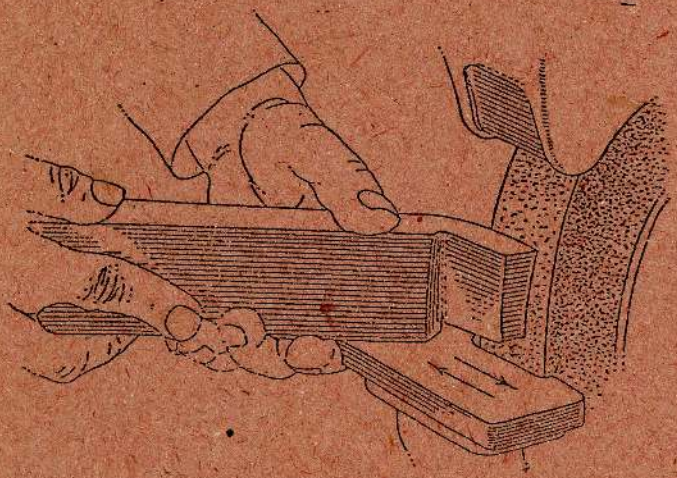
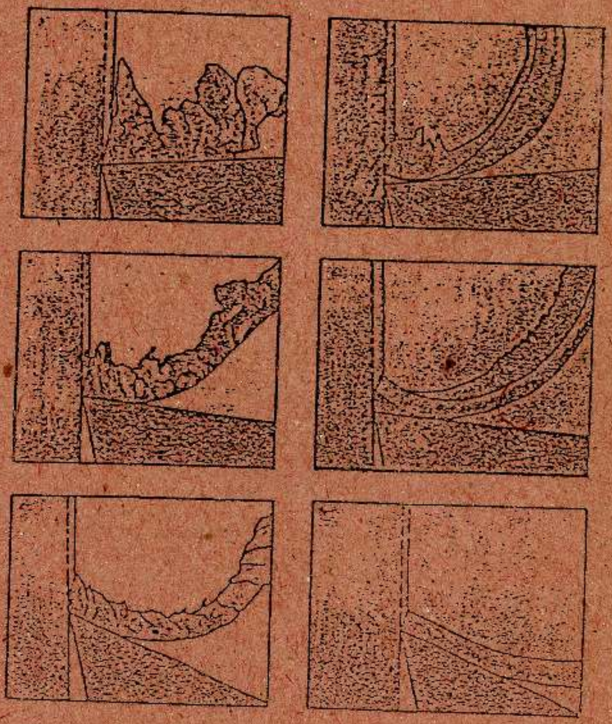
THE OPEN UNIVERSITY
DIPLOMA IN TECHNOLOGY
LEVEL 4





# FUNDAMENTALS OF WORKSHOP PRACTISE & PRODUCTION TECHNOLOGY

*MED 2208 /MEE4208*

*BOOK 03*
*PART A*

# DIPLOMA IN TECHNOLOGY

## ( MECHANICAL )

# FUNDAMENTALS OF WORKSHOP PRACTISE & PRODUCTION TECHNOLOGY

**MED 2208 / MED 4208**
**BOOK 3**
**PART A**

THE OPEN UNIVERSITY OF SRI LANKA

Printed in Sri Lanka

by

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NAWALA,
NUGEGODA,
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# CONTENTS

AIMS AND OBJECTIVES :

(i) To classify plain carbon steels and cast ions.

(ii) To inter-relate the macroscopic properties of plain carbon steels and cast ions to their structure.

(iii) To explain the properties of alloy steels and indicate the influence, the alloying elements have on the properties.

## 3.1 PLAIN CARBON STEELS :

Plain carbon steels contain up to about 1.7 weight percent carbon. These steels can be classified according to their carbon content.

Low carbon steels are of two types

(i) dead mild steel.
(ii) mild steel.

Dead mild steel has up to 0.15 weight percent carbon.

Mild steel has a carbon content from 0.15 to 0.25 weight percent.

