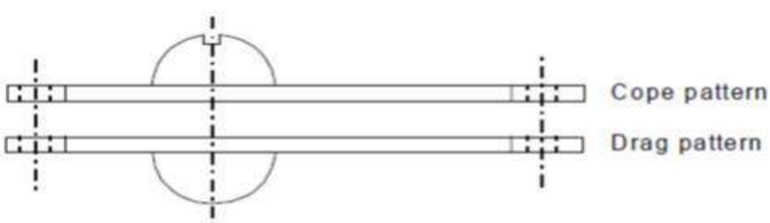
When solid pattern is difficult for withdrawal from the mould cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the Withdrawal of the pattern. A typical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



Two piece pattern

3. 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 Figure below



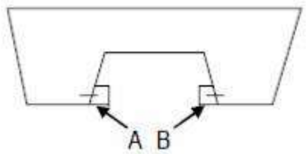
Cope and drag pattern

4. Three-piece or multi-piece pattern

Some patterns are of complicated kind in shape and hence cannot be made in one or two pieces because of difficulty in withdrawing the pattern. Therefore these patterns are made in either three pieces or in multi-pieces. Multi moulding flasks are needed to make mould from these patterns.

5. Loose-piece Pattern

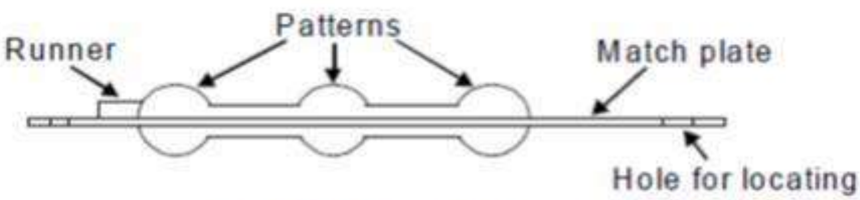
Loose piece pattern is used when pattern is difficult for withdrawal from the mould. Loose pieces are provided on the pattern and they are the part of pattern. The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately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



Loose piece pattern

6. Match plate pattern

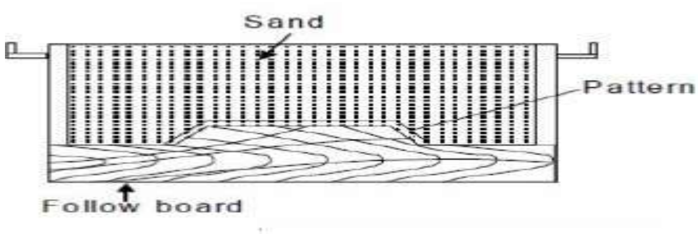
This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine moulding. A typical example of match plate pattern is shown in Figure below



Match plate pattern

7. Follow board pattern

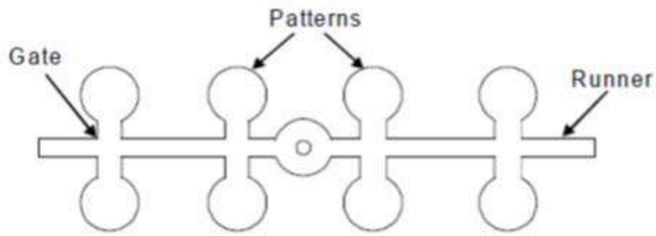
When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a moulding board for the first moulding operation as shown in Figure below



Follow board pattern

8. Gated pattern

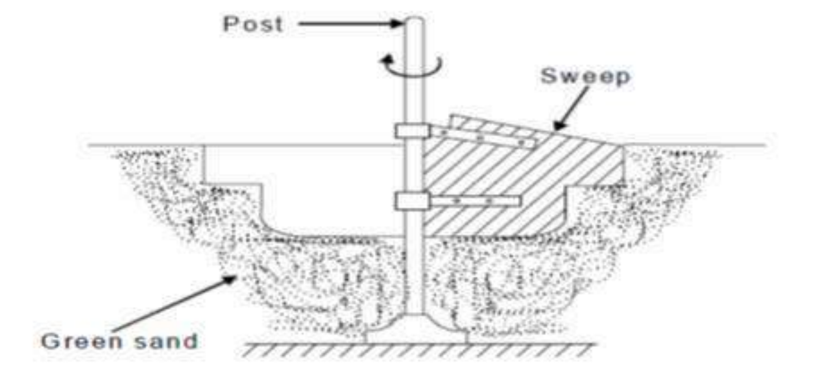
In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Figure below. These patterns are made of metals, and metallic pieces to form gates and runners are attached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



Gated pattern

9. Sweep pattern

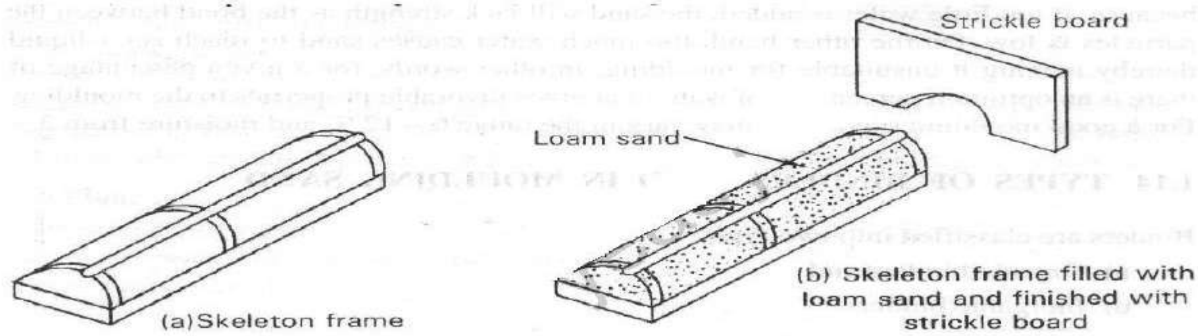
Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle as shown in Figure below. Actually a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape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



Sweep pattern

10. Skeleton pattern

When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood which forms an outline of the pattern to be made. This frame work is filled with loam sand and rammed. The surplus sand is removed by stickle board. For round shapes, the pattern is made in two halves which are joined with glue or by means of screws etc. A typical skeleton pattern is shown in Figure below



Skeleton pattern

PATTERN MATERIAL

Patterns may be constructed from the following materials. Each material has its own advantages, limitations, and field of application. Some materials used for making patterns are: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins.

- **Wood**

  Wood is the most popular and commonly used material for pattern making. It is cheap, easily available in abundance, repairable and easily fabricated in various forms using resin and glues. It is very light and can produce highly smooth surface.

- **Metal**

  Metallic patterns are preferred when the number of castings required is large enough to justify their use. These patterns are not much affected by moisture as wooden pattern. The wear and tear of this pattern is very less and hence possesses longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes.

- **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 moulding sand, durable and they are not affected by the moisture of the moulding sand. Moreover they impart very smooth surface finish on the pattern surface. These materials are somewhat fragile, less resistant to sudden loading and their section may need metal reinforcement.

- **Plaster**

  This material belongs to gypsum family which can be easily cast and worked with wooden tools and preferable for producing highly intricate casting. The main advantages of plaster are that it has high compressive strength and is of high expansion setting type which compensate for the shrinkage allowance of the casting metal.

- **Wax**

  Patterns made from wax are excellent for investment casting process. The materials used are blends of several types of waxes, and other additives which act as polymerizing agents, stabilizers, etc. The commonly used waxes are paraffin wax, shellac wax, bees-wax, ceresin wax, and micro-crystalline wax.

