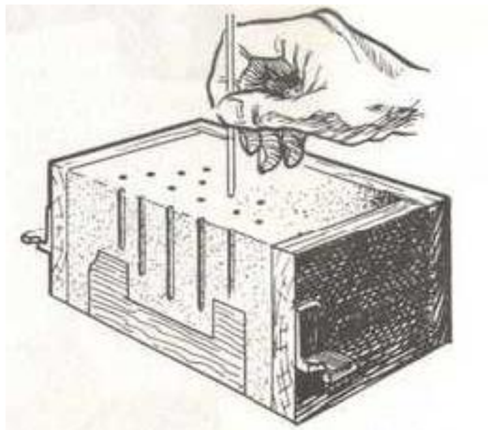
Foundry Works

Level-II

Based on March, 2022 Curriculum Version 1



Module Title: - Producing Molds and Core by Hand and Machines

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Table of Content

Acknowledgment

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Acronyms

AFS	American Foundry Society
OHS	Occupational Health & Safety
LAP	Learning Activity Performance
PPE	Personal Protective Equipment
UFS	Use Foundry Sand
EMS	Environmental Management System
CAD	Computer Aid Design
CAM	Computer Aid Manufacturing

List of figures

Introduction to the Module

The production of moulds and cores are the elements of foundry industry requires the preparation activities for receiving molten metal and it acts as a negative of the desired product. A core is a device used in casting and molding processes to produce internal cavities and reentrant angles (an interior angle that is greater than 180°). The core is normally a disposable item that is destroyed to get it out of the piece. They are most commonly used in sand casting, but are also used in die casting and injection molding. Molding is nothing but the mold preparation activities for receiving molten metal. Molding usually involves, preparing the combined sand mold around a pattern held within a supporting metal frame, removing the pattern to leave the mold cavity with cores. Mold cavity is the primary cavity. The mold cavity contains the liquid metal and it acts as a negative of the desired product. The mold also contains secondary cavities for pouring and channeling the liquid material in to the primary cavity and will act a reservoir, if required.

This module is designed to meet the industry requirement under the Foundry works occupational standard, particularly for the unit of competency: **Producing Molds and Core by Hand and Machines.**

This module covers the units:

- Job requirements
- Inspect and prepare pattern equipment
- Mold and core
- Pre-operational checks
- Machine to produce mold/cores
- Assemble molds/cores
- Clean and restore work area

Learning Objective of the Module:

- Identify job requirements
- Inspect and prepare pattern equipment
- Make mold and core
- Conduct pre-operational checks
- Operate machine to produce mold/cores

- Assemble molds/cores
- Clean and restore work area

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for farther knowledge, Examples and exercise

Unit One: Job Requirements
This unit is developed to provide you the necessary information regarding the following content coverage and topics: • Job requirements • Mold materials • Sequence of operation This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Identifying job requirements • Selecting mold materials • Determining sequence of operation

1.1 Job requirements

1.1.1 Introduction to molding

Molding is nothing but the mold preparation activities for receiving molten metal. Molding usually involves:

- Preparing the combined sand mold around a pattern held within a supporting metal frame
- Removing the pattern to leave the mold cavity with cores.

Mold cavity is the primary cavity. The mold cavity contains the liquid metal and it acts as a negative of the desired product. The mold also contains secondary cavities for pouring and channeling the liquid material in to the primary cavity and will act a reservoir, if required

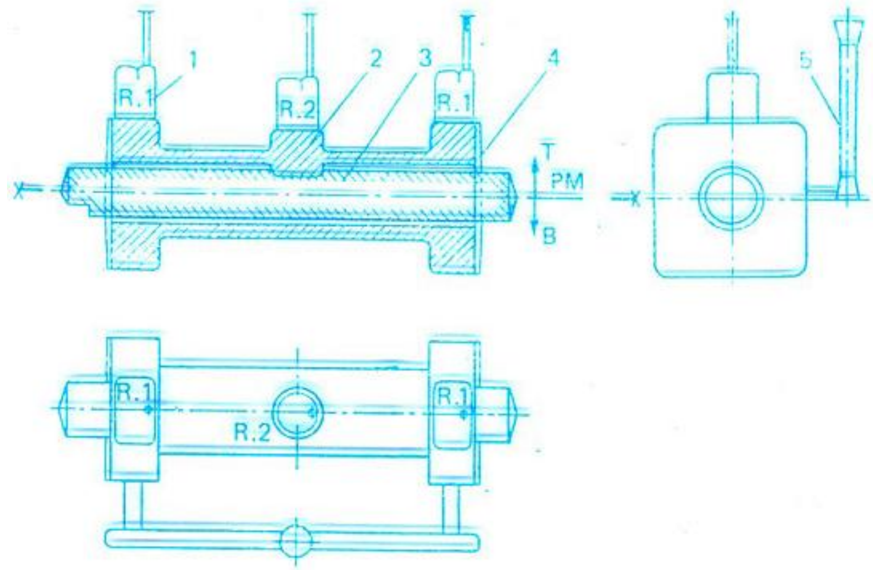
1.1.2 Drawing

The drawing of the part to be cast, such a process is the main process document. The drawing is define all the features of the casting process and is the basis for the design and manufacture of the molds and patterns and selection of other appliances, which are needed for the manufacturing of the casting mold (flask, template, etc.).

The elements of foundry technology indicated on the drawing should specify the following:

A. The best parting plane for the mold and pattern.

B. The positions of the mold for pouring which is depending on the shape of casting, kind of metal, gating system geometry, specifications of cast metal density, surface finish and many others.



1-riser; 2- casting; 3- core; 4- machining allowanes; 5- gating system

Figure 1.1.Engineering design of a casting

C. The machining allowances of the casting (thickness of metals to be removed after casting).

D. Draft allowances of the casting.

The following figure illustrates the manner in which taper (draft), and machining allowances are included in the pattern for a simple shape casting. Since allowances tend to be removed by machining, efforts made to reduce the allowances will be well received.

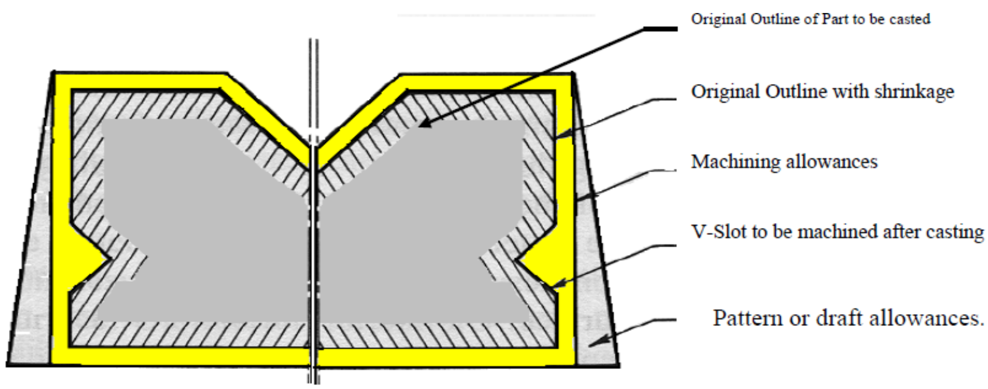


Figure 1.2. Taper (draft), and machining allowances

The number of cores to form the internal cavities in the castings or some shaped-portions at its extension. The cores are numbered in the order they will be set in the mold.

The assembled mold of the casting with all its measurements is represented in a drawing or sketch, the drawing should outline the location of cores, Gating system elements, chills, and sections drawing of the mold are made so that the molder could assemble the mold without referring to the casting drawing.

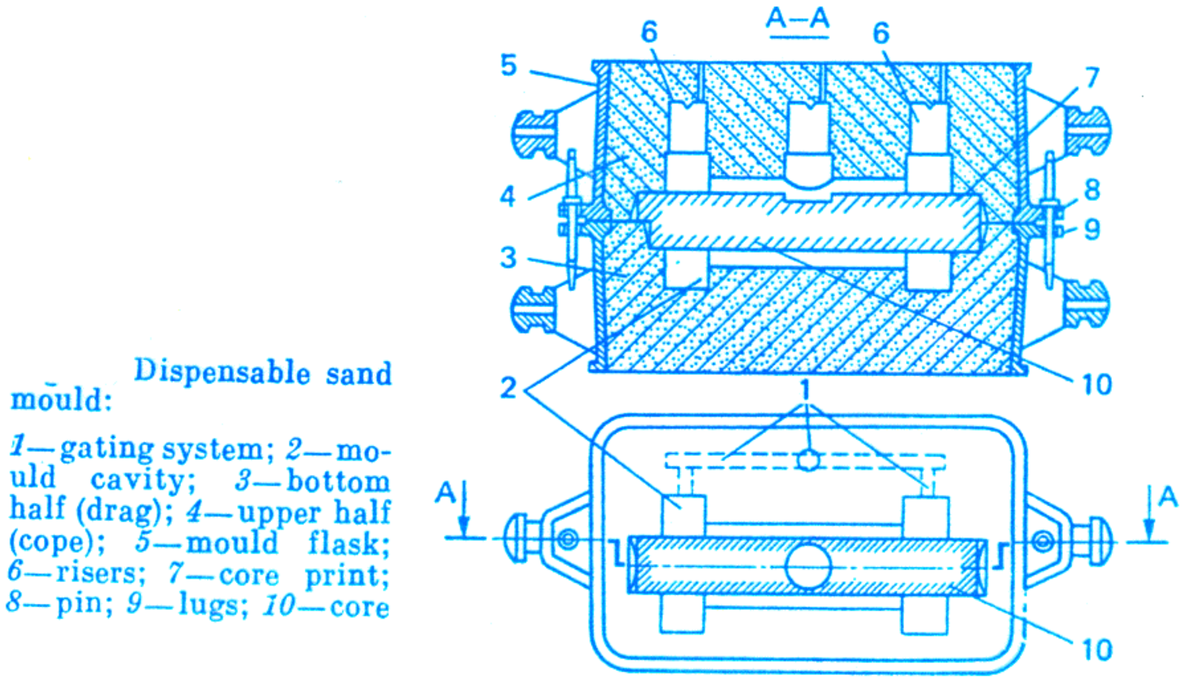


Figure 1.3. Dispensable sand mold

1.2 Mold materials

1.2.1 Molding sands

Sand is the principal molding material in the foundry shop where it is used for all types of castings, irrespective of whether the cast metal is ferrous or non-ferrous, iron or steel. This is because it possesses the properties vital for foundry purposes. The most important characteristic of sand is its refractory nature due to which it can easily withstand the high temperature of molten metal and does not get fused. Molding sand has chemical resistivity.

It does not chemically react or combine with molten metal and can therefore be used time and again. Sand has a high degree of permeability; it allows gases and air to escape from the mold when molten metal is poured without interfering with the rigidity and strength of the mold. The degree of strength, hardness, and permeability can also be adjusted, as desired, by varying the composition or the ingredients of the sand. Such flexibility is extremely difficult to achieve with any other molding material.

But the properties vary from one sand to another, and it should be noted that only those sands, characterized by the foregoing features, are considered suitable for molding work.

1.2.2. Principal ingredients of molding sands

The principal ingredients of molding sands are

- silica sand grains
- clay (bond)
- moisture

A. Silica Sand Grains

Silica sand grains are of paramount importance in molding sand because they impart refractoriness, chemical resistivity, and permeability to the sand. They are specified according to their average size and shape. The finer the grains, the more intimate will be the contact and lower the permeability. However, fine grains tend to fortify the mold and lessen its tendency to get distorted. The grains are classified according to their shape.

(i) Rounded Grains These grains have the least contact with one another in a rammed structure, thereby making the sand highly permeable to gases. Sand having rounded grains, however, lacks strength and does not pack up to the optimum extent. The binder requirements are minimum.

(ii) Sub angular Grains These grains have comparatively lower permeability and greater strength than the rounded ones.

(iii) Angular Grains These grains have defined edges, and the surfaces are nearly flat. They produce higher strength and lower permeability in the mold than sub- angular grains. The binder consumption is likely to be high.

(iv) Compounded Grains In some cases, the grains are cemented together such that they fail to separate when screened. They may consist of rounded, sub angular, or angular grains or a combination of the three. Such grains are called compounded grains and are least desirable due to their tendency to break down at high temperature.

In practice, sand grains contain mixed grain shapes, depending on origin. A sub angular-to-rounded grain mixture would be the best combination.

B. Clay

Clay imparts the necessary bonding strength to the molding sand so that after ramming, the mold does not lose its shape. However, as the quantity of the clay is increased, the permeability of the mold is reduced.

Clay is defined by the American Foundry men's Society (AFS), as those particles of sand (under 20 microns in diameter) that fail to settle at a rate of 25 mm per minute, when suspended in water. Clay consists of two ingredients: fine silt and true clay. Fine silt is a sort of foreign matter of mineral deposit and has no bonding power.

True clay supplies the necessary bond. Under high magnification, true clay is found to be made up of extremely minute aggregates of crystalline particles, called clay minerals. These clay minerals are further composed of flake-shaped particles, about 2 microns in diameter, which are seen to lie flat on one another.

C. Moisture

Clay acquires its bonding action only in the presence of the requisite amount of moisture. When water is added to clay, it penetrates the mixture and forms a microfilm which coats the surface of each Hake. The molecules of water forming this film are not in the original fluid state but in a fixed and definite position.

As more water is added, the thickness of the film increases up to a certain limit after which the excess water remains in the fluid state. The thickness of this water film varies with the clay mineral. The bonding quality of clay depends on the maximum thickness of water film it can maintain.

When sand is rammed in a mold, the sand grains are forced together. The clay coating on each grain acts in such a way that it not only locks the grains in position but also makes them retain that position. If the water added is the exact quantity required to form the film, the bonding action is best. If the water is in excess, strength is reduced and the mold gets weakened. Thus, moisture content is one of the most important parameters affecting mold and core characteristics and consequently, the quality of the sand produced.

1.2.3. Constituents of molding sand

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

Silica sand

Silica sand in form of granular quarts is the main constituent of molding sand having enough refractoriness which can impart strength, stability and permeability to molding and core sand. But along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities.

The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present. The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable.

The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub angular and rounded).