Medium carbon steel has carbon from 0.25 to 0.5 weight percent.

High carbon steel has carbon from 0.5 to about 1.7 weight percent.

Steels when they are prepared under equilibrium conditions would have a microstructure either that of a hypo-eutectoid steel, a eutectoid steel or a hyper-eutectoid steel.

---

SAQ 01 : To which one of the categories would the microstructure of a medium carbon steel obtained under equilibrium conditions be similar (i) eutectoid (ii) hypo-eutectoid (iii) hyper-eutectoid.

* * * * * *

ANSWER : (ii) hypo-eutectoid

---

S.A.Q. 02 : High carbon steel obtained under rapid cooling conditions would have a microstructure similar to
(i) hypo-eutectoid steel (ii) eutectoid steel
(iii) hyper-eutectoid steel (iv) Martensite

* * * * * *

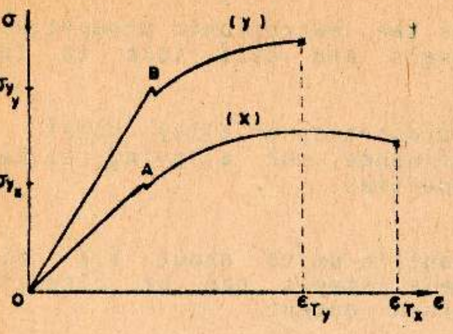
ANSWER : (iv) Martensite

---

S.A.Q. 03 : Explain with reference to stress/strain diagrams the terms ductility, strength and toughness.

* * * * * *

ANSWER :




1. Ductility:

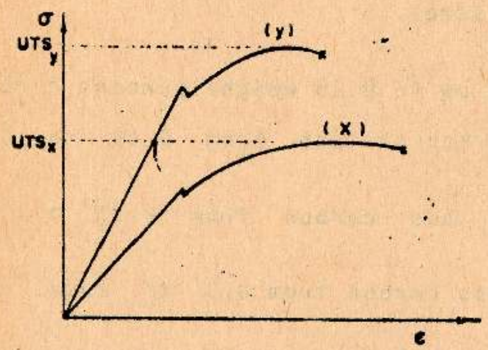
Consider the two specimens X and Y. The stress/strain curve indicates that the yield point of Y is greater than the yield point of X

$$\sigma_{y_Y} > \sigma_{y_X}$$

X has a lower Young's Modulus when compared to Y. (Young's Modulus is the ratio stress to strain of the linear portion). Gradient of line OB is greater than the gradient of line OA. Also X can withstand a greater total strain up to the break point than Y.

$$\epsilon_{T_X} > \epsilon_{T_Y}$$

When the three conditions, yield point, Young's Modulus and Total strain at break point are observed in this manner, X is said to be more ductile than Y.

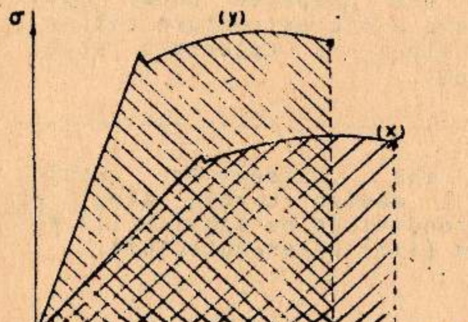



2. Strength:

The tensile strength or ultimate tensile strength (UTS) is measured by the maximum of the σ Vs ε graph.

$$UTS_Y > UTS_X$$

Thus specimen Y is stronger than specimen X.

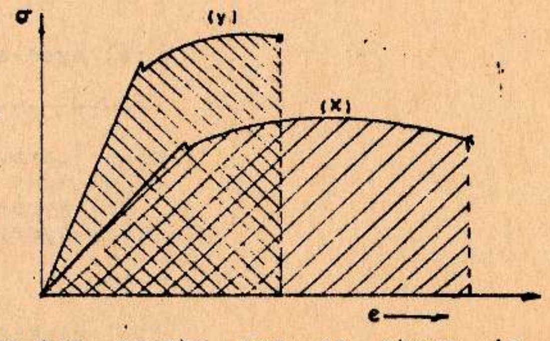



3. Toughness:

Toughness is a measure of the energy needed to cause fracture in a material. The area under the stress strain graph is a measure of toughness.