VARIOUS PATTERN ALLOWANCES

1. **Shrinkage of contraction allowance**: The various metals used for casting contract after solidification in the mould. Since the contraction is different for different metals, therefore their corresponding allowances also different and there is a shrink or correction scale for each type of metal used in a casting
2. **Draft allowance**: It is a taper which is given to all the vertical walls of the pattern for easy and clean withdrawal of the pattern from the sand without damage the mould cavity. It may be expressed in millimeters per meter on a side or in degrees. The amount of taper varies with the type of patterns.
3. **Machining allowance**: This allowance is provided on the pattern if the casting is to be machined. This allowance is given in addition to shrinkage allowance. The amount of this allowance varies from 1.6 to 12.5mm which depends upon the type of casting metal size, shape of casting, method of casting used, and method of machining.
4. **Distortion allowance**: This allowance is provided on pattern used for castings of such design in which the contraction is not uniform throughout.
5. **Rapping or shaking allowance**: This allowance is provided in the pattern to compensate for the rapping of the mould because the pattern is to be rapped before removing it from the mould. In small and medium -Silica sized casting, these allowances can be neglected.

Functions of the Pattern

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

Sand Molding

Types Of Base Sand

It is a mass of refractory grains. Grains are formed due to the withering action of rocks. It is available in plenty in nature along sea beaches and deserts etc. Base send refers to sand grains without any other ingredients. They are normally oxides of elements.

Examples of base sand are as follows:

Silica sand - SiO_2

Zircon sand - ZrO_2SiO_2

Magnesite sand - MgO

Silimanite sand - Al_2O_3 SiO_2

Olivine Sand - $(MgFe)_2SiO_4$

Chromite sand- Cr_2O_3

REQUIREMENTS OF BASE SAND

For producing a good casting the sand has to fulfill the following

- **Base sand should be sub angular grain shape**

Sand grains may have different shapes like angular, sub angular or spherical. Sub angular sand grains have edges and corners formed due to the erosive action over a period of time. If the grains are sub angular then they will offer better surface for the clay to coat and develop proper bonding.

- **Should have good grain**

Sand to be suitable for moulding the size of the grains should not be too fine or too coarse but should be composed of various sizes. Too fine sand grains improve surface finish of the casting. Whereas too coarse sand results in rough surface on the casting. Coarse sand allows mould gases to escape easily and fine sand restrict easy gas flow. Hence a proper mixture of the different grain size is desired for better casting properties.

Should have high refractoriness

Sand should be able to withstand high temperatures without fusing. This is called high refractoriness. Better quality casting surfaces is realized with sand having high refractoriness. High refractory sand permits castings of high melting point metals and alloys.

- **Should have low impurities**

Impurities in base sand reduce the properties appreciably. Especially the fusion temperature is decreased. It will not have sufficient resistance against high temperature of the metal. Hence the impurity level in the sand must be as low as possible**.**

- **Should have low expansion characteristics**

All materials expand when heated .Even sand grains undergo expansion is the sand grains expand appreciably then the mould made by such sand cannot accommodate expansion and will show cracks on the surface. Hence the expansion characteristics of sand should be as low as possible.

- **Should be thermally stable**

When sand grains are heated and cooled subsequently the sand will expand and then contract. During this period the sand should not disintegrate or decompose at high temperatures of the metal. It should not fuse also. This property is called as thermal stability.

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 cannot develop bonds among sand grains without the presence of moisture in moulding sand and core sand.

ADDITIVES

Additives are the materials generally added to the moulding and core sand mixture to develop some special property in the sand. Some common used additives for enhancing the properties of moulding and core sands are discussed as under:

- **Coal dust**

Coal dust is added mainly for producing a reducing atmosphere during casting. This reducing atmosphere results in any oxygen in the poles becoming chemically bound so that it cannot oxidize the metal. It is usually added in the moulding sands for making moulds for production of grey iron and malleable cast iron castings.

- **Corn flour**

It belongs to the starch family of carbohydrates and is used to increase the collapsibility of the moulding and core sand. It is completely volatilized by heat in the mould, thereby leaving space between the sand grains. This allows free movement of sand grains, which finally gives rise to mould wall movement and decreases the mould expansion and hence defects in castings. Corn sand if added to moulding sand and core sand improves significantly strength of the mould and core.

- **Dextrin**

Dextrin belongs to starch family of carbohydrates that behaves also in a manner similar to that of the corn flour. It increases dry strength of the moulds.

- **Sea coal**

Sea coal is the fine powdered bituminous coal which positions its place among the pores of the silica sand grains in moulding sand and core sand. When heated, it changes to coke which fills the pores and is unaffected by water: Because to this, the sand grains become restricted and cannot move into a dense packing pattern. Thus, sea coal reduces the mould wall movement and the permeability in mould and core sand and hence makes the mould and core surface clean and smooth.

- **Pitch**

It is distilled form of soft coal. It can be added from 0.02 % to 2% in mould and core sand. It enhances hot strengths, surface finish on mould surfaces and behaves exactly in a manner similar to that of sea coal.

- **Wood flour**

This is a fibrous material mixed with a granular material like sand; its relatively long thin fibers prevent the sand grains from making contact with one another. It can be added from 0.05 % to 2% in mould and core sand. It volatilizes when heated, thus allowing the sand grains room to expand. It will increase mould wall movement and decrease expansion defects. It also increases collapsibility of both of mould and core

- **Silica flour**

It is called as pulverized silica and it can be easily added up to 3% which increases the hot strength and finish on the surfaces of the moulds and cores. It also reduces metal penetration in the walls of the moulds and cores.

Preparation of Mold Sand

The general sources of receiving moulding sands are the beds of sea, rivers, lakes, granular elements of rocks, and deserts. The common sources of moulding sands available in India are as follows:

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)

Moulding sands may be of two types namely natural or synthetic. Natural moulding sands contain sufficient binder. Whereas synthetic moulding sands are prepared artificially using basic sand moulding constituents (silica sand in 88-92%, binder 6-12%, water or moisture content 3-6%) and other additives in proper proportion by weight with perfect mixing and mulling in suitable equipments.

Types Of Moulding Sand

Moulding sands can also be classified according to their use into number of varieties which are Described below.

1.Green sand

Green sand is also known as tempered or natural sand which is a just prepared 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. Moulds prepared by this sand are not requiring backing and hence are known as green sand moulds. This sand is easily available and it possesses low cost. It is commonly employed for production of ferrous and non-ferrous castings.

2.Dry sand

Green sand that has been dried or baked in suitable oven after the making mould and cores is called dry sand. It possesses more strength, rigidity and thermal stability. It is mainly suitable for larger castings. Mould prepared in this sand is known as dry sand moulds.

3.Loam sand

Loam is mixture of sand and clay with water to a thin plastic paste. Loam sand possesses high clay as much as 30-50% and 18% water. Patterns are not used for loam moulding and shape is given to mould by sweeps. This is particularly employed for loam moulding used for large grey iron castings.

4.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. Initial Coating around the pattern and hence for mould surface is given by this sand. This sand is subjected severest conditions and must possess, therefore, high strength refractoriness. It is 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. They are sometimes mixed with 6-15 times as much fine moulding sand to make facings. The layer of facing sand in a mould usually ranges from 22-28 mm. From 10 to 15% of the whole amount of moulding sand is the facing sand.

5.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 moulding flask. Used moulding sand is mainly employed for this purpose. The Backing sand is sometimes called black sand because that old, repeatedly used moulding sand Is black in color due to addition of coal dust and burning on coming in contact with the molten Metal.

6. System sand

In mechanized foundries where machine moulding is employed. So-called system sand is used to fill the whole moulding flask. In mechanical sand preparation and handling units, no facing sand is used. 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 mould is made of this system sand, the properties such as strength, permeability and refractoriness of the moulding sand must be higher than those of backing sand.

7. Parting sand

Parting sand without binder and moisture is used to keep the green sand not to stick to the Pattern and also 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.