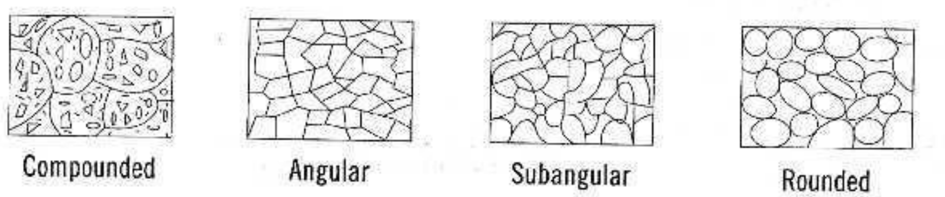


Figure 1.4 Types of Sand Grains

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 Kaolinite, 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 grins without the presence of moisture in molding sand and core sand.

Moisture

The amount of moisture content in the molding sand varies generally between 2 to 8 percent. This amount is added to the mixture of clay and silica sand for developing bonds. This is the amount of water required to fill the pores between the particles of clay without separating them. This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand.

The effect of clay and water decreases permeability with increasing clay and moisture content. The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing. For increasing the molding sand characteristics some other additional materials besides basic constituents are added which are known as additives.

Additives

Additives are the materials generally added to the molding and core sand mixture to develop some special property in the sand. Some common used additives for enhancing the properties of molding 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 molding sands for making molds 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 molding and core sand. It is completely volatilized by heat in the mold, thereby leaving space between the sand grains. This allows free movement of sand grains, which finally gives rise to mold wall movement and decreases the mold expansion and hence defects in castings. Corn sand if added to molding sand and core sand improves significantly strength of the mold 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 molds.

Sea coal

Sea coal is the fine powdered bituminous coal which positions its place among the pores of the silica sand grains in molding 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 mold wall movement and the permeability in mold and core sand and hence makes the mold and core surface clean and smooth.

Pitch

It is distilled form of soft coal. It can be added from 0.02 % to 2% in mold and core sand. It enhances hot strengths, surface finish on mold 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 mold and core sand. It volatilizes when heated, thus allowing the sand grains room to expand. It will increase mold wall movement and decrease expansion defects. It also increases collapsibility of both of mold 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 molds and cores. It also reduces metal penetration in the walls of the molds and cores.

1.2.4. Kinds of molding sand

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

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.

Molds prepared by this sand are not requiring backing and hence are known as green sand molds. This sand is easily available and it possesses low cost. It is commonly employed for production of ferrous and non-ferrous castings.

Dry sand

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

Loam sand

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

Facing sand

Facing sand is just prepared and forms the face of the mold. It is directly next to the surface of the pattern and it comes into contact molten metal when the mold is poured. Initial coating around the pattern and hence for mold 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 molding sand to make facings. The layer of facing sand in a mold usually ranges from 22-28 mm. From 10 to 15% of the whole amount of molding sand is the facing sand.

Backing sand

Backing sand or floor sand is used to back up the facing sand and is used to fill the whole volume of the molding flask. Used molding sand is mainly employed for this purpose. The backing sand is sometimes called black sand because that old, repeatedly used molding sand is black in color due to addition of coal dust and burning on coming in contact with the molten metal.

System sand

In mechanized foundries where machine molding is employed. A so-called system sand is used to fill the whole molding 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 mold is made of this system sand, the properties such as strength, permeability and refractoriness of the molding sand must be higher than those of backing sand.

Parting sand

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.

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.

1.3 Sequence of operation

1.3.1 Core sand preparation:

The first consideration in making a core is to mix and prepare the sand properly.

- ✓The best selected sand and binders will not produce good casting, until they are properly and efficiently mixed and prepared.
- ✓Sand preparation means mixing the molding sand ingredients such as sand, binder, moisture and other additives.
- ✓Mixing can be done manually or by using mechanical mixers.
- ✓An operation in addition with sand preparation is called as sand tempering, which is a process by which adequate amount of moisture is added to the molding sand to make it workable.
- ✓Sand conditioning consists of preparing of the molding sand, so that it becomes suitable for molding purposes.

1.3.2 Core making: Cores are made separately in a core box made of wood or metal. The various steps in core making are

- ✓Ramming of core sand in the box,
- ✓Venting

- ✓reinforcing
- ✓removing of core from box,
- ✓Baking, pasting, sizing etc.

This work of producing cores can either be done by hand or by some machines designed for this purpose. In machine molding, the core-sand mixture is rammed by jolting, squeezing or blowing by means of suitable machine. Venting, reinforcing and other Operations are carried out by hand.

1.3.3 Core Baking:

- ✓ After the cores are prepared they are baked in baking furnace where the moisture is removed from the core.
- ✓ In the green state, cores have round shape hence they are placed on the core plate for baking, where they tend to flatten.
- ✓ The special shapes, which support the green sand cores having curved surfaces, are known as core driers.
- ✓ After supporting on the core drier, they are sent to ovens for baking.
- ✓ The core oven may be batch type or continuous type

1.3.4 Finishing:

- ✓After baking, cores are given certain finishing operation before they are finally set in the mold.
- ✓The fins and other sand projections are removed from the sand surface of the cores by rubbing or filing, to bring them to correct dimensions and to provide a good surface finish.
- ✓The cores are also coated with refractory or protective materials to improve their refractoriness.
- ✓The surface may be coated with heat resistant paint.
- ✓Core coating materials are finely ground graphite, silica and zircon flour.
- ✓Finally core assembling is done; it means two or more parts of the core are joined together by pasting, welding or bolting before the core can be set in the mold.

1.3.5 Setting the cores

- ✓ Core setting means placing cores in the mold.
- ✓ To obtain correct cavities in the casting, the cores should be accurately positioned in the molds.

Self-Check 1

Part I Directions: Select the correct answers of the following multiple Choice Questions.

1. The ________________ preparation activities for receiving molten metal.

   A. Mold B. Casting C. Foundry D. None

2. The _______________ is defining all the features of the casting process.

   A. Mold B. Foundry C. Drawing D. All

3. ____________ are included in the pattern for a simple shape casting.

   A. Allowances B. Molds C. Foundries D. Sands

4. The first step in the sand casting process.

   A. Assembling the cast B. Pouring the molten C. create the mold D. All.

5. Too soft ramming will generate ________ mold.

   A. Good B. hard C. weak D. Smooth

Part II Directions: True or false the questions listed below.

1. The first consideration in making a core is to mix and prepare the sand properly

2. The temperature for baking are not depends on the core material used

Part III Directions: Matching, match column “A” with column “B” (4%)

Column “A”	Column “B”
1.___ Materials used to stick	A. Core sand
2.___ made separately in a core box	B. Core binders
	C. Core sand
	D. Core

Unit Two: Inspect and Prepare Pattern Equipment

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Pattern equipment
- Inspecting pattern equipment
- Assembling pattern
- Setting up pattern equipment

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identifying pattern equipment
- Inspecting pattern equipment
- Pattern
- Set up pattern equipment

2.1 Pattern equipment

2.1.1 Introduction

Patterns are used to mold the sand mixture into the shape of the casting and may be made of wood, plastic, or metal. The selection of a pattern material depends on the size and shape of the casting, the dimensional accuracy and the quantity of castings required, and the molding process. Because patterns are used repeatedly to make molds, the strength and durability of the material selected for a pattern must reflect the number of castings that the mold will produce

Patterns may be made of a combination of materials to reduce wear in critical regions, and they usually are coated with a parting agent to facilitate the removal of the casting from the molds.

Patterns can be designed with a variety of features to fit specific applications and economic requirements. One-piece patterns, also called loose or solid patterns, generally are used for simpler shapes and low-quantity production; they generally are made of wood and are inexpensive. Split patterns are two piece patterns, made such that each part forms a portion of the cavity for the casting; in this way, castings with complicated shapes can be produced.

The pattern is the principal tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The quality of the casting produced depends upon the material of the pattern, its design, and construction. The costs of the pattern and the related equipment are reflected in the cost of the casting. The use of an expensive pattern is justified when the quantity of castings required is substantial.

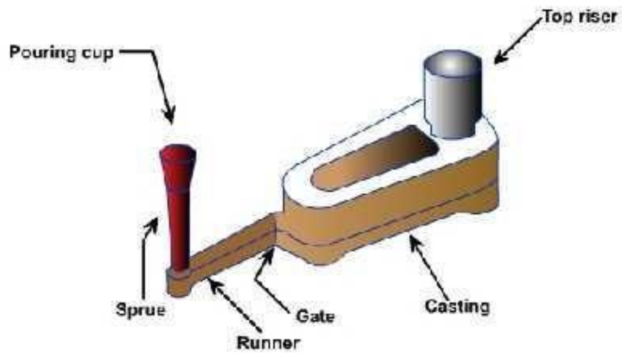


Figure 2.1 a typical pattern attached with gat and riser system

2.1.2. Functions of the pattern

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

2.1.3 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. To be suitable for use, the pattern material should be:

- Easily worked, shaped and joined
- Light in weight
- Strong, hard and durable
- Resistant to wear and abrasion

- Resistant to corrosion, and to chemical reactions
- Dimensionally stable and unaffected by variations in temperature and humidity
- Available at low cost

The usual pattern materials are wood, metal, and plastics. The most commonly used pattern material is wood, since it is readily available and of low weight. Also, it can be easily shaped and is relatively cheap. The main disadvantage of wood is its absorption of moisture, which can cause distortion and dimensional changes. Hence, proper seasoning and upkeep of wood is almost a pre-requisite for large-scale use of wood as a pattern material.

2.1.4 Common pattern materials

The common materials used for making patterns are wood, metal, plastic, plaster, wax or mercury. The some important pattern materials are discussed as under.

❖ **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. Wood can preserve its surface by application of a shellac coating for longer life of the pattern.

But, in spite of its above qualities, it is susceptible to shrinkage and warpage and its life is short because of the reasons that it is highly affected by moisture of the molding sand. After some use it warps and wears out quickly as it is having less resistance to sand abrasion. It cannot withstand rough handily and is weak in comparison to metal. In the light of above qualities, wooden patterns are preferred only when the numbers of castings to be produced are less. The main varieties of woods used in pattern-making are shisha, kale, deodar, teak and mahogany.

A. Shisham

It is dark brown in color having golden and dark brown stripes. It is very hard to work and blunts the cutting tool very soon during cutting. It is very strong and durable. Besides making pattern, it is also used for making good variety of furniture, tool handles, beds, cabinets, bridge piles, plywood etc.

B. Kail

It has too many knots. It is available in Himalayas and yields a close grained, moderately hard and durable wood. It can be very well painted. Besides making pattern, it is also utilized for making wooden doors, packing case, cheap furniture etc.

C. Deodar

It is white in color when soft but when hard, its color turns toward light yellow. It is strong and durable. It gives fragrance when smelled. It has some quantity of oil and therefore it is not easily attacked by insects. It is available in Himalayas at a height from 1500 to 3000 meters. It is used for making pattern, manufacturing of doors, furniture, patterns, railway sleepers etc. It is a soft wood having a close grain structure unlikely to warp. It is easily workable and its cost is also low. It is preferred for making pattern for production of small size castings in small quantities.

D. Teak Wood

It is hard, very costly and available in golden yellow or dark brown color. Special stripes on it add to its beauty. In India, it is found in M.P. It is very strong and durable and has wide applications. It can maintain good polish. Besides making pattern, it is used for making good quality furniture, plywood, ships etc. It is a straight-grained light wood. It is easily workable and has little tendency to warp. Its cost is moderate.

e) Mahogany

This is a hard and strong wood. Patterns made of this wood are more durable than those of above mentioned woods and they are less likely to warp. It has got a uniform straight grain structure and it can be easily fabricated in various shapes. It is costlier than teak and pine wood, It is generally not preferred for high accuracy for making complicated pattern. It is also preferred for production of small size castings in small quantities. The other Indian woods which may also be used for pattern making are deodar, walnut, kail, maple, birch, cherry and shisham.

Advantages of wooden patterns

1. Wood can be easily worked.
2. It is light in weight.
3. It is easily available.
4. It is very cheap.
5. It is easy to join.
6. It is easy to obtain good surface finish.
7. Wooden laminated patterns are strong.
8. It can be easily repaired.

Disadvantages

1. It is susceptible to moisture.
2. It tends to warp.
3. It wears out quickly due to sand abrasion.
4. It is weaker than metallic patterns.

- **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 possess longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes. It can withstand against corrosion and handling for longer period. It possesses excellent strength to weight ratio.

The main disadvantages of metallic patterns are higher cost, higher weight and tendency of rusting. It is preferred for production of castings in large quantities with same pattern. The metals commonly used for pattern making are cast iron, brass and bronzes and aluminum alloys.

A. Cast Iron

It is cheaper, stronger, tough, and durable and can produce a smooth surface finish. It also possesses good resistance to sand abrasion. The drawbacks of cast iron patterns are that they are hard, heavy, and brittle and get rusted easily in presence of moisture.

Advantages

1. It is cheap
2. It is easy to file and fit
3. It is strong
4. It has good resistance against sand abrasion
5. Good surface finish

Disadvantages

1. It is heavy
2. It is brittle and hence it can be easily broken
3. It may rust

B. Brasses and Bronzes

These are heavier and expensive than cast iron and hence are preferred for manufacturing small castings. They possess good strength, machinability and resistance to corrosion and wear. They can produce a better surface finish. Brass and bronze pattern is finding application in making match plate pattern

Advantages

1. Better surface finish than cast iron.
2. Very thin sections can be easily casted.

Disadvantages

1. It is costly
2. It is heavier than cast iron.

C. Aluminum Alloys

Aluminum alloy patterns are more popular and best among all the metallic patterns because of their high light ness, good surface finish, low melting point and good strength. They also possesses good resistance to corrosion and abrasion by sand and thereby enhancing longer life of pattern. These materials do not withstand against rough handling. These have poor repair ability and are preferred for making large castings.

Advantages

1. Aluminum alloys pattern does not rust.
2. They are easy to cast.
3. They are light in weight.
4. They can be easily machined.

Disadvantages

1. They can be damaged by sharp edges.
2. They are softer than brass and cast iron.
3. Their storing and transportation needs proper care.

D**. White Metal (Alloy of Antimony, Copper and Lead)**

Advantages

1. It is best material for lining and stripping plates.
2. It has low melting point around 260°C
3. It can be cast into narrow cavities.

Disadvantages

1. It is too soft.
2. Its storing and transportation needs proper care
3. It wears away by sand or sharp edges.

- **Plastic**

Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non-sticky to molding sand, durable and they are not affected by the moisture of the molding sand. 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.