The diagram given shows that (X) is tougher than (Y), because the area under the curve (X) is greater than the area under the curve (Y).

It should be remembered that this relation depends on the two graphs.




If the two graphs are as shown in figure (Y) is together than (X).

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The dependence of the microscopic (bulk) physical properties of plain carbon steels on the carbon content could be explained using stress/strain diagrams.

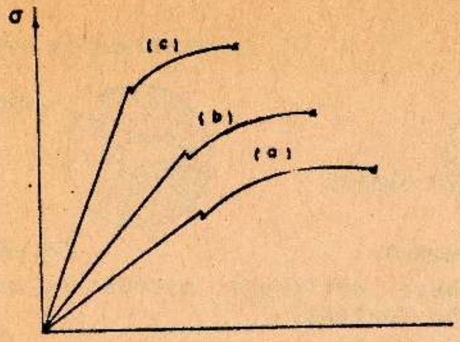


Fig. 3.1 Stress strain graphs of Plain Carbon Steels

Figure 3.1 gives the stress/strain graphs of mild steel, Medium-carbon steel and High carbon steel.

(a) Mild steel.
(b) Medium Carbon steel.
(c) High Carbon Steel.

These graphs of the plain carbon steels indicate a comparison of properties.

1. Ductility.

Mild steel > Medium Carbon Steel > High Carbon Steel.

2. Strength.

High Carbon Steel > Medium Carbon steel > Mild Steel

3. Toughness

This property unlike ductility and strength cannot be generalised

If the carbon content of High carbon steels is low then the toughness varies as

High Carbon Steel > Medium Carbon steel > Mild Steel.

(Compare curves (1) and (2) of Figure 3.2)

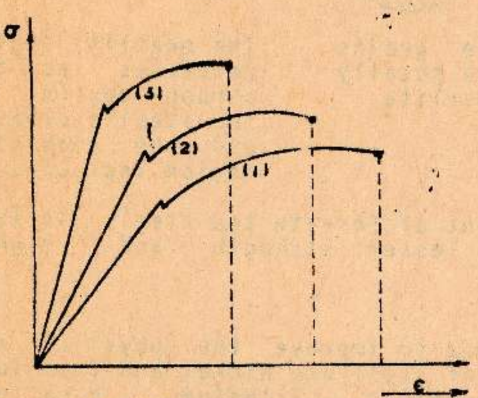


Fig. 3.2 Stress strain graphs of Plain Carbon Steels

But as the content of cementite increases the toughness of High carbon steels decrease. Thus high carbon steels with high contents of carbon may be less tougher than Medium Carbon Steels or Mild steels.

(Compare curves (1) and (3) of Figure 3.2)

(1) Medium Carbon Steel

(2) High Carbon Steel (Carbon content is little higher than that of medium carbon steel).

(3) High carbon steel (carbon content is very high).

EXERCISE 01 : Draw the stress/strain graph of dead mild steel and compare it with that of a mild steel.

---

S.A.Q 04 : Compare the toughness of dead mild steel with that of pure iron.

* * * * * *

ANSWER : Dead mild steel has a microstructure similar to that of pure iron as it is mainly ferrite. The difference being the small content of carbon which makes it stronger, less ductile and has a decreased toughness. Mild steel too would have a microstructure like dead mild steel with ultimate grains of pearlite. As the content of carbon increases the gains of pearlite increase in size.