8. Core sand

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

1. **Permeability**: - It is that property of sand which permits the steam and other gases to pass through the sand mould. When hot metal is poured into the sand mould, it evolves a great amount of steam and other gases while coming in contact with the moist sand. If these gases do not escape completely through the mould, the casting will contain gas holes and pores.
2. **Plasticity**: - It is that property of sand due to which it flows to all portions of the moulding box or flask and acquires a predetermined shape under ramming pressure and retains this shape when the pressure is removed.
3. **Adhesiveness**: - It is the property of the sand due to which it adheres or clings to the sides of the moulding box. Good sand must have sufficient adhesiveness so that heavy sand masses can be successfully held in the moulding box or flask with- out any danger of its falling out when the flask is removed.
4. **Cohesiveness**: - It is that property of sand due to which the sand grains stick together during ramming.
5. **Refractoriness**: - It is that property of the sand which enables it to resist high temperature of the molten metal without breaking down or fusing.
6. **Flow ability**: - It is that property of sand due to which it behaves like a fluid so that, when rammed, it flows to all portions of a mould and distributes the ramming pressure evenly. Flow ability increases with decrees in green strength and de- crease in grain size. It also varies with the moisture content.

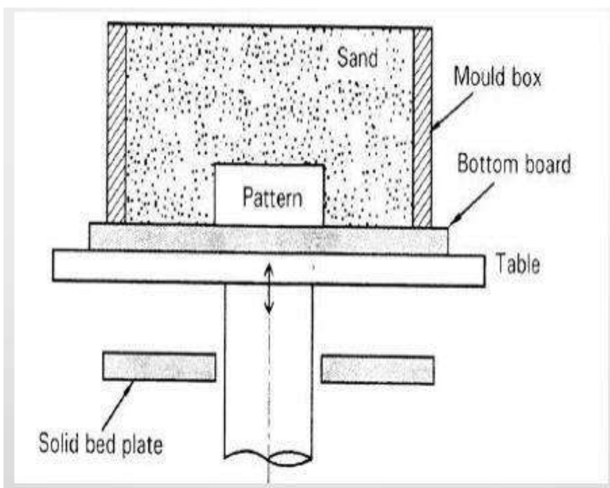
7. **Collapsibility**: - It is that property of the sand due to which the sand mould collapses automatically after the solidification of the casting in order to allow free construction of the metal.

CLASSIFICATION OF MOULDING MACHINES

The large variety of moulding machines that are available in different designs which can be classified as squeezer machine, jolt machine, jolt-squeezer machine, slinging machines, pattern draw machines and roll over machines. These varieties of machines are discussed as under.

JOLT TYPE MACHINE

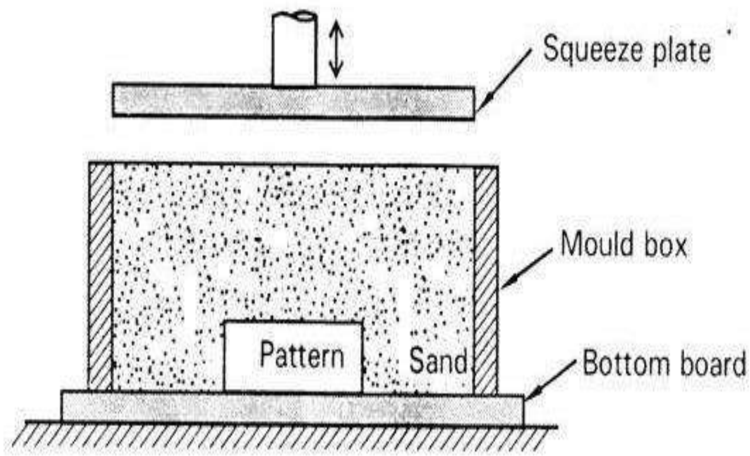
A jolt machine consists of a flat table mounted on a piston cylinder arrangement and can be raised or lowered by means of compressed air. In operation, the mould box with the pattern and sand is placed on the table. The table is raised to a short distance and then dropped down under the influence of gravity against as solid bed plate. The action of raising and dropping (lowering) is called 'Jolting'. Jolting causes the sand particles to get packed tightly above and around the pattern. The number of 'jolts 'may vary depending on the size and hardness of the mould required. Usually, less than 20 jolts are sufficient for a good moulding. The disadvantage of this type is that, the density and hardness of the rammed sand at the top of them mould box is less when compared to its bottom portions. The below figure shows jolt type machine.



JOLT TYPE MACHINE

SQUEEZER MACHINE

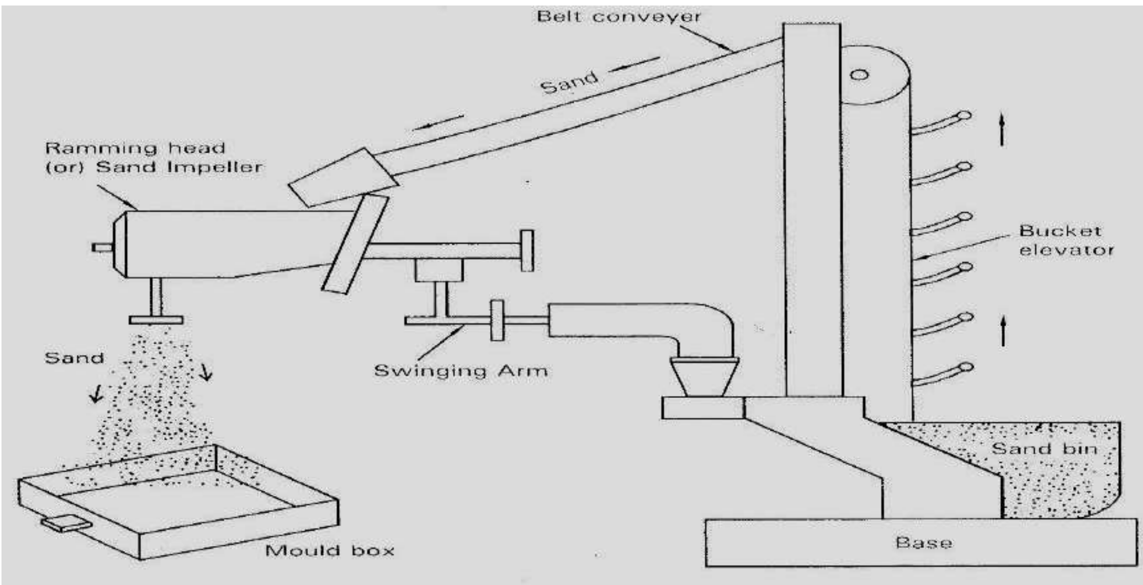
In squeeze machine, the mould box with pattern and sand in it is placed on a fixed table as shown in figure A flat plate or a rubber diaphragm is brought in contact with the upper surface of the loose sand and pressure is applied by a pneumatically operated piston. The squeezing action of the plate causes the sand particles to get packed tightly above and around the pattern. Squeezing is continued until the mould attains the desired density. In some machines, the squeeze plate may be stationary with the mould box moving upward. The disadvantage of squeeze machine is that, the density and hardness of the rammed sand at the bottom of the mould box is less when compared to its top portions. The below figure shows squeezer machine



SQUEEZER MACHINE

SAND SLINGER

A sand slinger is an automatic machine equipped with a unit that throws sand rapidly and with great force into them old box. Figure shows a sand slinger. Sand slinger consists of a rigid base, sand bin, bucket elevator, belt conveyor, ramming head (sand impeller) and a swinging arm. In operation, the premixed sand mixture from the sand bin is picked by the bucket elevator and is dropped on to the belt conveyor .The conveyor carries the sand to the ramming head, inside which there is a rotating impeller having cup shaped blades rotating at high speeds (around1800rpm).