The plastics used for this purpose are thermosetting resins. Phenolic resin plastics are commonly used. These are originally in liquid form and get solidified when heated to a specified temperature. To prepare a plastic pattern, a mold in two halves is prepared in plaster of Paris with the help of a wooden pattern known as a master pattern. The phenolic resin is poured into the mold and the mold is subjected to heat. The resin solidifies giving the plastic pattern.

Recently a new material has stepped into the field of plastic which is known as foam plastic. Foam plastic is now being produced in several forms and the most common is the expandable polystyrene plastic category. It is made from benzene and ethyl benzene.

- **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.

Plaster of Paris pattern can be prepared either by directly pouring the slurry of plaster and water in molds prepared earlier from a master pattern or by sweeping it into desired shape or form by the sweep and stickle method. It is also preferred for production of small size intricate castings and making core boxes.

- **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, cerasin wax, and micro-crystalline wax.

The properties desired in a good wax pattern include low ash content up to 0.05 per cent, resistant to the primary coat material used for investment, high tensile strength and hardness, and substantial weld strength.

The general practice of making wax pattern is to inject liquid or semi-liquid wax into a split die. Solid injection is also used to avoid shrinkage and for better strength. Waxes use helps in imparting a high degree of surface finish and dimensional accuracy castings.

Wax patterns are prepared by pouring heated wax into split molds or a pair of dies. The dies after having been cooled down are parted off. Now the wax pattern is taken out and used for molding. Such patterns need not to be drawn out solid from the mold. After the mold is ready, the wax is poured out by heating the mold and keeping it upside down. Such patterns are generally used in the process of investment casting where accuracy is linked with intricacy of the cast object.

2.1.5 Factors effecting selection of pattern material

The following factors must be taken into consideration while selecting pattern materials.

- Number of castings to be produced. Metal pattern are preferred when castings are required large in number
- Type of mold material used
- Kind of molding process
- Method of molding (hand or machine)
- Degree of dimensional accuracy and surface finish required
- Minimum thickness required

2.2 Patterns

Since patterns are the forms for the castings, the casting can be no better than the patterns from which it is made. Where close tolerances or smooth casting finishes are desired, it is particularly important that patterns be carefully designed, constructed, and finished.

Patterns serve a variety of functions, the more important being:

- ❖ To shape the mold cavity to produce castings,
- ❖ To accommodate the characteristics of the metal cast,
- ❖ To provide accurate dimensions,
- ❖ To provide a means of getting liquid metal into the mold (gating system), and
- ❖ To provide a means to support cores by using core prints outside of the casting.

2.2.1 Pattern allowances

Usual allowances built into the pattern to ensure dimensional accuracy include the following:

A. Draft: the taper on the vertical walls of the casting which is necessary to extract the pattern from the mold without disturbing the mold walls and is also required when making the core.

B. Shrinkage allowance, a correction to compensate for the solidification shrinkage of the metal and its contraction during cooling. These allowances vary with the type of metal and size of casting. Typical allowances for cast iron are to in/ft; for steel, to in/ft; and for aluminum, to in/ft. A designer should consult appropriate references (AFS, "Cast Metals Handbook"; ASM, "Casting Design Handbook"; "Design of Ferrous Castings") or the foundry. These allowances also include a size tolerance for the process so that the casting is dimensionally correct.

C. Machine finish allowance is necessary if machining operations are to be used so that stock is provided for machining. Tabulated data are available in the references cited for shrinkage allowances.

D. If a casting is prone to distortion, a pattern may be intentionally distorted to compensate. This is a distortion allowance.

Patterns vary in complexity, depending on the size and number of castings required. Loose patterns are single prototypes of the casting and are used only when a few castings are needed. They are usually constructed of wood, but metal, plaster, plastics, urethanes, or other suitable material may be used. With advancements in solids modeling utilizing computers, CAD/CAM systems, and laser technology, rapid prototyping is possible and lends itself to the manufacture of porotype patterns from a number of materials, including dense wax paper, or via stereolithographic processes wherein a laser-actuated polymerized plastic becomes the actual pattern or a prototype for a pattern or a series of patterns. The gating system for feeding the casting is cut into the sand by hand. Some loose patterns may be split into two parts to facilitate molding.

Gated patterns incorporate a gating system along with the pattern to eliminate hand cutting.

Match-plate patterns have the cope and drag portions of the pattern mounted on opposite sides of a wooden or metal plate, and are designed to speed up the molding process. Gating systems are also usually attached.

These patterns are generally used with some type of molding machine and are recommended where a large number of castings are required.

For fairly large castings or where an increase in production rate is desired, the patterns can be mounted on separate pattern plates, which are referred to as cope- and drag-pattern plates. They are utilized in horizontal or vertical machines. In horizontal molding machines, the pattern plates may be used on separate machines by different workers, and then combined into completed molds on the molding floor prior to pouring. In vertical machines, the pattern plates are used on the same machine, with the flask less mold portions pushed out one behind the other. Vertical machines result in faster production rates and provide an economic edge in overall casting costs.

Special Patterns and Devices For extremely large castings, skeleton patterns may be employed. Large molds of a symmetric nature may be made for forming the sand mold by sweeps, which provide the contour of the casting through the movement of a template around an axis.

Follow boards are used to support irregularly shaped loose patterns which require an irregular parting line between cope and drag. A master pattern is used as an original to make up a number of similar patterns that will be used directly in the foundry.

2.2.2 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
11. Segmental or part 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 Fig. 2.1

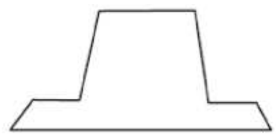


Figure. 2.2 Single piece pattern

2. Two-piece or split pattern

When solid pattern is difficult for withdrawal from the mold 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 Fig. 2.2.

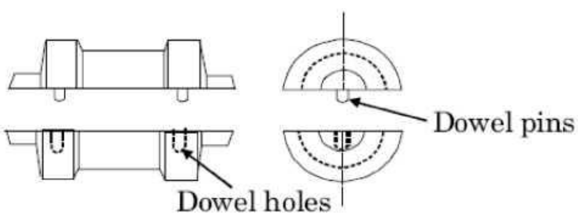


Figure 2.3 Two piece pattern

3. Cope and drag pattern

In this case, cope and drag part of the mold are prepared separately. This is done when the complete mold is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates. A typical example of match plate pattern is shown in Fig. 2.3.

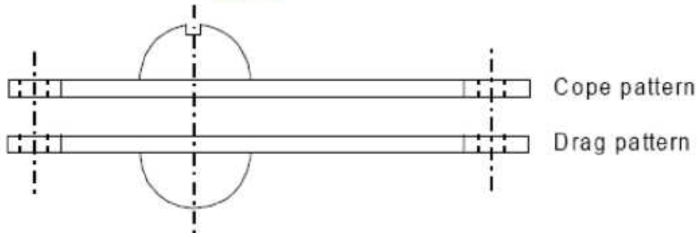


Figure 2.4 Cope and drag pattern

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 molding flasks are needed to make mold from these patterns.

5. Loose-piece Pattern

Loose piece pattern (Fig. 2.4.) is used when pattern is difficult for withdrawal from the mold. 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 mold. Finally the loose piece is withdrawal separately leaving the intricate mold.

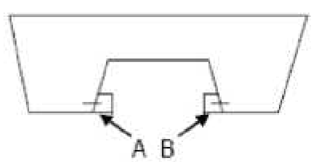


Figure 2.5 Loose piece pattern

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 molding. A typical example of match plate pattern is shown in blow.

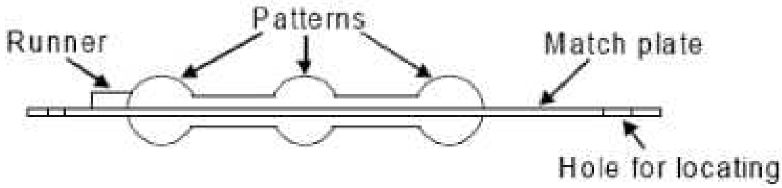


Figure 2.6 Match plate pattern

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 molding board for the first molding operation as shown in Fig. 2.6.

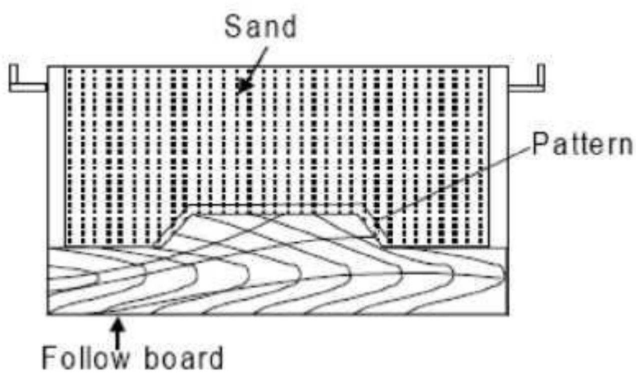


Figure 2.7 Follow board pattern

8. Gated pattern

In the mass production of casings, multi cavity molds are used. Such molds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Fig. 2.7. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.

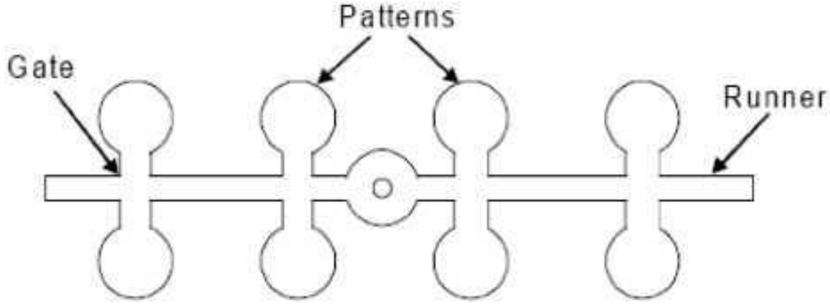


Figure 2.8 Gated pattern

9. Sweep pattern

Sweep patterns are used for forming large circular molds of symmetric kind by revolving a sweep attached to a spindle as shown in Fig. 2.8. 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 mold. The pivot end is attached to a stake of metal in the center of the mold.

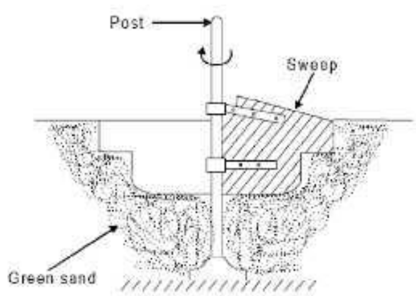


Figure 2.9 Sweep pattern

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.

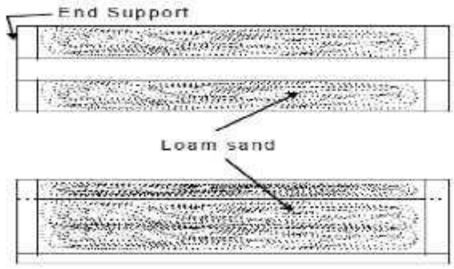


Figure 2.10 Skeleton pattern

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 Fig. 2.10

11. Segmental pattern

Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mold by being moved to form each section of the mold. The movement of segmental pattern is guided by the use of a central pivot. A segment pattern for a wheel rim is shown in Fig. 2.11

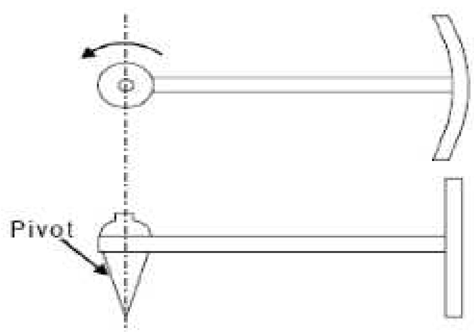


Figure 2.11 Segmental or part pattern

2.2.3 Pattern allowances

Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting. The selection of correct allowances greatly helps to reduce machining costs and avoid rejections. The allowances usually considered on patterns and core boxes are as follows:

1. Shrinkage or contraction allowance
2. Machining or finish allowance
3. Draft or taper allowance
4. Rapping or Shake allowance
5. Distortion or camber allowance
6. Mold wall Movement Allowance

1. Shrinkage or Contraction Allowance

All most all cast metals shrink or contract volumetrically on cooling. The metal shrinkage is of two types:

i. **Liquid Shrinkage**: it refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mold.

ii. **Solid Shrinkage**: it refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

The rate of contraction with temperature is dependent on the material. For example steel contracts to a higher degree compared to aluminum. To compensate the solid shrinkage, a shrink rule must be used in laying out the measurements for the pattern.

A shrink rule for cast iron is 1/8 inch longer per foot than a standard rule. If a gear blank of 4 inch in diameter was planned to produce out of cast iron, the shrink rule in measuring it 4 inch would actually measure 4 -1/24 inch, thus compensating for the shrinkage. The various rate of contraction of various materials are given below.

Material	Dimension	Shrinkage allowance (inch/ft)
Grey Cast Iron	Up to 2 feet	0.125
	2 feet to 4 feet	0.105
	over 4 feet	0.083

Cast Steel	Up to 2 feet	0.251
	2 feet to 6 feet	0.191
	over 6 feet	0.155
Aluminum	Up to 4 feet	0.155
	4 feet to 6 feet	0.143
	over 6 feet	0.125
Magnesium	Up to 4 feet	0.173
	Over 4 feet	0.155

Table 2.1 Rate of Contraction of Various Metals

2. Machining Allowance

It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting. If this allowance is not given, the casting will become undersize after machining. The amount of this allowance depends on the size of casting, methods of machining and the degree of finish. In general, however, the value varies from 3 mm. to 18 mm.

3. Draft or Taper Allowance

Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt.

These values are greatly affected by the size of the pattern and the molding method. In machine molding its, value varies from 10 mm to 50 mm/mt.

4. Rapping or Shake Allowance

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

5. Distortion Allowance

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

6. Mold wall Movement Allowance

Mold wall movement in sand molds occurs as a result of heat and static pressure on the surface layer of sand at the mold metal interface. In ferrous castings, it is also due to expansion due to graphitization. This enlargement in the mold cavity depends upon the mold density and mold composition. This effect becomes more pronounced with increase in moisture content and temperature.

2.3.3 Life expectancy of patterns

The life of patterns and core boxes can be expressed in terms of the number of molds or cores that can be produced. The material of the pattern, type of construction, method of molding and core-making, care with which patterns are handled, and type of storage affect the life expectancy. Table 2.2 gives the expected life of patterns for guidance purposes.