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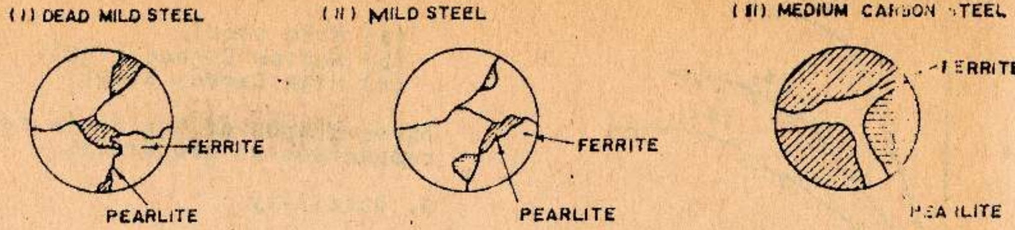
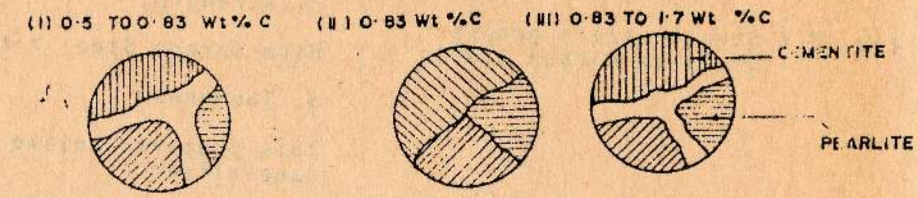
EXERCISE 02 : Draw the microstructure of pearlite.

### 3.1.1 MICRO STRUCTURES OF DIFFERENT STEELS :




High carbon steels have different microstructures depending on the carbon content.




The perlite grains become larger as the carbon content increases and the fertite region becomes smaller.

The grains are totally pearlite

The pearlite region decreases as the carbon content in the steel increases and the cementite region increases.

The higher the content of ferrite the steel displays greater ductility, lesser strength and higher toughness.

### 3.2 ALLOY STEELS :

The common metals used to improve the physical and chemical properties of steel are Nickel and Chromium. But for special purposes Titanium, Vanadium, Tungstan, Molybdenum and Cobalt are used. It is importaent to note that the Iron ore and hence the steel from which it is obtained may contain elements, like Silicon, Phosphorus, Sulphur and Mangenese.

EXERCISE 03 : Explain the harmful effects of phosphorus and Sulphur on the properties of a steel.

Some of these elements though present as impurities have benefical effects. Example, mangenese in steel prevents the harmful effects caused to steel by sulphur, it acts as a deoxidant and it strengthens the ferrite. Generally alloying elements are added (i) to improve the strength (ii) to increase the corrosion resistance (iii) to improve the heat treatability of the steel.

(Heat treatment of metals and alloys would be covered in a later lesson).

Elements like Mangenese, Nickel, Coblt stabilize the austenite since they possess a face centered cubic structure, whereas elements like Choromium, Tungsten, Molybdenum and Vanadium stabilise the ferrite as these elements crystallise in the body centered cubic form.

EXERCISE 04 : What type of unit cell would (i) Austenite (ii) Ferrite possess? at what positious are the carbon atoms placed in these alloys?

The two metals commonly used for alloying of steels, Nickel and Chromium produce the stainless steels.

Iron has advantageous properties mainly because of lattice transformation with temperature. But to improve its strength because engineers needed a stronger material than pure iron metal, plain carbon steels were discovered.

The basic disadvantage with iron is that it corrodes. With steel the strength is greater than that of iron, but steel too undergoes corrosion.

---

S.A.Q. 05 : What do you understand by corrosion?

* * * * * *

ANSWER : Corrosion is the decay of a meterial when exposed to a corrosive that is reactive environment. Normally it is moist air. The components water vapour, Oxygen and carbon dioxide in moist air are normally responsible for atmospheric corrosion.

---

### 3.2.1 STAINLESS STEELS :

The name indicates that the material is resistant to corrosion.

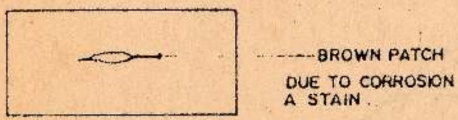



FIG 3.3 PIECE OF PLAIN CARBON STEEL

With stainless steels these stains due to corrosion do not appear, hence the name stainless steels.