SANDSLINGER

STUDY OF MOULDING PROCESSES

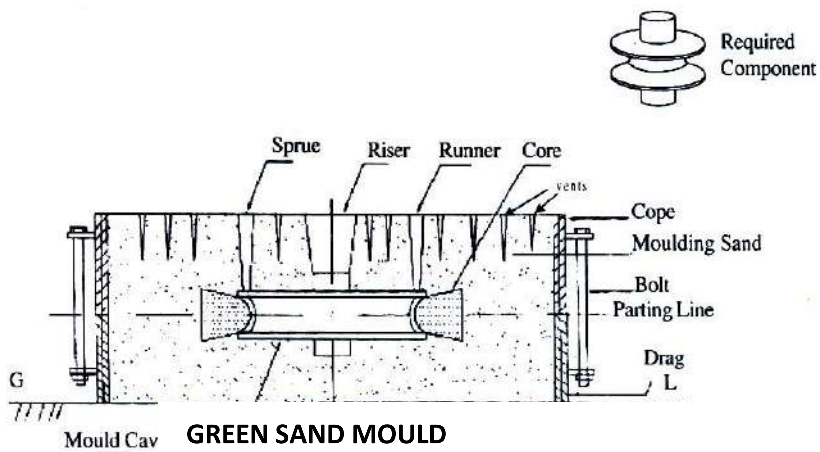
Moulding processes can be classified in a number of ways. Broadly they are classified either on the basis of the method used or on the basis of the mould material used.

(i) Classification based on the mould material used:

(a) Sand moulding:

1. Green sand mould
2. Dry sand mould,
3. Cement bonded sand mould
4. Carbon-dioxide mould.
5. Shell mould.
6. Plaster mould
7. Investment mould.
8. Sweep moulding.

1. **GREEN SAND MOULD:** The word green has nothing to do with the color, but signifies that the moulding sand is in the moist state at the time of metal pouring. The main ingredients of green sand are silica sand, clay and moisture (water). Additives may be added in small amounts to obtain desired properties of mould/ casting. Nearly 60 % of the total castings are prepared from green sand moulds. A typical composition of green sand mixture includes 90% sand, 7% binder, and 3% clay.



GREEN SAND MOULD

Advantages of green sand moulds:

- Preferred for simple, small and medium size castings.
- Suitable for mass production
- Least expensive
- Sand can be reused many times after reconditioning with clay and moisture.

Disadvantages:

- Moulds/cores prepared by this process lack in permeability, strength and stability.
- They give rise to many defects like porosity, blow holes etc., because of low permeability and lot of steam formation due to their moisture content.
- Moulds/cores cannot be stored for appreciable length of time.

- Not suitable for very large size castings.
- Surface finish and dimensional accuracy of castings produced are not satisfactory.
- Difficult to cast thin and intricate shapes.
- Mould erosion which is common in green sand moulds is another disadvantage.

2. DRY SAND MOULD:

The word dry signifies that the mould is dry or free from moisture at the time of metal pouring. The absence of moisture makes dry sand moulds to overcome most of the disadvantages of green sand moulds.

A dry sand mould is prepared in the same manner as that of green sand mould, i.e., by mixing silica sand, clay and water. The entire mould/core is then dried (baked) in ovens to remove the moisture present in them. Also, baking hardens the binder thereby increasing the strength of moulds/cores. The temperature and duration of baking ranges from **200 - 450°C** and from a few minutes to hours respectively, depending on the type of metal being poured, and size of the casting.

Advantages:

- Strength and stability of moulds is high when compared to green sand moulds.
- Baking removes moisture and hence, defects related to moisture are eliminated.
- Better surface finish and dimensional tolerance of castings.

Disadvantages:

- Consumes more time, labor and cost due to baking process. Hence, not suitable for mass production.
- Not suitable for large and heavy size castings, as they are difficult to bake.
- Under baked or over baked moulds/cores is another disadvantage.
- Capital cost of bake ovens

3. CEMENT BONDED SAND MOULDS.

A mixture of silica sand containing 8-12% cement and 4-6% water is used. When making the mould, the cement-bonded sand mixture must be allowed to harden first, before the pattern is withdrawn. The mould obtained is then allowed to cure for about 3-5 days. When the metal is poured, heat causes the water of crystallization of the cement to be driven off, and thus steam must be allowed to pass off through the sand by means of its porosity and suitably distributed vent holes. Large castings with intricate shapes, accurate dimensions and smooth surfaces are usually produced by this method. The only shortcoming being the long time required for the moulding process.

4. CARBON-DIOXIDE GAS MOULDING

This process is widely used for rapid hardening the moulds & cores made up of green sand. The mould making process is similar to conventional moulding procedure except the mould material which comprises of pure dry silica sand free from clay, 3-5% sodium silicate as binder and moisture content generally less than 3%. A small amount of starch may be added to improve the green compression strength and a very small quantity of coal dust, sea coal, dextrin, wood floor, pitch, graphite and sugar can also be added to improve the collapsibility of the moulding sand. The prepared moulding sand is rammed around the pattern in the mould box and mould is prepared by any conventional technique. After packing, carbon dioxide gas at about 1.3-1.5 kg/cm2 pressure is then forced all-round the mould surface to about 20 to 30 seconds using CO_2 head or probe or curtain. Cores can be baked this way. The sodium silicate presented in the mould reacts with CO_2 and produce a very hard constituents or substance commonly called as silica gel.

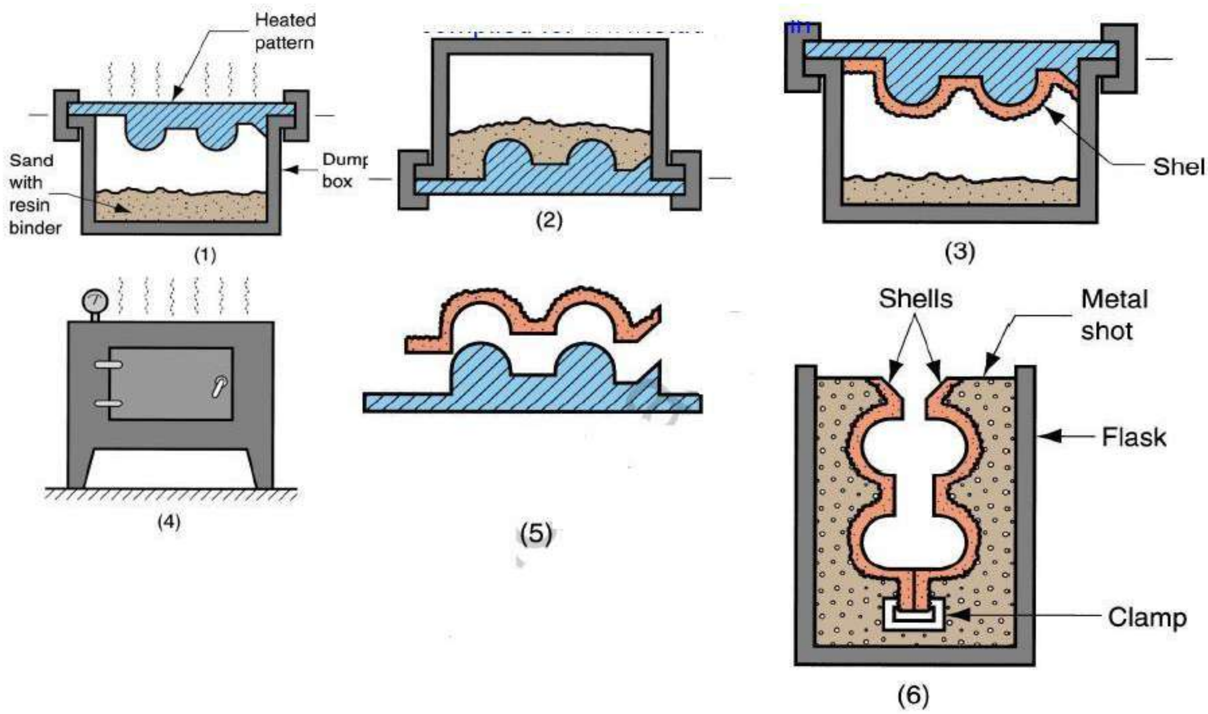
5. SHELL MOULDING

Shell mould casting or shell moulding is a metal casting process in manufacturing industry in which the mould is a thin hardened shell of sand and thermosetting resin binder backed up by some other material. Shell mould casting is particularly suitable for steel castings less than 10 kg; however almost any metal that can be cast in sand can be cast with shell moulding process. Typical parts manufactured in industry using the shell mould casting process include cylinder heads, gears, bushings, connecting rods, camshafts and valve bodies.