SL.	Method of	Pattern Material	Type of	Expected Life in Number of

No.	Using Pattern		Construction	Moulds
1.	Loose	Soft wood	Skeleton	10
2.	Loose		Segmental, disc, box, etc.	50
3.	Loose	Hard wood	Ring, tongue and groove, header and stave, disc, box and composite	200
4.	Mounted			1000
5.	Mounted	Epoxy resin	Cast in plaster or plastic molds	2000
6.	Mounted	Epoxy resin with filler	Gel coat, lamination with glass fiber	5000
7.	Mounted	Aluminum pressure cast	As cast artd cleaned	3000-5000
8.	Mounted	Aluminum, sand cast	Machined all over and polished	30,000
9.	Mounted	Brass, SG iron, grey iron, steel	Machined all over	50,000

Table 2.2 Life expectancy of patterns

2.2.4 Pattern storage and repair

In order to be able to use the patterns for a long time, it is essential to give due consideration to storage and repair requirements. It is advisable that the patterns, after use in the foundry, are carefully inspected for any breakage or loss, adequately repaired, and sent for safe storage. Similarly, when a pattern is requisitioned by the foundry, it should be obtained from storage, inspected, repairs, if any, carried out, and then issued to the foundry.

It is also desirable to maintain a complete history of each pattern by recording, date-wise on a card, the issue and return of patterns to and from the foundry, number of molds produced, inspection carried out, and nature of repairs done.

The principal factors governing space requirements for pattern storage are

- Quantity and volume of patterns
- Rate of acquisition of new patterns to be added to storage
- Types Of Patterns
- General rate of obsolescence due to changes in casting design, or design of product.

Pattern-storage areas should be so designed that they are weather-proof and fireproof, with adequate arrangements for extinguishing fires. For expensive patterns, it is also desirable to have temperature and humidity controls. Separate areas or floors should be earmarked for light, medium and heavy patterns. Small patterns are kept in racks, and large ones are placed on the floor with proper identification marks.

Repair of patterns is often required for various reasons. It is relatively easier to manufacture new patterns than repair old ones. It needs skill, hard work and experience to correctly repair the pattern equipment. Pattern repair may be required due to normal wear and tear during use, breakage during transportation and handling, careless molding work, falling of slag or molten metal, seasonal effects, improper placement when not in use, use of sub-standard material, wrong designs and weak construction.

In case of foundries with a large turnover of patterns, it is preferable to have a repair section attached to the storage area and separate from the main pattern shop. A properly organized pattern-repair facility can help improve the technological discipline amongst patternmakers, keep a constant check on undesirable and careless practices during manufacture, and even guide in improving molding and core-making practices.

2.3 Set up pattern equipment

2.3.1 Selection of Pattern Type

The type of pattern or core box used and the pattern or core box material used for a given set of castings depend on the following fundamental factors:

- The number of castings to be produced
- The molding or core making process to be employed
- The casting design
- The dimensional tolerances required

The life and cost of a pattern can both vary dramatically, depending on the pattern material and the type of pattern equipment.

In the developmental stage of a pattern design, only a few prototype castings need to be produced before modifications are made to the pattern dimensions or to the gating and riser. If such revisions are likely, an inexpensive wood pattern is often used first. This will enable engineering changes to be made quickly and inexpensively. After the design and the tolerances of the casting have been approved, a permanent pattern is selected based on production quantity and the molding or core making processes to be used.

Costs that are influenced by pattern equipment selection depend largely on the pattern material and pattern type and are dictated by production quantity. Expensive pattern equipment can often be justified if production quantities are high. The complexity of the pattern and the quality of the material used to make the pattern generally increase with the number of castings to be produced from one set of patterns. For example, an unmounted or loose softwood pattern could be used only for very limited production before it would require repair or replacement. A similar pattern made from a more durable material and mounted on a pattern board would increase the useful life of the pattern dramatically.

Foundries also use various molding processes, casting processes, and core making processes. Therefore, during molding, patterns and core boxes can be subjected to differing degrees of abrasion, temperature, and stress that affect the pattern type and choice of pattern material.

For example, the stresses that the pattern encounters during automated high-pressure green sand molding necessitate the use of high-strength pattern materials and rigid pattern construction. When large green sand molds are made with sand slingers, the rapid abrasive wear of softer pattern materials is a major concern. Shell molds or cores can be made only from metal patterns because they are heated to temperatures of approximately 260 °C (500 °F). In V-process molding, a thin polyethylene sheet prevents the sand mold from contacting the pattern during molding, and this allows inexpensive wood patterns to have an almost indefinite pattern life.

2.4.2Tolerances

The type of pattern used also has a significant effect on the casting tolerances that can be obtained and maintained. In general, final casting tolerances can be held within tighter limits as the rigidity and durability of the pattern equipment increase. When close tolerances are required, it may be desirable to construct the pattern equipment so that it can be dimensionally adjusted based on the results of prototype castings. These adjustments may involve refitting and re-machining.

It is very difficult to compare the cost of castings made from EPS patterns to similar castings made from permanent patterns. The additional casting design flexibility and reduced molding costs associated with the evaporative foam casting process may off-set high pattern and pattern die costs, resulting in lower total casting cost

Self-Check 2

Part I Directions: Answer all the questions listed below.

1. What are the functions of pattern

   A. Minimize the overall casting cost   C. produce seats for the cores in the mold

   B. Minimize casting defects   D. All

2. The use of gages for assembling cores is necessary for producing quality castings

   A. False   B. True

3. Rebuilding procedures used depend on the pattern material and the service life required for the rebuilt pattern.

   A. True   B. False

4. Epoxies and urethanes are widely used to rebuild **all** types of pattern materials

   A. True   B. False

5. Improper storage and handling cannot cause pattern deterioration and damage.

   A. True   B. False

Part II Directions: Write the correct answer

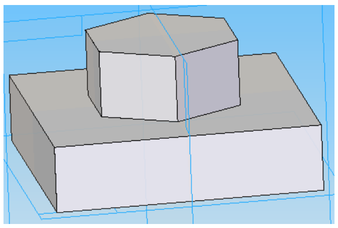
1. Write at list three the common types of patterns?

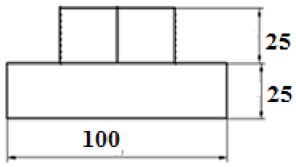
   1. ____________________ 2. _____________________3.______________

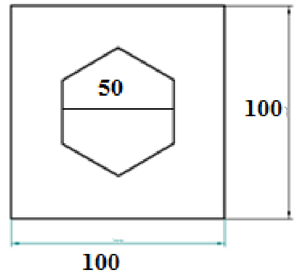
2. Write at list three pattern allowances?

   1. ____________________ 2. _____________________3.______________

Operation Sheet 2.1







Operation title: Make a Solid Pattern

Purpose: To make a Solid Pattern

Instruction: use the necessary tools and equipment to perform pre start up.

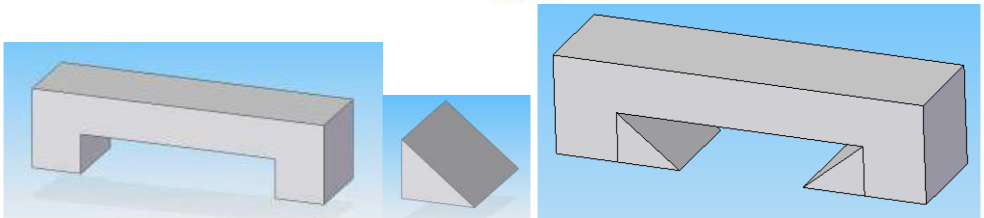
Required tools and equipment:

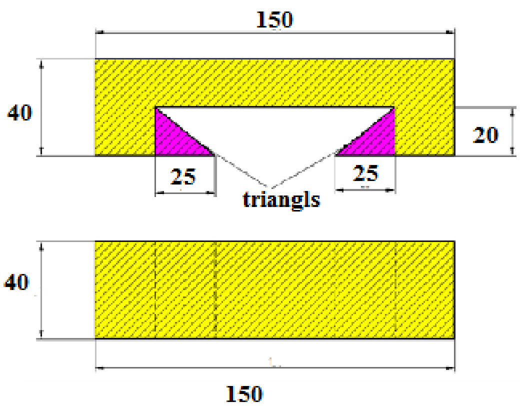
1. Steel rule
2. Try square
3. Marking gauge
4. Rip saw
5. Tenon saw
6. Mallet
7. Jack plane
8. Wood rasp file etc.

Procedures:

1. The wooden pieces are checked for dimensions.
2. One side of pieces is planned with jack plane and for straightness.
3. An adjacent side is planned and checked for squareness with a try square.
4. Marking gauge is set and lines are marked hexagonal according to given figure.
5. Using ten on saw, the portions to be removed are cut from the piece.

Operation Sheet 2.2





Operation title: Make a Loose Piece Pattern

Purpose: To make a Loose Piece Pattern

Instruction: use the necessary tools and equipment to perform pre start up.

Required tools and equipment:

1. Steel rule
2. Try square
3. Marking gauge
4. Rip saw
5. Tenon saw
6. Mallet
7. Jack plane
8. Wood rasp file

Procedure:

1. The wooden pieces are checked for dimensions.
2. One side of pieces is planned with jack plane and for straightness.
3. An adjacent side is planned and checked for squareness with a try square.
4. The excess material is planned to correct size.
5. Marking gauge is set and lines are marked hexagonal according to given figure.
6. Using ten on saw, the portions to be removed are cut from the piece.

Unit Three: Make Mold and Core

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Position core using chaplets and chills
- Mold alignment
- Appropriate molding/core making equipment
- Appropriate molding materials
- Securing mold
- Molding materials to produce core
- Pouring basin
- Ramming mold and core
- Parting and stripping systems
- Positioning loose pieces, vents, risers and runners
- Removing pattern and loose pieces
- Inspecting and repairing mold
- Cleaning and painting mold and core

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Position core using chaplets and chills
- Clos and check molds alignment
- Select appropriate molding/core making equipment
- Select appropriate molding materials
- Secure mold
- Use molding materials to produce core
- Select pouring basin
- Ram mold and core
- Utilize parting and stripping systems
- Position loose pieces, vents, risers and runners

- Remove pattern and loose pieces
- Inspect and repair mold
- Clean and paint mold and core

3.1 Position core using chaplets and chills

3.1.1 Setting cores, chills, and chaplets

In the setting of cores, it is important to check the size of the core print against the core itself. A core print is a depression or cavity in the cope or drag, or both. The print is used to support a core and, when the core is set, is completely filled by the supporting extensions on the core. An oversize print or an under size core will cause fins on the completed castings, which may lead to cracks or chilled sections in the core area. An oversize core or an under size print may cause the mold to be crushed and result in loose sand in the mold and a dirty casting.

Setting simple cores in the drag should be no problem to a molder. Care should be taken in handling and setting the core. After a core has been properly set, it should be seated by pressing it lightly into the prints. Another item which should be checked is the venting of cores through the mold. Many times, the cores themselves are properly vented but the molder forgets to provide a vent through the mold for the core gases to escape.

Income instances, the cores may have to be tied to the cope. In such a case, they are attached to the cope by wires extending through the cope. The wires are wound around long rods resting on the top of the cope to provide additional support. The rods should rest on the flask to prevent crushing or cracking of the cope.

Such operations should be done with the cope resting on its side or face up. The tying should be done with as little disturbance as possible to the rammed surface. The core should be drawn up tight to prevent any movement of the core while the mold is being closed. Before closing the mold, the cope should be checked to make sure it is free of any loose sand.

Chills are rammed in place with the mold and are described under "Molding Tools" in this chapter. Again it is emphasized that chills must be clean and dry. Even chills which have just been removed from a newly shaken-out mold should be checked before immediate reuse.

The use of chaplets was described earlier in this chapter under "Molding Tools." It must be remembered that chaplets should be used only when absolutely necessary. Preferably, another method for support (for example, core prints) should be used, if at all possible. The use of chaplets in pressure castings should be completely avoided.

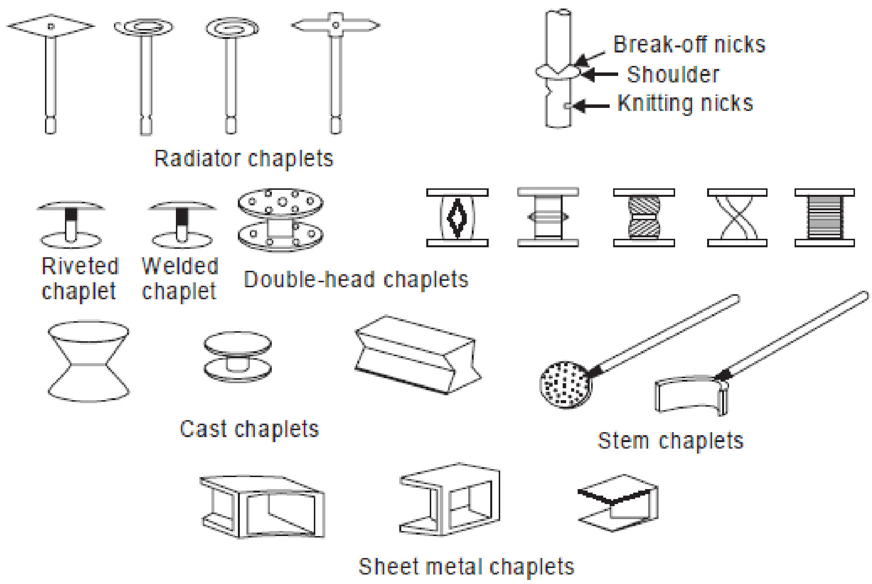


Figure 3.1 Types of chaplets

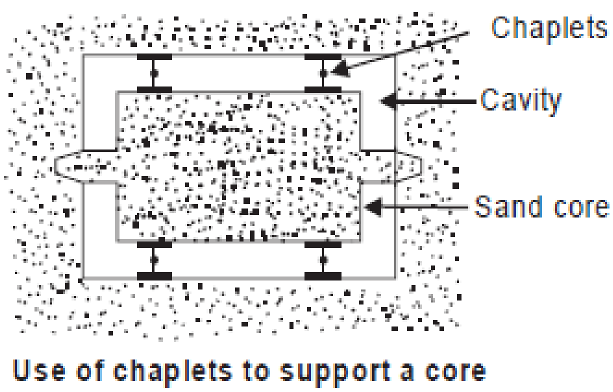


Figure .3.2 Use of chaplets

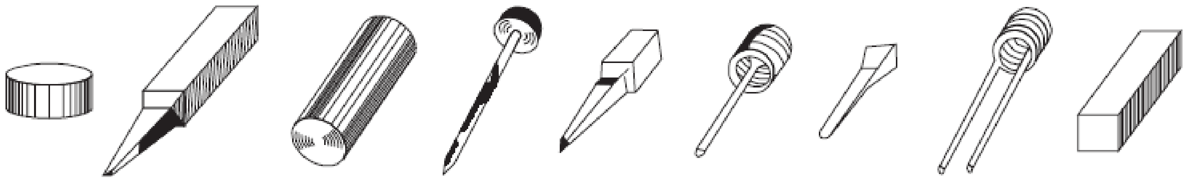


Figure3.3 Types of chills

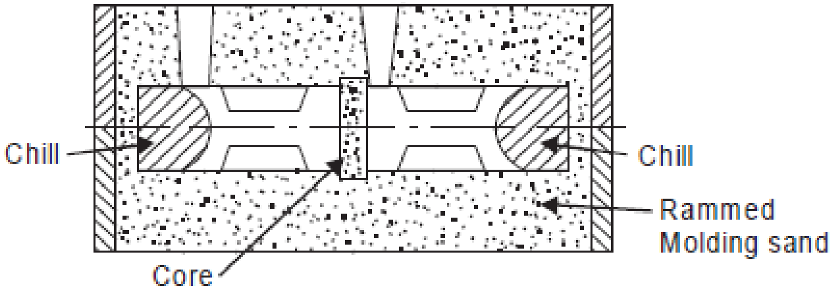


Figure. 3.4 Use of a chill

3.2 Mould alignment

3.2.1 Mold hardening

Many molds are hardened before closing and casting, whether by drying or chemical reaction: factors influencing the choice between this and greensand practice were reviewed in previous information sheet. The introduction of high pressure molding machines enhanced the capabilities of the greensand process, but the use of dry sand, even for heavy castings, became widely replaced by cold setting chemically bonded sands.