Stainless steel is resistant to corrosion. The protection that Nickel and Chromium gives to steel is a property seen only with particular metals. Example, aluminium, a very reactive element much more reactive than Iron does not corrode when exposed to moist air. This is because when Aluminium is first exposed to moist air a coating of Aluminium Oxide is formed, on the metal.

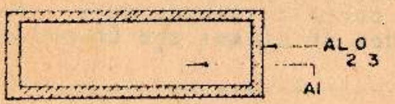



Fig. 3.4 How Al protect from corrosion

This coating of the oxide is adherent and non-porous. So that the coating prevents further reaction and the metal is protected from corrosion like a coating of paint prevents the metal from coming into contact with moist air.

Nickel and Chromium are two other metals which has this property like Aluminium, but to a lesser extent. Thus to prevent steel from corrosion it is alloyed with Nickel and Chromium.

Stainless steels have the alloying elements Carbon, Chromium and Nickel in Iron.

EXERCISE 05 : The atomic numbers of Iron, Carbon, Chromium and Nickel are 26, 6, 24 and 27. What type of solid solution is formed between Carbon and Iron, Chromium and Iron, Nickel and Iron?

(Note: The atomic number is an indication of the size of the atom).

EXERCISE 06 : Chromium has a body centered cubic structure. Nickel has a face centered cubic structure.

Indicate the order of solubility of Chromium and Nickel in (i) Austemite (ii) Ferrite.

Since chromium and ferrite has the same lattice structure in heat treatment process, the chromium stabilises the Ferrite, whereas nickel has a structure like austenite, thus it stabilises the austenite.

One difficulty with stainless steels is that when they are welded the carbides of chromium and Nickel get precipitated on either side of the weld. This happens not at the weld but on either side because on either side of the weld the temperature has the right value for precipitation of the carbides. Precipitation or removal of Nickel and chromium as the carbides causes corrosion at these points.

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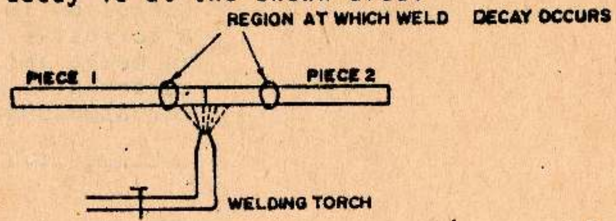
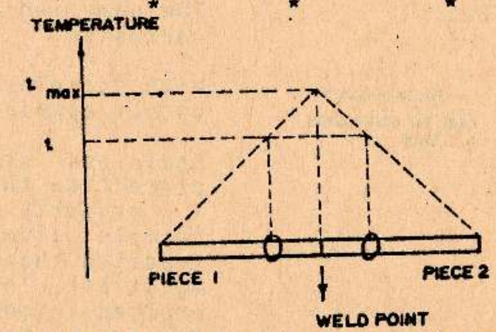
S.A.Q. 05 : When two pices of stainless steel are welded, at what point does the highest temperature arise? Why the weld decay is at the shown area?




The maximum temperature is at the point where it is welded t .. t is the correct temperature for precipitation of the carbides of Nickel and Chromium.

---

To prevent weld decay stainless steels are further alloyed with <u>Titanium</u>, <u>Vanadium</u> or <u>Molybdenum</u>, but <u>mainly Titanium</u> is used. When these elements are present on welding it is not the carbides of Nickel and Chromium that are precipitated but it is the carbides of Titanium, Vanadium or Molybdenum that are precipitated preferentially. Because Nickel and Chromium are not removed the stainless character of the steel is maintained and weld decay does not occur. Thus stainless steels to be welded are mainly Titanium steels. Instead of Titanium, Vanadium and Molybdenum also could be used.

## 3.3 CAST IRONS :

Cast irons contain from about 2.2 to 4.4 weight percent carbon. Generally they are divided into two categories.