The Process includes

- The first step in the shell mould casting process is to manufacture the shell mould. The sand we use for the shell moulding process is of a much smaller grain size than the typical greensand mould. This fine grained sand is mixed with a thermosetting resin binder. A special metal pattern is coated with a parting agent; (typically silicone), which will latter facilitate in the removal of the shell. The metal pattern is then heated to a temperature of (175 °C-370 °C).
- The sand mixture is then poured over the hot casting pattern. Due to the reaction of the thermosetting resin with the hot metal pattern a thin shell forms on the surface of the pattern. The desired thickness of the shell is dependent upon the strength requirements of the mould for the particular metal casting application. A typical industrial manufacturing mould for a shell moulding casting process could be 7.5mm thick. The thickness of the mould can be controlled by the length of time the sand mixture is in contact with the metal casting pattern.
- The excess “loose" sand is then removed leaving the shell and pattern.
- The shell and pattern are then placed in an oven for a short period of time, (minutes), which causes the shell to harden onto the casting pattern.
- Once the baking phase of the manufacturing process is complete the hardened shell is separated from the casting pattern by way of ejector pins built into the pattern.

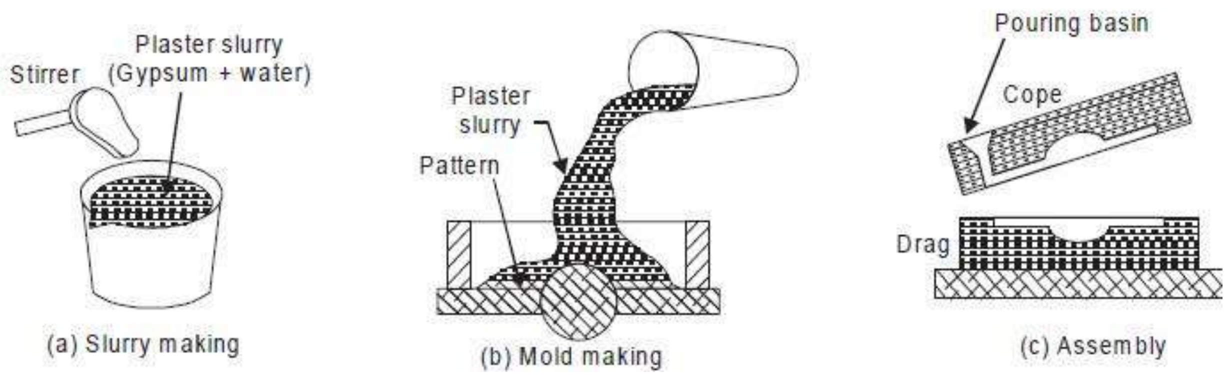
- Two of these hardened shells, each representing half the mould for the casting are assembled together either by gluing or clamping. The manufacture of the shell mould is now complete and ready for the pouring of the metal casting. In many shell moulding processes the shell mould is supported by sand or metal shot during the casting process.



SHELL MOULD PROCESS

6. PLASTER MOULDING

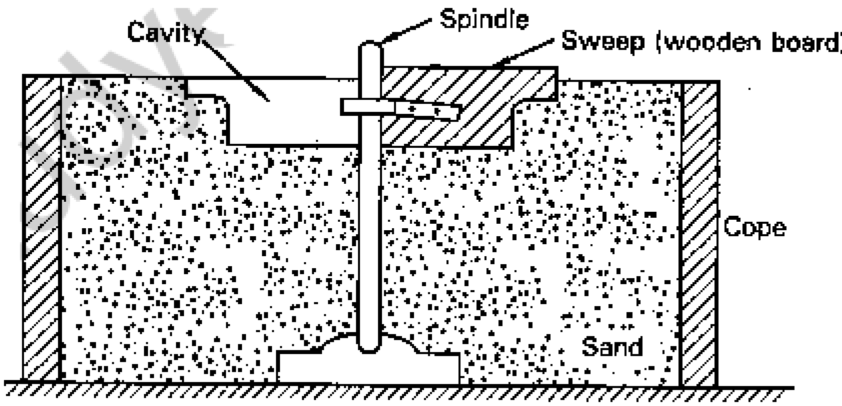
The mould material in plaster moulding is gypsum or plaster of paris. To this plaster of paris, additives like talc, fibers, asbestos, silica flour etc. are added in order to control the contraction characteristics of the mould as well as the settling time. he plaster of paris is used in the form of slurry. This plaster slurry is poured over a metallic pattern confined in a flask. The pattern is usually made of brass and it is generally in the form of half portion of job to be cast and is attached firmly on a match plate which forms the bottom of the moulding flask. Wood pattern are not used because the water in the plaster raises the grains on them and makes them difficult to be withdrawn. Some parting or release agent is needed for easy withdrawal of the pattern from the mould. As the flask is filled with the slurry, it is vibrated so as to bubble out any air entrapped in the slurry and to ensure that the mould is completely filled up. The plaster material is allowed to set, finally when the plaster is set properly the pattern is then withdrawn. The plaster mould thus produced is dried in an oven to a temperature range between 200-70 degree centigrade and cooled in the oven itself. In the above manner two halves of a mould are prepared and are joined together to form the proper cavity. The necessary sprue, runner etc. are cut before joining the two



PLASTER MOULDING

7. SWEEP MOULDING

In sweep moulding, the cavity is formed as the pattern sweeps the sand all-around the circumference. A thin wooden piece is attached to a spindle at one edge while the other edge has a contour depending on the desired shape of the casting. The spindle is placed at the centre of the mould and rotated so that the wooden piece sweeps in the mould box generating the shape of the required casting. Green sand, loam sand or sodium silicate sand can be used symmetrical shapes.



SWEEP MOULDING

CORES:

Definition: A core is a pre-formed (shaped) mass of sand placed in the mould cavity to form hollow cavities in castings. The core defines a volume or location in a mould cavity where the molten metal will not flow into.

When molten metal is poured into the mould, it surrounds the core filling the cavity. After solidification, the casting is removed from the mould, with the core still at the center of the solidified casting. The core when knocked out leaves a void or cavity in the casting.

Types of cores:

Cores are classified based on:

(a) The material from which they are made

- Green sand core
- Dry sand core
- No-bake sand core

(b) Their position and use

Based on position:

- Horizontal core
- Vertical core
- Balanced core
- Drop core

Based on use:

- Kiss core
- Ram-up core etc.

(i) Green sand core:

A green sand core is composed of a mixture of silica sand, binder (bentonite), moisture and additives. The preparation of green sand core is similar to that used for green sand moulds.

(ii) Dry sand core:

The sand mixture used for preparing a dry sand core is different from that used for dry sand moulds. A dry sand core is composed of a mixture of silica sand and binder. The binders may be sodium silicate, ester, Portland cement, rubber cement, linseed oil, mineral oil, natural resins (gum resin, pine resin, coal tar resin etc.), cereals etc.