The hardening of cold-set sands has been discussed elsewhere. Where molds do need to be dried the operation may involve complete stove of the mold parts or may be confined to surface drying with portable equipment.

3.2.2 Clamps and weights

Clamps and weights are used to hold the cope and drag sections of a mold together and to prevent lifting of the cope by the force of the molten metal. It is safe practice to use a weight on small molds, but when the molds are of considerable size, both weights and clamps should be used. The use of insufficient weights is a common cause of defective castings.

3.2.3 Closing molds

The most important factor in the proper and easy closing of molds is to have flask equipment in good condition. Clean pins and bushings and straight sides on the flasks are the factors that make the closing of molds an easy operation. The opening of a mold after it has been closed is sometimes recommended. This procedure may prove useful. By using an excess of parting compound, the molder can then determine, with a fair degree of certainty, any mismatch or crushing of the mold. Nevertheless, the fewer times a mold is handled, the fewer chances there are to jar it and cause sand to drop.

3.3 Appropriate molding/core making equipment

3.3.1 Core Making Tools And Accessories

Tools and accessories used in the making of cores are the same as those used for making molds, with the addition of core boxes, sweeps, core driers, and special venting rods. Cores are shaped by the use of the core boxes, by the use of sweeps, or by a combination of these methods. Sweeps are limited in their use and will not be discussed here. Core driers are special racks used to support complicated cores during baking. They are usually not used unless a large number of cores of a particular design are being made. Complicated cores can often be made as split cores, baked on flat drying plates, and then assembled by pasting.

Figure 3.5 Sand slinging

Figure 3.6 Ramming

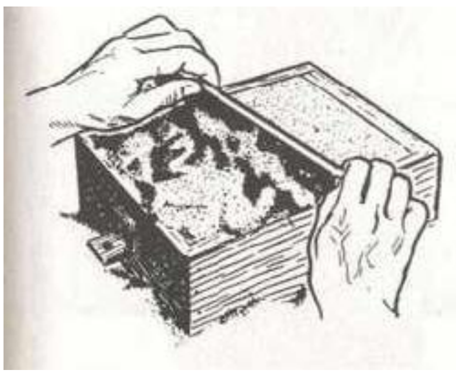


Figure 3.7 Venting with pointed wire

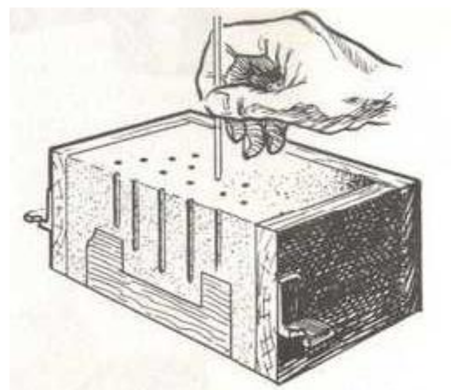


Figure 3.8 Stickling away surplus sand

Figure 3.9. Dusting with parting powder

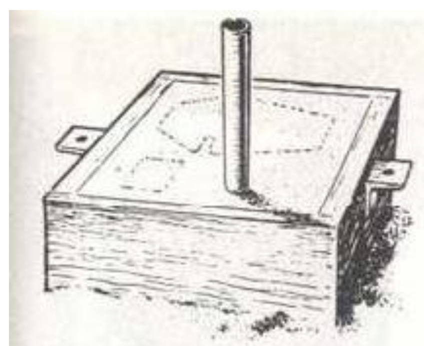


figure 3.10.Positioning runner tube

3.4 Secure mold

3.4.1 Securing mold

After all the above operations are complete, the cope box is again placed on the drag and clamped securely. Now the mold is ready for pouring molten metal.

3.4.2 Clamps

Are used for holding together the cope and drag of the completed mold or for clamping together the mold-board and the bottom-board on either side of the drag when the latter is rolled over. They are of many styles and sizes. Some are adjustable and are tightened on the flask by means of a lever. Other types use wedges to secure them on the flask. The WEDGES are usually of soft wood, but for the heavier works are either of hard wood or iron.

3.4.3 Clamps and Weights

Clamps and weights are used to hold the cope and drag sections of a mold together and to prevent lifting of the cope by the force of the molten metal. It is safe practice to use a weight on small molds, but when the molds are of considerable size, both weights and clamps should be used. The use of insufficient weights is a common cause of defective castings.

3.5 Molding materials to produce core

3.5.1 Materials required to make cores

- Core sand
- Bentonite clay: - It is the most suitable material used in molding sands. Limonite and Kaolinite are not commonly used as binders as they have comparatively low binding properties.
- Pulverized coal
- Resin oil

3.5.2 Requirements for cores

- Green strength: In the green condition, there must be adequate strength for handling
- In the hardened state, it must be strong enough to handle the forces of casting; therefore, the compression strength should be 100 to 300 psi (0.69 to 2.07 MPa).
- Permeability must be very high to allow for the escape of gases.
- Friability: As the casting or molding cools, the core must be weak enough to break down as the material shrinks. Moreover, they must be easy to remove during shakeout.

- Good refractoriness is required as the core is usually surrounded by hot metal during casting or molding.
- A smooth surface finish.
- Minimum generation of gases during metal pouring.

3.5.3 Core making:

Cores are made separately in a core box made of wood or metal. The various steps in core making are ramming of core sand in the box, venting, reinforcing, removing of core from box, baking, pasting, sizing etc. This work of producing cores can either be done by hand or by some machines designed for this purpose. In machine molding, the core-sand mixture is rammed by jolting, squeezing or blowing by means of suitable machine. Venting, reinforcing and other operations are carried out by hand.

3.5.4 Core binders: - are materials used to stick or bind the grains of sand together in making cores, such as flour, rosin, linseed oil, etc.

3.5.5 Functions of cores

Core is used to produce hollowness in castings in form of internal cavities.

- It may form a part of green sand mold
- It may be deployed to improve mold surface
- It may provide external undercut features in casting
- It may be used to strengthen the mold
- It may be used to form gating system of large size mold
- It may be inserted to achieve deep recesses in the casting

3.6 Pouring basin

3.6.1 Pouring basin:-

The main function of a pouring basin is to reduce the momentum of the liquid flowing into the mold by settling first into it. In order that the metal enters into the sprue without any turbulence it is necessary that the pouring basin be deep enough, also the entrance into the sprue be a smooth radius of at least 25 mm. The pouring basin depth of 2.5 times the sprue entrance diameter is enough for smooth metal flow and to prevent vortex formation. In order that vortex is not formed during pouring, it is necessary that the pouring basin be kept full and constant conditions of flow are established. This can be achieved by using a delay screen or a strainer core. A delay screen is a small piece of perforated thin tin sheet placed in the pouring basin at the top of the down sprue. This screen usually melts because of the heat from the metal and in the process delays the entrance of metal into the sprue thus filling the pouring basin fully. This ensures a constant flow of metal as also exclude slag and dirt since only metal from below is allowed to go into the sprue. A similar effect is also achieved by a strainer core which is a ceramic coated screen with many holes. The strainer restricts the flow of metal into the sprue and thus helps in quick filling of the pouring basin. Pouring basins are most desirable for alloys which form troublesome oxide skins (aluminum, aluminum bronze, etc.).

The molten metal is entered into the pouring basin, which acts as a reservoir from which it moves into the sprue. The pouring basin stops the slag from entering into the mold cavity by the help of skimmer or skim core. It holds the slag and dirt which floats on top and only allows the clean metal. It should be always full during pouring and one wall should be inclined 450 to the horizontal.

Function:-This will reduce the momentum of liquid flowing into mold

Design: - Pouring basin should be deep enough. Entrance into sprue be a smooth radius of 25mm.

Pouring basin depth should be 2.5 times the sprue entrance diameter. A strainer core restricts the flow of metal into the sprue and thus helps in quick filling of the pouring basin. It is a ceramic coated screen with many small holes.

3.7 Ramming mold and core

3.7.1 Ramming up Molds

Sand is then tightly packed in the drag by means of hand rammers. Peen hammers (used first close to drag pattern) and butt hammers (used for surface ramming) are used.

The ramming must be proper i.e. it must neither be too hard or soft. Too soft ramming will generate weak mold and imprint of the pattern will not be good. Too hard ramming will not allow gases/air to escape and hence bubbles are created in casting resulting in defects called ‘blows’. Moreover, the making of runners and gates will be difficult.

Figure 3. 11 Ramming the Sand

3.8 Parting and stripping systems

3.8.1 Utilizing Parting and stripping systems

After the ramming is finished, the excess sand is leveled/removed with a straight bar known as strike rod.

3.8.2 Parting Line

By parting line we mean a line or the plane of a pattern corresponding to the point of separation between the cope and drag portions of a sand mold. Parting lines must be flat or drafted so that the mold can be opened, the pattern removed and then closed for pouring without damage to the sand**.**

3.8.3 Parting line design

1. Parting line should be along a flat plane rather than be contoured. Irregular parting lines should be prevented until and unless it is unavoidable.

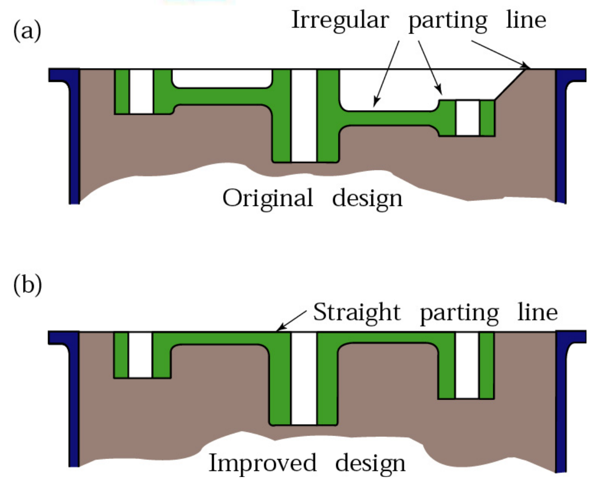


Figure 3.12.Designing for a straight parting line to reduce pattern and casting costs. (a) Irregular parting line is a costly design. (b) Straight parting line is less expensive.

2. For less dense material (like Al alloys), parting line should be placed as low as possible
3. For denser metals (like steels), mid-height location is recommended.
4. Parting line greatly influences the total cost of the casting process. It has effects on the total required number of cores, gating system and weight of the final casting.
5. Critical dimensions should not cross parting lines in molds.

3.9 Positioning loose pieces, vents, risers and runners

3.9.1 Sprue:

The passage through which the molten metal, from the pouring basin, reaches the mold cavity. In many cases it controls the flow of metal into the mold.

3.9.2 Runner:

The channel through which the molten metal is carried from the sprue to the gate. Gate: A channel through which the molten metal enters the mold cavity.

3.9.3 Riser:

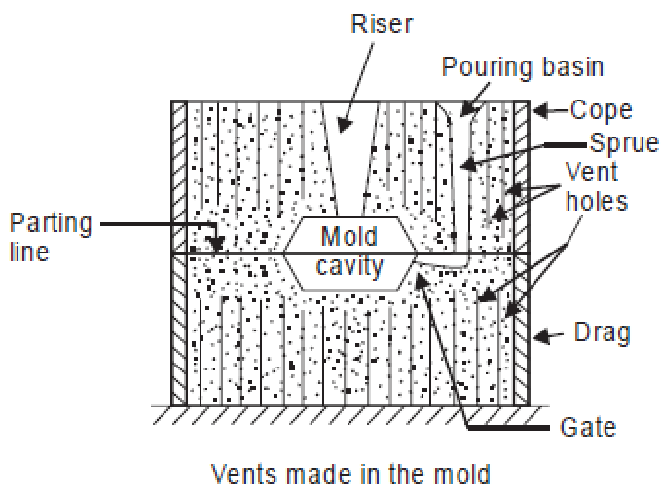
A column of molten metal placed in the mold to feed the castings as it shrinks and solidifies. Also known as "feed head".

3.9.4 Vent:

Small opening in the mold to facilitate escape of air and gases.

Vents are very small pin types holes made in the cope portion of the mold using pointed edge of the vent wire all around the mold surface as shown in Fig. 6.1.(b). These holes should reach just near the pattern and hence mold cavity on withdrawal of pattern. The basic purpose of vent holes is to permit the escape of gases generated in the mold cavity when the molten metal is poured. Mold gases generate because of evaporation of free water or steam formation, evolution of combined water (steam formation), decomposition of organic materials such as binders and additives (generation of hydrocarbons, CO and CO2), expansion of air present in the pore spaces of rammed sand. If mold gases are not permitted to escape, they may get trapped in the metal and produce defective castings. They may raise back pressure and resist the inflow of molten metal. They may burst the mold. It is better to make many small vent holes rather than a few large ones to reduce the casting defects.

(a)



(b)

Figurer 3. 13 Venting of holes in mold

Then, the cope is placed on the drag, and Sprue and riser pins are placed in vertically position at suitable locations using support of molding sand. It will help to form suitable sized cavities for pouring molten metal. Talcum powder and sand are again sifted over the pattern, and rammed to fill the cope. The pins are then carefully pulled out of the sand. The critical part of the operation is to separate the cope and drag to remove the pattern.

Vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification. Done by vent rod.

A sprue pin for making the sprue passage is located at some distance from the pattern edge. Riser pin is placed at an appropriate place.

Filling, ramming and venting of the cope is done in the same manner.

Remove sprue and riser pins and create vent holes in the cope with a vent wire. The basic purpose of vent creating vent holes in cope is to permit the escape of gases generated during pouring and solidification of the casting.

Runners and gates are made by cutting the parting surface with a gate cutter. A gate cutter is a piece of sheet metal bent to the desired radius.

3.10 Removing pattern and loose pieces

3.10.1 Remove the pattern from mold

The first thing to be considered in looking at a pattern is how it will best draw out of the sand. Every complicated form of casting presents a partially new problem to the pattern maker. If a piece will readily draw out of the sand except one or more small projections , they can sometimes be left on a dovetail slide , which will allow the pattern to be drawn , leaving a part in the sand to be removed later on ; or if it be a cavity , it must be cored out.

3.10.2 Pattern draw

On completion of ramming the mold is ready for pattern withdrawal. In hand molding the mold part is usually turned over after ramming, for which a crane, hoist, or simple turnover unit can be used. The pattern is rapped to provide clearance and lifted out by hand or crane: care is needed to avoid dimensional errors from excessive rap. Machine draw systems have already been discussed: The initial clearance is normally provided by low amplitude vibration, giving greater dimensional consistency.

The pattern may be vibrated with a powered vibrator, or the pattern, and maybe the cope and drag flask, will be lightly tapped with a small hammer. The pattern is lifted from the sand. When the pattern is withdrawn, its imprint provides the mold cavity. This cavity is filled with metal to become the casting.

3.11 Inspecting and repairing mold

After removing wooden pattern halves, the mold cavities may be repaired in case any corners etc. have been damaged. This is a delicate operation.

Before closing of the mold boxes, graphite powder is sprinkled on the mold surface in both boxes. In the drag box, a gate is cut below the location of the runner (in the cope box). The molten metal poured in the runner will flow through the gate into the mold cavity.

In case, the molds have been dried, instead of graphite powder, a mold wash containing suspension of graphite in water is lightly spread over the mold surface.

3.12 Cleaning and painting mold and core

3.12.1 Cleaning

If any sand has fallen into the mold cavity, it is carefully lifted or blown away by a stream of air.

Cleaning refers to all operations necessary to the removal of sand, and scale, from the mold and core. Excess sand and scale are removed to improve the surface appearance of the mold. Inspection of the molding for Brocken, damages and general quality is performed.

3.12.2 Coating benefits

Most of the reasons for using coatings center around reducing casting costs by improving sand peel and reducing mold/core reaction, reducing or eliminating metal penetration (burn-in and/or burn-on), and reducing or eliminating veining. These reasons are directly associated with casting cleaning costs. Coatings are also used to reduce machining time and tool wear by having a clean smooth surface, to improve casting appearance, to facilitate handling (especially where low-strength cores may be required because of shakeout conditions), or to promote chill or increase hardness in metal (for which selenium or tellurium paste is used). Coatings should not be used indiscriminately. No coating will compensate for a poor-quality core.

Self-Check 3

Part I Directions: Choose the correct answer.

1The first three procedures for making cores are

A. Sand slinging , ramming and venting

B. Sand slinging , ramming and dusting powder

C. Sand slinging , ramming and Stickling away surplus sand

D. none

1. why making stickling away surplus sand in the core making

A. Holding hot casting

B. Clearing unwanted sand from patterns

C. Cleaning of unwanted sand from casting

D. Dusting powder

2. The use of dusting powder is

A. Separating easily the two halves parts of pattern

B. Easily to entering the molten metal

C. Creating smooth surface of casting

D. None

3. The use of feeder in the core making process is

A. To join the molten metal

B. To pour easily molten metal

Part II Directions: True or false

1. All type of cores require internal reinforcing to prevent breakage or shifting.
2. Wires are used to support the barrel of the cylinder core.

Part III Directions: Fill in the blank space

1. ____________silica sand mixed with core oil which is composed of linseed oil, resin, light mineral oil and other binding material.
2. Sand is then tightly packed in the drag by means of ____________________.

Operation Sheet 3.1

Operation title: **Core Making**

Purpose: To core making

Instruction: use the necessary tools and equipment to perform core.

Required tools and equipment:

1. Molding board
2. Drag and cope boxes
3. Core sand
4. Parting sand
5. Rammer
6. Strike-off bar
7. Bellows
8. Riser and sprue pins
9. Gate cutter
10. Vent rod
11. Draw spike
12. Brush

Procedure:

Step 1. Preparing sand and its additives for core.

Step 2. Preparing core box.

Step 3. Assembling a core box.

Step 4. Mixing sands and its additives.

Step 5. Filling the mixed sand into the core box.

Step 6. Ramming properly.

Step 7. Removing surplus sand from core box.

Step 8. Dismantling core box from core

Operation Sheet 3.2

Operation title: **Mold Making**

Purpose: To mold making

Instruction: use the necessary tools and equipment to perform core.

Required tools and equipment:

1. Molding board
2. Drag and cope boxes
3. Core sand
4. Parting sand
5. Rammer
6. Strike-off bar
7. Bellows
8. Riser and sprue pins
9. Gate cutter
10. Vent rod
11. Draw spike
12. Wire brush

Procedure:

1. First a bottom board is placed either on the molding platform or on the floor, making the surface even.
2. The drag molding flask is kept upside down on the bottom board along with the drag part of the pattern at the centre of the flask on the board.
3. Dry facing sand is sprinkled over the board and pattern to provide a non-sticky layer.
4. Freshly prepared molding sand of requisite quality is now poured into the drag and on the pattern to a thickness of 30 to 50 mm.
5. Rest of the drag flask is completely filled with the backup sand and uniformly rammed to compact the sand.
6. After the ramming is over, the excess sand in the flask is completely scraped using a flat bar to the level of the flask edges.
7. Now with a vent wire which is a wire of 1 to 2 mm diameter with a pointed end, vent holes are in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during casting solidification. This completes the preparation of the drag.
8. Now finished drag flask is rolled over to the bottom board exposing the pattern.

9. Using a slick, the edges of sand around the pattern is repaired
10. The cope flask on the top of the drag is located aligning again with the help of the pins of the drag box.
11. Sprue of the gating system for making the sprue passage is located at a small distance of about 50 mm from the pattern. The sprue base, runners and in-gates are also located as shown risers are also placed. Freshly prepared facing sand is poured around the pattern.
12. The molding sand is then poured in the cope box. The sand is adequately rammed, excess sand is scraped and vent holes are made all over in the cope as in the drag.
13. The sprue and the riser are carefully withdrawn from the flask
14. Later the pouring basin is cut near the top of the sprue.
15. The cope is separated from the drag any loose sand on the cope and drag interface is blown off with the help of the bellows.
16. Now the cope and the drag pattern halves are withdrawn by using the draw spikes and rapping the pattern all around to slightly enlarge the mold cavity so that the walls are not spoiled by the withdrawing pattern.
17. The runners and gates are to be removed or to be cut in the mold carefully without spoiling the mold.
18. Any excess or loose sand is applied in the runners and mold cavity is blown away using the bellows.
19. Now the facing paste is applied all over the mold cavity and the runners which would give the finished casting a good surface finish.
20. A dry sand core is prepared using a core box. After suitable baking, it is placed in the mold cavity.
21. The cope is placed back on the drag taking care of the alignment of the two by means of the pins.
22. The mold is ready for pouring molten metal. The liquid metal is allowed to cool and become solid which is the casting desired.

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 4 hours.

Task 1- Perform a split core box using the given drawing.

Unit Four: Pre-Operational Checks
This unit is developed to provide you the necessary information regarding the following content coverage and topics: • Pattern/core box • Set up pattern/core box This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Selecting and inspecting pattern/core specifications • Setting up pattern/core box in bolster and core box

4.1 Pattern/core box

4.1.1 Introduction to core box

Cores are made with the help of core boxes. Core boxes are made of wood and have a cavity cut in them, which is the shape and size of the core. The sand in mixed and filled in the core boxes. It is then rammed. A core box is made in two halves, each half contains half impression of core. Sometimes a core may need reinforcements to hold it together. The reinforcements are in the shape of wire or nails, which can be extracted from the hole in the casting along with core sand.

4.1.2 Common Types of Core Boxes

A. Half core box: - To prepare the core in two halves which are later on cemented together to form the complete core. (See fig. 1.1.)

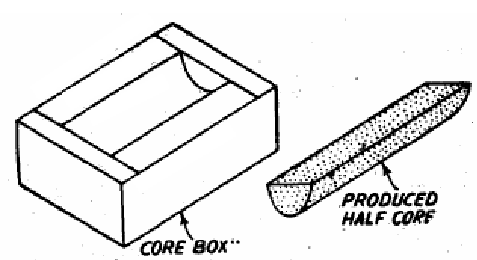


Figure. 4.1 A half core box

B. Dump core-box*:* - Used to prepare complete core in it. Generally, rectangular cores are prepared in these boxes. (See fig.1.2)

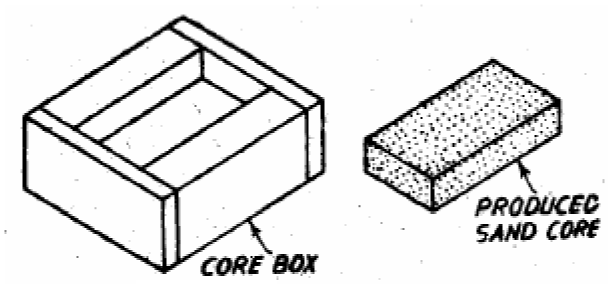


Figure 4.2 a dump core box

C. Split core-box: - It is made in two parts, which can be joined together by means of dowels to form the complete cavity for making the core. (See fig.1.3.)

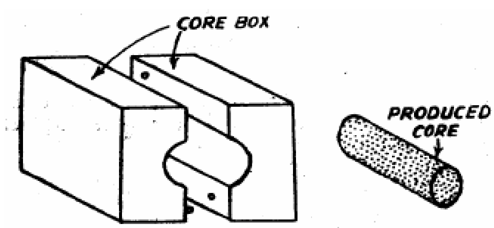


Figure 4.3 a Split core box

D. Strickle type core-box: - It is used to form cores of irregular or unsymmetrical shapes, as shown in fig.1.4.

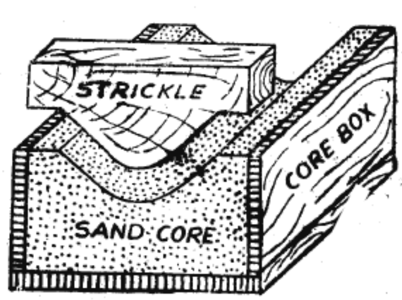


Figure 4.4 Strickle type core box

Loose piece core-box: - It is used to prepare, in the same core box, the two halves of a core of which the halves are not identical in shape and size. (See fig 4.5.)

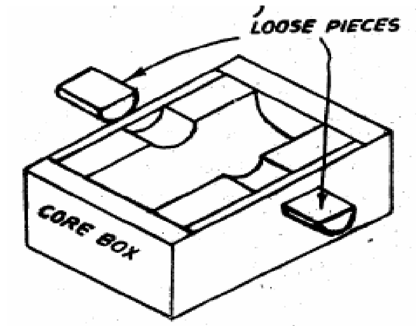


Figure. 4.5. Loose piece core box

Gang core box: −Gang core box contains a number of cavities, so that more than one core can be rammed at a time. (See fig 4.6.)

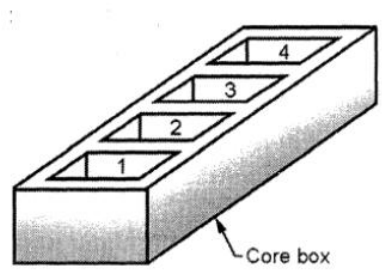


Figure 4.6. Gang core box

Left and right hand core boxes: −These core boxes are used to make cores for producing pipe bends. Half of the pipe bend core is made in each core box. Two halves of pipe bends are then rammed, baked and joint together to form a full core. See Fig. 1.7.

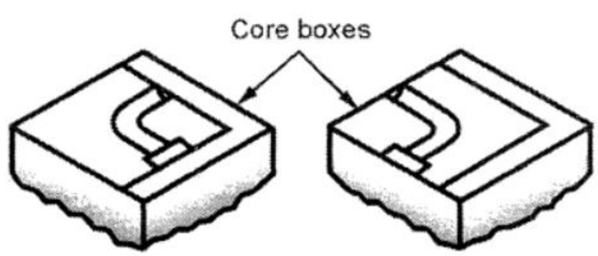


Figure 4.7. Left and right hand core boxes

4.1.3 Core Prints

Core prints are basically extra projections provided on the pattern. They form core seats in the mold when pattern is embedded in the sand for mold making. Core seats are provided to support all the types of cores. Though the core prints are the part of pattern, they do not appear on the cast part.