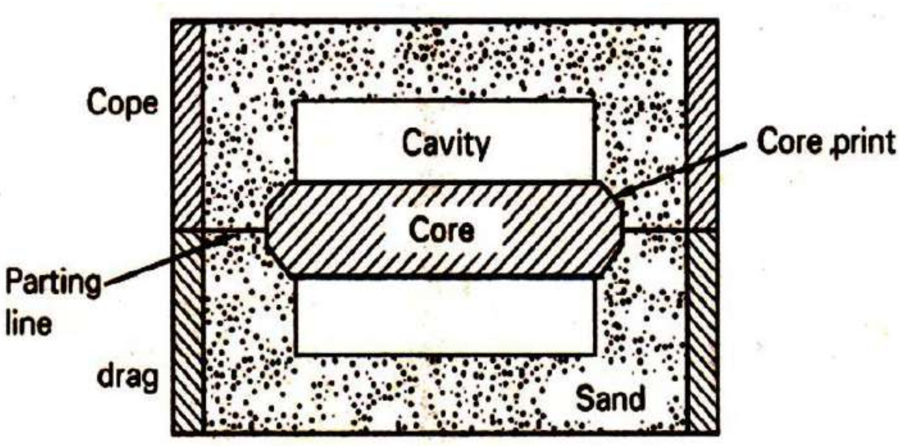
(iii) No-bake sand cores:

The sand used for preparing no-bake core is similar to that used for making no-bake sand moulds. Synthetic resins like phenol or urea formaldehyde are used as binder for bonding silica sand. Certain chemicals are used as hardeners and catalysts to bring about a chemical reaction with the binder due to which bonding of sand grains takes place.

(b) Based on position of core and their uses:

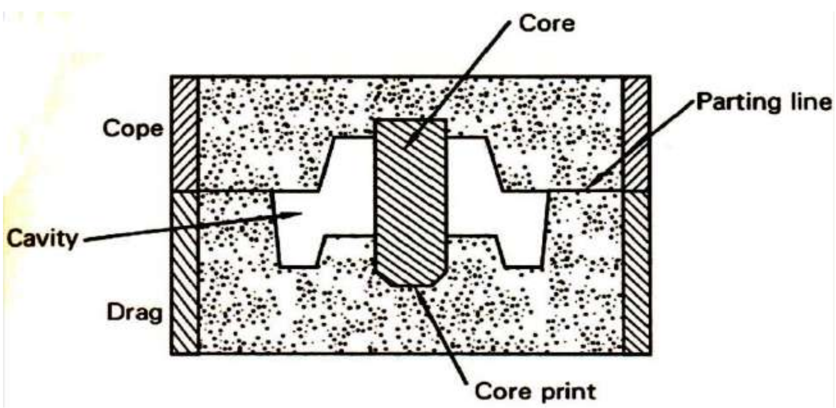
i) Horizontal core:

When the core is placed horizontally in the mould, it is known as **horizontal core.** The core prints provided at both ends of the core rests in the seats initially provided by the pattern. These core prints help the core to be securely and correctly positioned in the mould cavity**.**



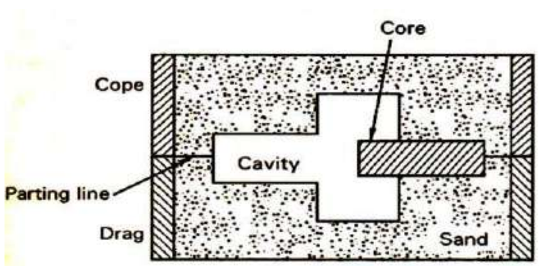
(ii) Vertical core:

When the axis of the core is vertical, it is known as vertical core.



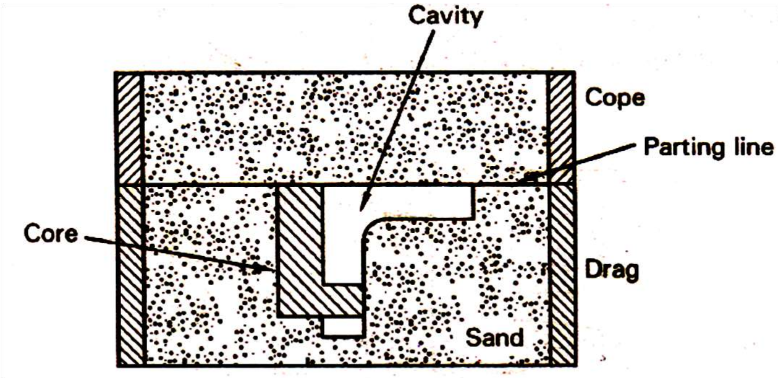
(iii) Balanced core

A balanced core is one that is supported and balanced from its one end only. Such cores are used when the cavity required is only to a certain depth.



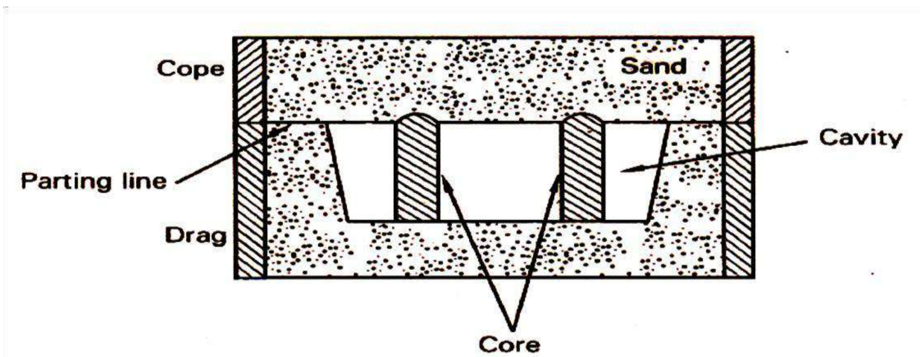
(iv) Drop core:

Drop core is used when the axis of the desired hole does not coincide with the parting line of the mould, i.e., the core is required to be placed either above or below the parting line. Figure shows a drop core placed in the mould.



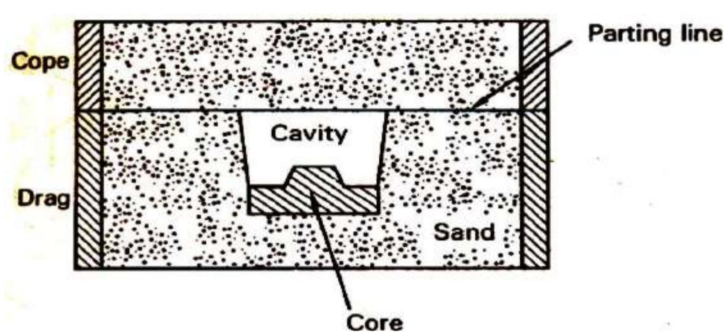
(v) Kiss core:

In some cases, patterns cannot be provided with core prints, and hence, no seat will be available as a rest for the core. In such cases, the core is held in position between the cope and the drag by the pressure exerted from the cope on the drag. Such a core is called a *kiss* core and is shown in figure.



(vi) Ram-up core:

When a core is to be placed in an inaccessible position, it is difficult to place it after ramming the mould. The core used in this case is called a ram-up core, and is placed in the mould along with the pattern before ramming. Figure shows a ram-up core placed in the mould.



METHOD OF CORE MAKING

Core making consists of the following four steps:

(i) Core sand preparation
(ii) Core moulding
(iii) Core baking
(iv) Core finishing

(i) Core sand preparation:

The core sand of desired type (dry sand, no-bake etc.,) and composition, along with additives is mixed manually or using muller of suitable type. [Muller - It is a mixer type that needs, shears, slices through and stirs the sand by means of revolving wheels or rollers. A muller can be assumed to be like a wet grinder.]

(ii) Core moulding or Core making:

Cores are prepared manually or using machines depending on the needs. Machines like jolt machine, sand slinger, core blower etc., are used for large scale continuous production, while small sized cores for limited production are manually made in hand filled core boxes.

A core box is similar to a pattern that gives suitable shape to the core. Figure (a) shows a core box used to produce rectangular shaped cores.