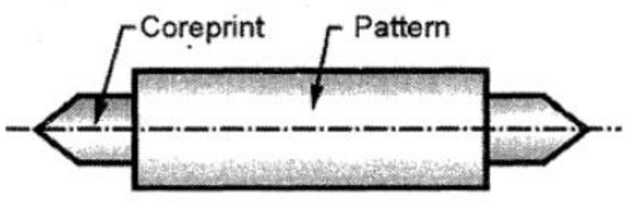


Figure 4.8. Core print

4.1.4 Types of core prints

- ✓ Horizontal core print
- ✓ Vertical core print
- ✓ Cover core print
- ✓ Wing core print
- ✓ Balance core print

4.1.5 Core Box Allowances

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

4.2 Set up pattern/core box

4.2.1 Setting Cores, Chills, and Chaplets

In the setting of cores, it is important to check the size of the core print against the core itself. A core print is a depression or cavity in the cope or drag, or both. The print is used to support a core and, when the core is set, is completely filled by the supporting extensions on the core. A typical example of a core print in use is shown at the extreme left of the mold in figure 3.1. An oversize print or an undersized core will cause fins on the completed castings, which may lead to cracks or chilled sections in the core area. An oversize core or an undersized print may cause the mold to be crushed and result in loose sand in the mold and a dirty casting.

Setting simple cores in the drag should be no problem to a molder. Care should be taken in handling and setting the core. After a core has been properly set, it should be seated by pressing it lightly into the prints. Another item which should be checked is the venting of cores.

Chaplets are metal distance pieces inserted in a mold either to prevent shifting of mold or locate core surfaces. The distances pieces in form of chaplets are made of parent metal of which the casting is. These are placed in mold cavity suitably which positions core and to give extra support to core and mold surfaces. Its main objective is to impart good alignment of mold and core surfaces and to achieve directional solidification. When the molten metals poured in the mold cavity, the chaplet melts and fuses itself along with molten metal during solidification and thus forms a part of the cast material.

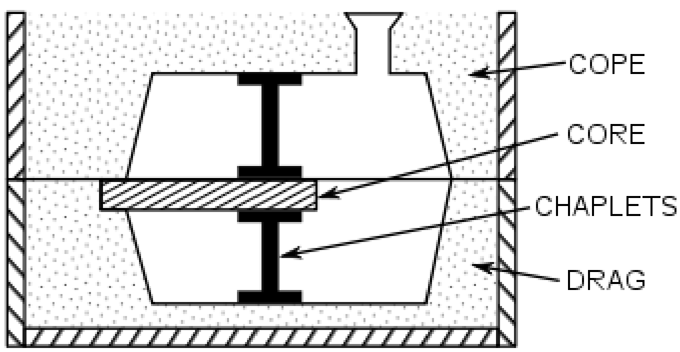


Figure. 4.9 Diagram of chaplet usage

Types of Chaplets

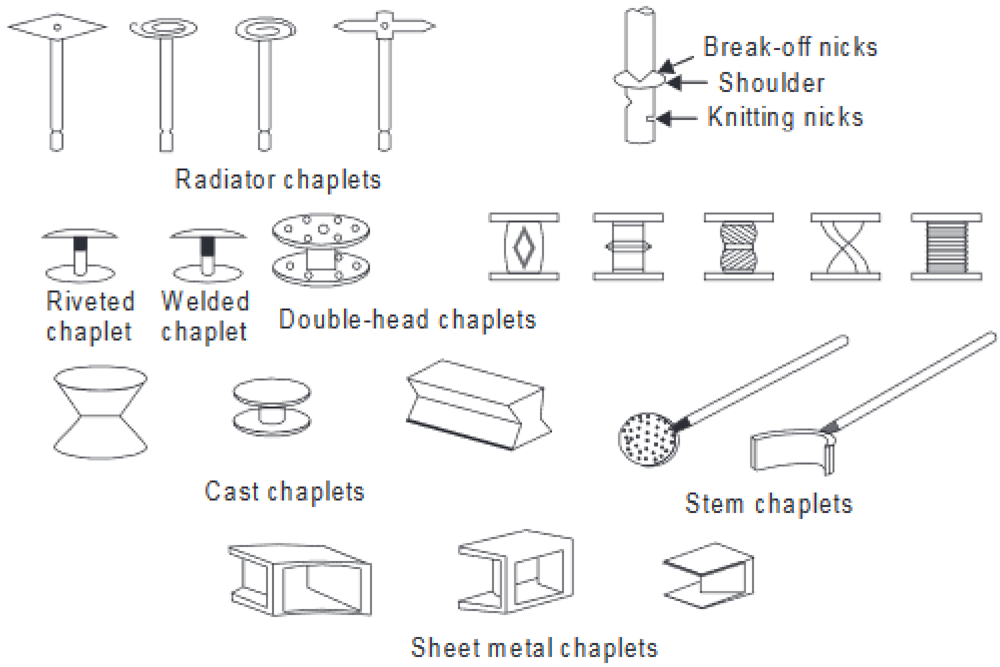
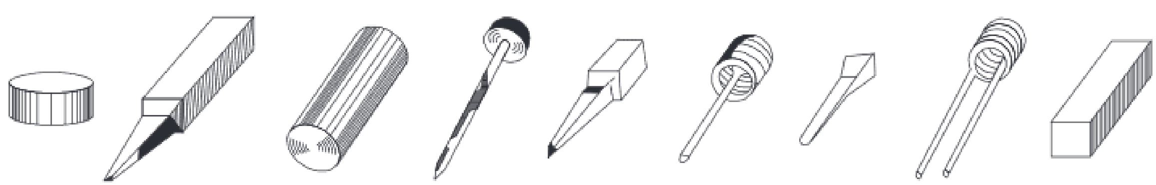


Figure 4.10 Types of chaplets

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

Types of chills



Figurer 4. 11 types of chills

Self-Check 4

Part I Directions: Choose the correct answer.

1. Oversize print or an undersized core will cause _________on the completed castings.
   A. good surface B. fins C. cracks D. all
2. _____are placed in mold cavity suitably which positions core and to give extra support to core and mold surfaces.
   A. Chills B. chaplets C. gauge D. all

3. Which of the following core box used to form cores of irregular or unsymmetrical shapes

   A. Loose piece core-box C. Strickle type core-box
   B. Gang core box D. Split core-box

4. Which of the following is **not** types of core print

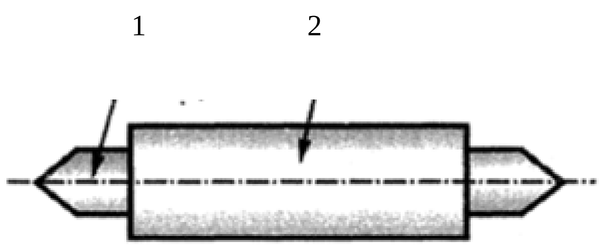
   A. Cover core print C. Balance core print
   B. Wing core print D. None

Part II Directions: True or false

1. An oversize core or an undersized print may cause the mold to be crushed and result in loose sand in the mold and a dirty casting.

Part III Directions: Writing questions

1. List the name for indicated on the picture



2. List at least five types of chaplets (5 pt.)

Unit Five: Operate Machine to Produce Mold/Cores
This unit is developed to provide you the necessary information regarding the following content coverage and topics: • Appropriate molding media • Molds/cores with specifications • Foundry machines • Safe unloading machines • Stripping, inspecting and painting molds/cores This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Selecting appropriate molding media • Filling molds/cores with specifications • Operating foundry machines • Perform safe unloading machines • Stripping, inspecting and painting molds/cores

5.1 Appropriate molding media

5.1.1 Sources of Molding Sand

Sand used in foundries is available in

- River beds
- Sea
- Deserts
- Lakes

5.1.2 Types of Molding Sand

The following section introduces three type of sand; include green sand, resin-sand and CO2-sand that are commonly used in casting industry.

A. Green Sand

The most common method used to make metal casting is green sand molding. “Green sand” is a mixture of silica sand / zircon sands, bentonite clay, moisture and other additives. The additives help to harden and hold the mold shape to withstand the pressures of the molten metal. The moisture contents have to control in around 7%, too dry or too wet of sand mixture are also not suitable. The “Green sand” mixture can be compacted by hand or through mechanical force around a pattern to create a mold. It is the least expensive method of making molds.

B. Resin-Sand

Resin-sand is a mixture of sand and 2.5%-4% of thermoset resin binder. The binder coats the sand particles altogether and it became hard and bond the sand particles together once head applied. Resin-sand mold has better dimensional accuracy than green sand mold but is more expensive. Therefore, it is usually utilized for producing sand core instead of cope and drag.

C. CO2-Sand

CO2-Sand is a mixture of sand and 3-4% sodium silicate (water glass). Molding procedures are similar to that of the green sand process. However, after removal of the pattern, the mold is hardened by blowing of carbon dioxide gas via a tube. Since no heat is involved it is called a cold-setting process.

5.1.3 Binders used in molding sands

- Binders are added to give cohesion to molding sands.
- Binders provide strength to the molding sand and enable it to retain its shape as mold cavity.
- Binders should be added in optimum quantity as they reduce refractoriness and permeability.
- An optimal quantity of binders is needed, as further increases have no effect on properties of foundry sand.

The following binders are generally added to foundry sand:

- Fireclay
- Illite
- Bentonite
- Sodium montmorillonite
- Calcium montmorillonite
- Limonite
- Kaolinite

Fireclay: It is usually found near coal mines. For use in the foundry, the hard black lumps of fireclay are taken out, weathered and pulverized. Since the size of fireclay particles is nearly 400 times greater than the size of bentonite particles, they give poor bonding strength to foundry sand.

Illite*:* Illite is found in natural molding sands that are formed by the decomposition of micaceous materials due to weathering. Illite possesses moderate shrinkage and poor bonding strength than bentonite.

Bentonite: It is the most suitable material used in molding sands. Limonite and Kaolinite are not commonly used as binders as they have comparatively low binding properties.

5.1.4 Constituents of molding sand

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

Silica sand

- Silica sand in form of granular quarts is the main constituent of molding sand having enough refractoriness which can impart strength, stability and permeability to molding and core sand.
- Along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities.
- The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present.
- The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable.
- The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub-angular and rounded).

Moisture

- The amount of moisture content in the molding sand varies generally between 2 to 8 percent.
- This amount is added to the mixture of clay and silica sand for developing bonds.
- This is the amount of water required to fill the pores between the particles of clay without separating them.

- This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand.
- The effect of clay and water decreases permeability with increasing clay and moisture content.
- The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing.

Additives

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

(i) 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.

(ii) Dextrin

Dextrin belongs to starch family of carbohydrates. It increases dry strength of the molds.

(iii)Pitch

It is distilled form of soft coal. It can be added from 0.02 % to 2% in mold and core sand.
It enhances hot strengths, surface finish on mold surfaces.

(iv)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 mold and core sand. It increases collapsibility of both of mold and core.

5.2 Molds/cores with specifications

5.2.1 **Core sands**: - Core sand is different from molding sand as it has very low clay content and their grain size is large to increase the permeability.

It is silica sand mixed with core oil which is composed of linseed oil, resin, light mineral oil and other binding materials.

- Core sand is a suitable sand mixture, also used for making cores

5.2.2 Core Sand and Its Ingredients

- ✓ Core sand is a sand mixture suitable for cores.
- ✓ Core sand mixture consists of sand grains, binders for green and cured strength and other additives used for special purposes.
- ✓ The commonly used core sand mixture consists of sand, 1 % core oil, 1 % cereal and 2.5 to 6 % of water.
- ✓ Core sand is almost similar to molding sand but the main difference is that core sand has very low clay content and larger grain size.
- ✓ Large grain size assures higher permeability

5.3 Foundry machines

5.3.1. Molding machines

• Various molding methods are: – Bench molding – Floor molding – Pit molding – Machine molding

A. Bench molding

• Molding is carried out on a bench of convenient height.

• Small and light molds are prepared on benches.

• The molder makes the mold while standing.

• Both green and dry sand molds can be made by bench molding,

• Molds, both for ferrous and (especially) non-ferrous castings are made on bench molds.

• Both cope and drag are rammed on the bench.

B. Floor molding

• Molding work is carried out on foundry floor when mold size is large and molding cannot be carried out on a bench.

• Medium and large-sized castings are made by floor molding.

• The mold has its drag portion in the floor and cope portion may be rammed in a flask and inverted on the drag.

• Both green and dry sand molds can be made by floor molding

C. Pit molding

• Very big castings which cannot be made in flasks are molded in pits dug on the floor.

• Very large jobs can be handled and cast easily through pit molding.

• The mold has its drag part in the pit and a separate cope is rammed and used above the (pit) drag.

• The depth of the drag in pit molding is much more than that in floor molding.

• In pit molding, the molder may enter the drag and prepare it.

• A pit is of square or rectangular shape.

• The sides of the (pit) drag are lined with brick and the bottom is covered with molding sand .

• The cope (a separate flask) is rammed over the pit (drag) with pattern in position.

• Gates, runner, pouring basin, sprue etc. are made in the cope.

• The mold is dried by means of a stove(heater) placed in the pit.

• Cope and drag are then assembled. A crane may be used for lifting and positioning the cope over drag.

• Cope can be clamped in position.

• Mold is ready for being poured.

D. Machine molding

• In bench, floor and pit molding, the different molding operations are carried out manually by the hands of the molder, where as in machine molding, various molding operations like sand ramming, rolling the mold over, withdrawing the pattern etc. are done by machines.

• Machines perform these operations much faster, more efficiently and in a much better way.

• Molding machines produce identical and consistent castings.

• Molding machines produce castings of better quality and at lower costs. • Molding machines are preferred for mass production of the castings whereas hand molding (bench, pit and floor) is used for limited production.

• Machine molding is not a fully automatic process; many operations can though be performed by machines, yet some others have to be carried out by hands.

• A few different types of molding machines are listed below: – Jolt machine – Squeeze machine – Jolt-squeeze machine – Sand Slinger

• When large number of castings is to be produced, hand molding consumes more time, labor and also accuracy and uniformity in molding varies.

• To overcome this difficulty, machines are used for molding.

• Based on the methods of ramming, molding machines are classified as follows:

1. Jolt machine
2. Squeeze machine
3. Jolt-squeeze machine
4. Sand slinger

• 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 mold 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 a 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 mold required. Usually, less than 20 jolts are sufficient for a good molding. • The disadvantage of this type is that, the density and hardness of the rammed sand at the top of the mold box is less when compared to its bottom portions.

Squeeze Machine

• In squeeze machine, the mold 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 mold attains the desired density.

• In some machines, the squeeze plate may be stationary with the mold box moving upward.

• The disadvantage of squeeze machine is that, the density and hardness of the rammed sand at the bottom of the mold box is less when compared to its top portions.