(iii) Core baking:

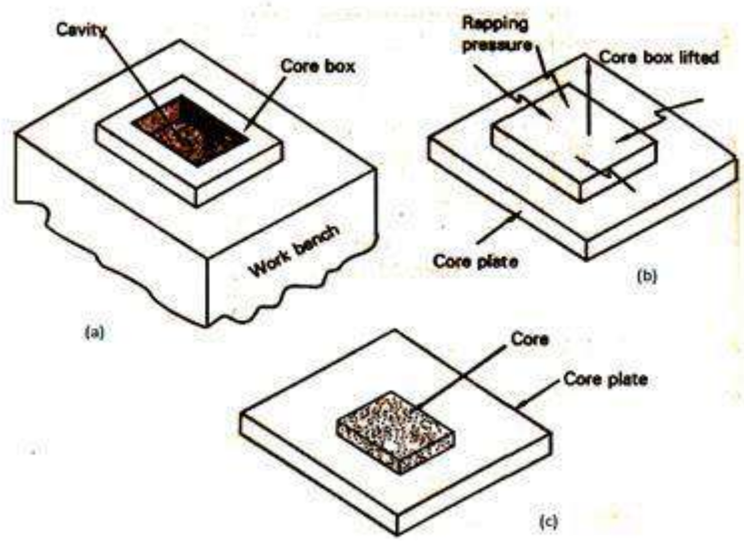
Cores are baked in ovens in order to drive away the moisture in them, and also to harden the binder thereby imparting strength to the core. The temperature and duration for baking may vary from 200 - 450°F and from a few minutes to hours respectively depending on the size of the core and type of binder used.

(iv) Core finishing:

The baked cores are finished by rubbing or filing with special tools to remove any fins, bumps, lose sand or other sand projections from its surface. The cores are also checked for dimensions and cleanliness. Finally, if cores are made in parts, they are assembled by using Suitable pastes pressed and dried in air before placing them in the mould cavity.

The procedure involved for preparing core is as follows:

- The prepared core sand mixture is rammed manually into the core box.
- The core box is inverted over a core plate and rapped in all directions using wooden mallet. Refer figure (b).
- The box is lifted vertically to leave the core on the core plate. Refer figure (c).
- The core along with the core plate is sent for baking.



CONCEPT OF GATING AND RISERING:

Gating:

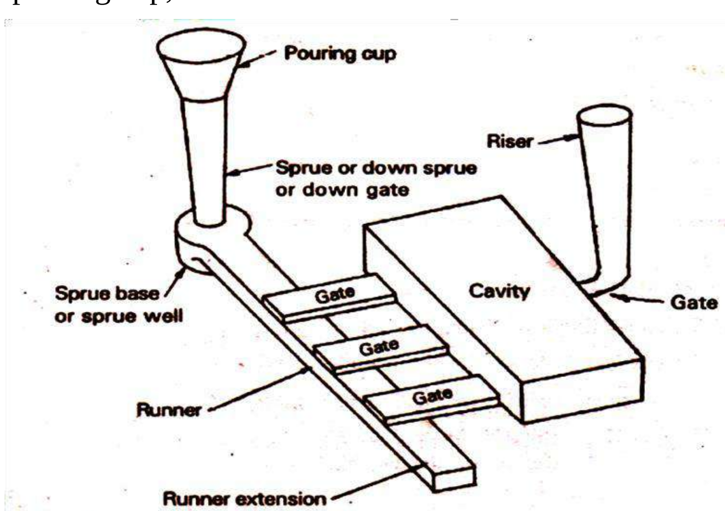
The concept of gating is very important, as it helps one to learn the controlled flow of molten metal from the crucible (ladle) into the mould cavity.

The term gating or gating system refers to all the channels or cavities through which the molten metal flows to reach and fill the mould cavity. Figure shows a simple gating system which consists of the following components.

- Sprue
- Pouring cup
- Runner
- Ingates or gates

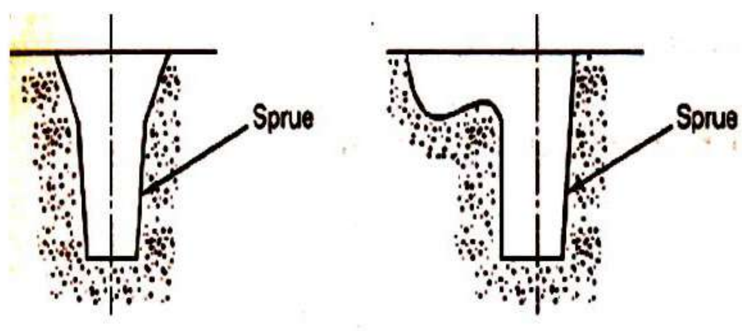
(a) Sprue:

A sprue is a vertical passage way through which the molten metal will enter the runner. It is also called down gate ordown sprue. The sprue is tapered in cross-section with its bigger end at the top connected to the pouring cup, while its smaller end connected to the runner.



(b) Pouring cup:

The enlarged portion (usually funnel shaped) of the sprue at its top into which the molten metal is poured is called pouring cup. Refer figure (a). In some cases, pouring basin is used instead of cup. The pouring basin has a larger opening as shown in figure (b). It makes pouring easier, eliminates aspiration [Aspiration- air pick up] and reduces the momentum of the liquid flowing into the mould by settling first into it.



Fig(a) Fig(b)

(c) Runner:

The runner is a horizontal passageway through which the molten metal flows into the gates. The cross-section of the runner may be square or trapezoid, and its length is very large compared to its width.

(d) Runner extension:

It is a small portion of the runner that extends beyond the last gate. It is used to trap the slag in the initial molten metal.

(e) In gates:

The in gate or gate is a short passageway which carries the molten metal from the runner to the mould cavity. The gates used may vary in number and depends on the size of the casting and rate of solidification of molten metal. A gate may be built as a part of the pattern, or it may be cut in the mould using gate cutter tool. The combination of sprue, sprue base, runner and ingates completes the total pouring system of any casting.

(f) Riser:

A riser or feeder head is a vertical passage made in the cope, to store the liquid metal and supply (feed) the same to the casting as it solidifies.

Molten metal flows into the mould cavity through the gating system, fills the cavity and then rises up through the riser till its top. At this moment, the pouring of molten metal is stopped. However during solidification, the metal in the cavity shrinks in volume and hence there will be no additional metal to be supplied into the mould cavity to compensate for the shrinkage. It is here where the riser comes to use to accomplish the required task. Since the riser is the last portion to be fed with molten metal, the metal contained in the riser will be in the liquid state compared to the metal in the gate and the runner. Thus the liquid metal in the riser flows into the cavity thereby compensating the shrinkage effects. The riser continues to feed liquid metal to the casting until the casting has completely solidified.

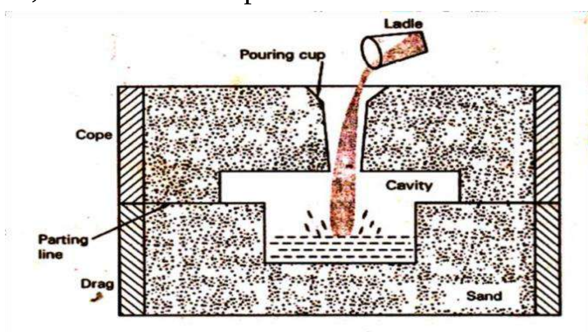
TYPES OF GATES:

The common types of gates are:

- Top gate
- Bottom gate and
- Parting gate

(a) Top gate:

A **top gate** is so called, because the molten metal from the pouring basin (from the top) is fed directly into the mould cavity. Figure shows a top gate. Top gate on one hand is advantageous, because the hottest metal remains at the top of the casting. This promotes directional solidification from the castings towards the gate. Top gate serves as a riser too. On the other hand, use of top gate is limited, because the turbulence of the falling metal tends to erode portions of the mould, as well as entraps air and metal oxides in the cavity itself.

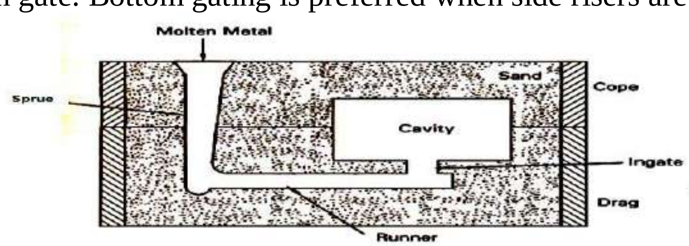


TOP GATE

(b) Bottom gate:

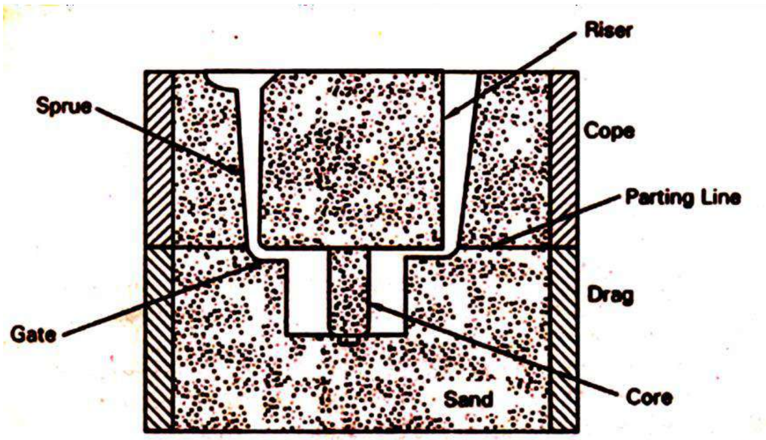
A bottom gate is so called, because the molten metal enters the mould cavity from its bottom. Figure shows a bottom gate. The molten metal fills the bottom portion of the mould cavity and rises steadily and gently up the mould walls.

Bottom gate minimizes turbulence and erosion in the mould cavity, but provides unfavorable temperature gradients that do not promote directional solidification. The reason is that: in bottom gating, the molten metal at the bottom of the mould remains hot due to the heat of the entering molten metal. As the metal rises in the mould cavity, it loses heat and the metal which finally goes into the riser located at the top of the casting is comparatively cooler than the metal near the in gate. Bottom gating is preferred when side risers are used.



(c) Parting gate:

Parting gate is the most commonly used gate and is a compromise between top and bottom gates. The gate is provided at the parting line of the mould as shown in figure.



PARTING GATE

In some cases, parting gates are provided with a choke that controls the rate of metal flow and, skim bob that restricts slag, dirt or sand particles from entering into the mould cavity. The molten metal will be trapped in the upper part of the skim bob due to its curvature.

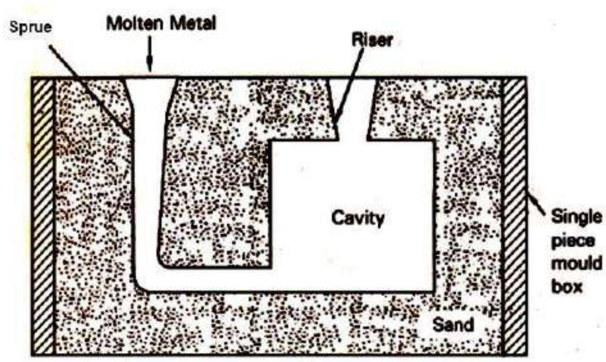
TYPES OF RISERS:

There are two types of risers:

- Open riser and Blind riser.

(a) Open riser

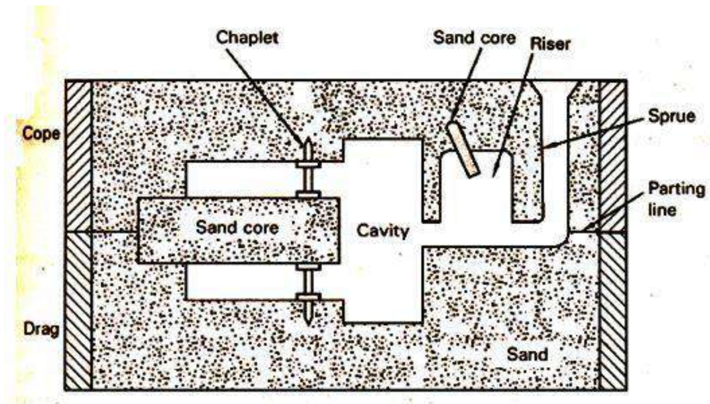
In this type, the top surface of the riser will be open to the atmosphere. An open riser is usually placed on the top of the casting as shown in figure or at the parting surface of the mould. Gravity and atmospheric pressure causes the liquid metal in the riser to flow into the solidifying casting. But, when a certain thickness of the liquid metal on the top surface of the riser solidifies, the atmospheric pressure will no longer be effective in feeding the molten metal. However, open riser is commonly used in foundries.



(b) Blind riser:

A blind riser as shown in figure is one which is completely enclosed in the mould and not exposed to the atmosphere. Due to this, the metal in the riser cools slower and thus stay liquid longer promoting directional solidification.

In blind risers, the liquid metal is fed to the solidifying casting under the force of **gravity** alone. Hence, when shrinkage occurs in the **blind riser,** a partial vacuum is developed in the riser. Due to this vacuum, the pressure due to gravity is also reduced. For efficient functioning of the blind riser, it is essential to make a provision to keep the riser open to the atmosphere enable atmospheric pressure to exert feeding pressure on the liquid metal. This is achieved by inserting a core of permeable sand at the top of the blind riser as shown in figure.



BLIND RISER

COMPARISON BETWEEN OPEN AND BLIND RISERS

Open Riser	Blind Riser
1. It is directly exposed to the atmosphere and clearly visible.	1. It is invisible, and not directly exposed to the atmosphere, but is vented with a permeable core.
2. It is fully moulded in the cope portion.	2. It is located either in the cope or drag depending on the convenience.
3. It is generally cylindrical in shape.	3. It can be convenient shape depending on the space and location.
4. It is larger than the blind riser, and casting yield is low.	4. It is smaller in size, hence casting yield is high.
5. It is convenient and fast to mould.	5. It is inconvenient and difficult to mould.
6. It solidifies fast, and not suitable for directional solidification.	6. It always remains hotter than the casting, thus promotes directional solidification.

QUESTIONS

1. Define Casting. Briefly explain the steps involved in making a sand casting. **(June 2013)**
2. Name the base sands used in metal casting and briefly discuss the requirement of base sand **(June 2014)**
3. What is a pattern? Explain different materials used for pattern making. **(June 2015)**
4. List different types of pattern. Explain any two types of pattern with a neat sketch **(June 2015)**
5. Explain in detail various allowances given to pattern and reasons to provide the allowances **(June 2013)**
6. List the types of moulding sand. Discuss the desirable properties of moulding sand. **(June 2015)**
7. With a neat sketch, describe the shell moulding process. List advantages of the process. **(June 2015)**
8. List different types of pattern. Explain match plate pattern with a neat sketch. **(June 2015)**
9. Briefly discuss the binders and additives in Sand moulding. **(June 2013)**
10. Explain with a neat sketch the gating system showing all its elements. . **(June 2015)**
11. What is a core? Explain method of core making **(Dec 2016)**
12. With a neat sketch explain the working principle of jolt and squeeze machine **(June 2014)**
13. Explain sand slinger with neat sketch**(Dec 2016)**
14. Explain with sketch different types of risers. **(Dec 2016)**
15. Explain sweep moulding with neat sketch **(Dec 2016)**
16. Explain squeeze casting with neat sketch **(Dec 2016)**