Jolt Squeeze Machine

• Jolt squeeze machine combines the operating principles of 'jolt' and 'squeeze' machines resulting in uniform ramming of the sand in all portions of the molds

• The machine makes use of a match plate pattern placed between the cope and the drag box.

• The whole assembly is placed on the table with the drag box on it.

• The table is actuated by two pistons in air cylinders, one inside the other. One piston called 'Jolt piston' raises and drops the table repeatedly for a predetermined number of times, while the other piston called 'squeeze piston' pushes the table upward to squeeze the sand in the flask against the squeeze plate. In operation, sand is filled in the drag box and jolted repeatedly by operating the jolt piston. • After jolting, the complete mold assembly is rolled over by hand.

• The cope is now filled with sand and by operating the squeeze piston, the mold assembly is raised against the squeeze plate. By the end of this operation, the sand in the mold box is uniformly packed.

• The match plate is now vibrated and removed. The mold is finished and made ready for pouring.

Sand slinger

• A sand slinger is an automatic machine equipped with a unit that throws sand rapidly and with great force into the mold 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 pre-mixed 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 (around 1800 rpm).

• The force of the rotor blades imparts velocity to the sand particles and as a result the sand is thrown with very high velocity into the mold box thereby filling and ramming the sand at the same time.

• The density of the ramming sand can be controlled by varying the speed of the impeller. Rest of the operations, viz., removal of pattern, cutting gates etc., are done manually.

• In the initial stages of ramming, the blades are rotated at slow speeds; around 1000 - 1200 rpm to avoid damage to the pattern due to the abrasive action of the high velocity sand particles.

5.4 Safe unloading machines

The basic principle upon which this Code of Practice is based is that the combined strength of the load restraint system must be sufficient to withstand a force not less than the total weight of the load forward, so as to prevent the load moving under severe braking, and half of the weight of the load backwards and sideways

5.5 Strip, inspect and paint molds/cores

5.5.1 Strip molds/cores

Sand which has been burned loses its bond. Thus a sprinkling of burned sand is applied to the joint face of the mold, before ramming up the cope, so that the two halves will come cleanly apart. Dry sea-shore sand may also be used for the same purpose while there is, occasionally. A case for separating a mold by means of strips of newspaper. Special parting powders, which perform most efficiently, and which may be composed of bone dust or produced from gypsum, are available and it is well worth the trouble to procure one of these as work progresses. Sometimes they can be of particular value, when dusted over a pattern, to assist in a clean withdrawal. In the making of oil sand molds and cores liquid parting, applied by brush or spray to the pattern or core box, is exceptionally useful in affording a clean strip. This again, a water repellent liquid, can be obtained from firms of foundry suppliers. When spraying liquid parting or applying liquid dressings to the mold in the same way, it is advisable to wear some form of respirator. If the only actual ill effect, the nasal irritation can be very bad.

5.5.2 Mold coatings

Coatings are frequently applied to cores to enhance the casting surface finish and to reduce casting defects at the mold/metal interface. Coatings accomplish this by having a higher refractory value than the sand and/or by forming an impermeable barrier between the metal and the core. Most coatings are formulated with five major components:

- ✓ Refractory material: - Refractory, usually oxides of many kinds ground to a particle size of 50 mm or less, but for cast irons carbonaceous material is common in the form of graphite or ground coke etc.
- ✓ Carrier system: - allows the refractory to be applied evenly to the sand mold or core. After the coating has been applied, the carrier must be removed. When the carrier is water, it can be torched or oven dried. Alcohol carriers are commonly ignited and

allowed to burn off. The volatile chlorinated hydrocarbons readily air dry and require neither torching nor oven drying.

- ✓ Suspension system: - The function of the suspension system is to maintain the refractory material uniformly dispersed in solution. With water carriers, sodium bentonite is commonly used, while organic bentonite or bentones are generally used with alcohol and chlorinated hydrocarbon carriers.
- ✓ Binder system: - in a coating is usually an organic resin, and it behaves similarly to the resins used to bond sands. The amount of binder used depends on the density and fineness of the refractory. It is used sparingly to avoid casting surface defects.
- ✓ Chemical modifiers: - including surfactants to improve wettability, antifoaming agents, and bactericides.

Aggregate molds

Although we have dealt at length with reactions that can occur between the metal and the mold, the purpose of a mold coating is to prevent such happenings by keeping the two apart. It has to be admitted that for many formulations, these attempts are of only limited success. Some useful reviews of coatings from which the author has drawn are given by Vingas (1986), Wile and colleagues (1988), and Beeley (2001). Vingas in particular describes techniques for measuring the thickness of coatings in the liquid and solid states. All describe the various ways in which coatings can be applied by **dipping**, **swabbing**, **brushing**, and **flow-over**. An important aspect to bear in mind, as with the provision of feeders, and the best action (if possible) is to avoid coatings.

Reasons for avoiding coatings. Disadvantages include:

- ✓ Cost of materials, especially those based on expensive minerals such as zircon.
- ✓ Potential loss of accuracy because of difficulty of controlling coat thickness and coating penetration.
- ✓ Possibility of cosmetic defects from runs and drops.
- ✓ Floor space for coating station.
- ✓ Energy cost to dry and possible capital cost and floor space for drying ovens and extraction ducting and fans.

- ✓ Floor space to dry if dried naturally (this might exceed molding space since drying is slow).
- ✓ Drying time can severely reduce productivity.
- ✓ Cores appear to be never fully dried, despite all attempts, after the application of a coating, so that there is enhanced danger of blow defects if the core cannot be vented to the atmosphere.

At this time many coatings are still alcohol (ethanol) based, and so burned off rather than dried. This requires minimal floor space and energy, but does add to the loading of VOCs (volatile organic compounds) in the environment. This approach is likely to be banned under future legislation, forcing the use of water-based coatings. The water-based coatings pose a significantly increased drying problem.

The advantages of coatings

- ✓ Reduction of cleaning costs because of improved surface finish (finer surface, reduced or eliminated veining, reduced penetration and/or burn-on and reduced reactions between metal and mold, for instance between (i) manganese steel and silica sand, and (ii) binder gases such as sulfur compounds from furan binders).
- ✓ Improved shake-out because of improved sand peel.

Reduced machining time and tool wear

Self-Check 5

Part I Directions: Choose the correct answer.

1. _____________ curing gas is purged from the cured core with compressed air

   A. Too small B. Excess C. None

2. Cores from the core-oil process are placed in ovens before stripping.

   A. True B. False

3. In the cold box processes, the appropriate gas for forced through the compacted sand in the process is

   A. carbon dioxide C. sulfur dioxide

   B. tertiary amines or methyl format D. all

4. Which one of the followings is **not** components of coatings

   A. Liquid carrier C. Binder agents

   B. Suspension agents (Rheology control system D. Additives

Part II Directions: True or false questions.

1. Newspaper can used as a means of strips separating a mold.
2. Cores liquid parting applied by only brushing.
3. Coating are applies either wet or dry methods
4. In dry coating method graphite will melt at the highest foundry temperatures but its carbon is driven off by oxidation at these temperatures depending on the air (containing oxygen) available at the metal-mold interface.
5. Foundry coatings for wet application are using aqueous carrier and organic solvent carriers.

Part III Directions: Matching, match column "A" with column "B" (4%)

Column "A"	Column "B"
1. ____ is moulding sand.	A. Lakes
2._____ is the amount of water used in green sand.	B. seas
3. _____ is **not** used as binders for mould materials.	C. 10%

D. 7%

E. Kaolinite

Unit six: Assemble moulds/cores
This unit is developed to provide you the necessary information regarding the following content coverage and topics: • Drying, gluing and venting moulds/cores • Setting runner bush This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Dry, gluing and vent moulds/cores • Set runner bush

F. Backelite

6.1 Dry, gluing and vent mounds/cores

6.1.1 Dry molds/cores

Complicated parts and those requiring internal cavities benefit from sand casting and core making. It is cost effective and extremely reliable if the molds are prepared properly. To ensure the best outcomes, molds must be able to withstand the high temperatures of the liquid metal. A common parting compound used in sand casting is a refractory wash. Made up of water or a solvent based liquid, magnesite talc, or graphite solids, the refractory wash is applied to the molds and cores and dried in a conveyor oven before the casting process. The refractory wash improves the surface finish of the casting and also protects the mold against the extreme heat of the molten metal.

Our sand mold and core drying ovens are used throughout the foundry industry to prepare molds and cores. As each type of metal has different requirements for casting, batch and conveyor ovens must be made to meet specific configurations and requirements. Available in all heat types and multiple conveyor options our Wisconsin oven provides precise temperatures controls that enable accurate mold setting and preparation.

6.1.2 Gluing molds/cores

To the joining of cores and molds produced by the carbon dioxide and self-setting silicate processes. Its adaptable characteristics make it equally suitable for air and self-setting resin and oil bonded sands in fact to a whole range of general joining and repair application.

6.1.3 Vent molds/cores

Discussing foundry practice recently at AFS with two foundry veterans, the subject of core and mold venting came up. One comment was that venting practice are not always followed, and another was that, when in doubt, vent and vent some more. The consensus was that venting is such a simple, inexpensive yet effective quality control procedure that it should not be overlooked.

6.2 Set runner bush

Using circle shaped and short sprue is preferred. The minimum of the sprue diameter is 5mmφ, and normally, use sprue with diameter of 7~8mmφ. To take out the sprue easily, put a 3°to 5°taper on the inner diameter of the sprue bush. Quench the sprue bush and to prevent getting out, hold it with the locate ring. Also, curvature radius of sprue bush spherical surface void, should be little bigger than the curvature radius of nozzle head. To make the flow of the melting resin smooth and even, the runner should be as thick as possible, short, placed well, and each corner should be round so that flow resistance will become smaller. When the melting resin flows through the runner, the resin close to the cold mold will solidify by decreased temperature. This solidified resin will work as a heat insulator, and the melting resin will flow through it. Therefore, a circular runner is the ideal. In the case of two plates mold, use a circular runner if the parting face is flat, and use a trapezoidal runner if not or if the mold has three plates. Also, place the cold slug well on the bottom of the sprue.

Self-Check 6

Part I Directions: Multiple choice questions.

1. ___ the most universal material is wheat flour, which acts in the core as it acts in bread.
   A. Rosin C. Flour
   B. Linseed oil D. Glue
2. Which of the following are not advantage of coating
   A. Improved shake-out because of improved sand peel
   B. Reduced machining time and tool wear
   C. Drying time can severely reduce productivity
   D. Floor space for coating station
   E. C & D are answer
3. Most coatings are formulated with
   A. Carrier system C. Refractory material
   B. Suspension system D. All
4. _______________ help to Protect the mold from thermal shock
   A. Mold coating C. Permanent molds and metal chills
   B. Dry coating D. all
5. _______________ is used to increases dry strength of the molds
   A. Dextrin C. Sea coal
   B. Wood flour D. Flour

Unit Seven: Clean and Restore Work Area
This unit is developed to provide you the necessary information regarding the following content coverage and topics: • Clearing all materials/debris from work area • Disposing unwanted treated sand This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Clear all materials/debris from work area • Dispose unwanted treated sand

7.1 Clearing all materials/debris from work area

7.1.1 Clearing all materials/debris and work site in a safe state

- Dusts, solvents, and other materials present a health hazard in foundries.
- Dust is generated in many foundry processes and presents a twofold problem:
  1) Cleaning to remove deposits
  2) Control at the point of origin to prevent further dispersion and accumulation
     - Vacuum cleaning is the best way to remove dust in foundries.
     - Once dust has been removed, prevent further accumulation by using local exhaust systems (LEV) that remove it at the point of origin.

7.1.2 **Personnel Facilities**

- Encourage frequent washing with soap and water, and install adequate facilities.
- Core room workers whose hands and arms may be exposed to sand and core oil mixtures are candidates for dermatitis.
- Prolonged contact with oil, grease, acids, alkalis, and dirt can produce dermatitis.
- Reference industrial sanitation standards.
- Sanitary food preparation and service is especially important in nonferrous foundries.

- Prohibit eating in work areas.

7.1.3 Work environment in foundries

- Good housekeeping, ventilation, and light help maintain a safe and healthy work environment.
- Proper inspections, maintenance, and fire protection increase workers' safety in foundries.
- Housekeeping
    - Clean machines and equipment after each shift, and keep them reasonably clean during the shift.
    - Place all trash in the proper trash bins.
    - Keep the floors and aisles in the work area unobstructed.
    - Properly stack and store materials.

Remove the dust /unwanted sand from the surrounding area with a brush/broom, never by hand. Clean the equipment upon completion of the task. Use a rag to clean the bench. Sweep the floor surrounding the molding bench area.

7.2 Disposing unwanted treated sand

7.2.1 Introduction

What sand reclamation?

- Sand reclamation, the process of cleaning previously used sand so it can be reused.

Why sand reclamation?

- Due to environmental regulations, the disposal of waste foundry sand has become one of the most pressing problems for the foundry.
- In recent years because of the high disposal costs encountered and difficulty in finding disposal sites.

7.2.2 Primary reclamation of sand in foundries

Primary reclamation is used by virtually all UK greensand foundries, though the degree of sophistication of the reclamation plant varies widely from a simple manual operation to fully automatic computer-controlled equipment. A proportion of sand is discarded from the system on each cycle to allow for the addition of new sand, replacement clay and other materials

7.2.3 Secondary reclamation

Greensand foundries currently treat the discarded sand proportion as a waste material for disposal. This sand could, however, be treated by secondary reclamation techniques to render it fit for use in place of new sand. This would reduce sand purchase and disposal costs, and lead to a reduction in waste to landfill.

Self-Check 7

Part I Directions: Multiple Choice Questions.

1. Foundry sand reuses for manufacturing another products such as

A. Cement
B. Concrete
C. Bricks
D. All

2. Excess metals formed in the casting process are to be removed

A. Fins
B. Parting line fins
C. Wires
D. Gates
E. All

Part II Directions: True or false the questions listed below.

1. To remove any mold remnants, the surface is cleaned using a blasting process.
2. In the cleaning media strikes the casting surface at low velocity to dislodge the mold remnants.

Part III Directions: Writing questions

1. List beneficial reuses of foundry sand?

List of Reference Materials

1. The ASM Handbook Committee, casting volume 15 9th Edition'
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4. Rajender Singh (2006), introduction to manufacturing processes and work shop technology.
5. The ministry of education and industrial relation , Queensland (2004),Foundry code of practice
6. Foundry Technology By peter Beeley

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