(1) White or Chilled cast iron.
(2) Grey cast iron.

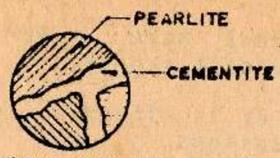



Fig. 3.5 Microstructure of White Cast Iron

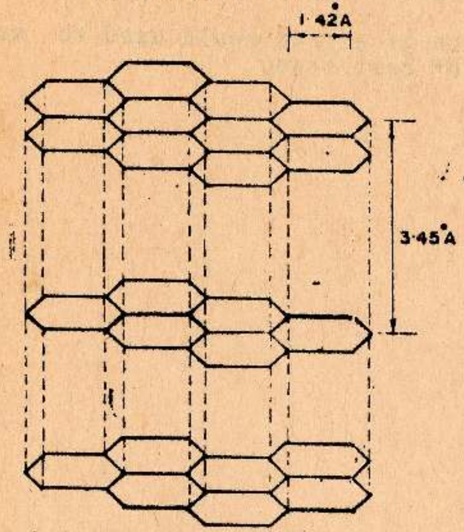



Fig. 3.6 Structure of Graphite Flakes

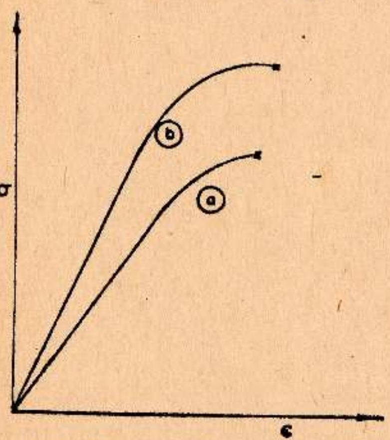



Fig. 3.7 Stress Strain diagrams of Cast Irons

White cast iron is so named because on fracture it has a dull white appearance.

Grey cast iron on the other hand on fracture gives an appearance which is dark-grey or almost black.

White cast iron has a microstructure of cementite and pearlite. Thus it is like a high carbon steel.

In grey cast irons even on slow cooling graphite is rejected from the structure. This seperation of graphite is caused by the presence of elements like silican which causes seperation of carbon. The rejection of graphite causes the structure to be ferrite and pearlite with the rejected carbon being in the form of graphite. The flakes of graphite has a tendency to reduce any strengthening of the structure since graphite is very soft.

What is the structure of graphite?

A block of graphite occurs as flakes. Within a layer the structure is very hard because bonding is very strong, but between layers the structure has poor or weak bonding. Thus one layer could be made to slip easily on another layer showing the properties of lubrication. Graphite is a solid lubricant.

Figure 3.6 shows the arrangement of the layers in a block of graphite. In any particular layer the carbon atoms form hexagonal rings bound by strong covalent bonds.

Bond length = 1.42°A (1°A = $10^{-10}$ m)

Distance between layers = 3.45°A.

Figure 3.7 indicates the stress/strain diagrams of cast ions.

(a) Grey cast ion.
(b) White cast iron.

These stress/strain diagrams indicate that grey cast iron is less stronger than white cast iron.

Fracture occurs at a lower stress in grey cast iron. Also the toughness of white cast iron is greater than that of grey cast iron. Also the graphs indicate that the cast irons have very low ductility, hence these have to be shaped by casting. Thus the term cast iron.

TUTORIAL QUESTIONS :

1. A high carbon steel is found to be less toughe than a mild steel.

   Compare (i) the strength (ii) the ductility of these two carbon steels.

2. Draw the microstructure of a high carbon steel containing 0.90 weight percent carbon and compare this microstructure with that of a high carbon steel containing 1.5 weight percent carbon.

3. If Aluminium (Atomic No. 13) is alloyed with plain carbon steel would the alloy steel obtained be stainless. If it is stainless would it be better than Nickel/Chromium stainless steels.

4. How does titanium steels prevent weld decay ?

5. Why do grey cast irons have wider direct applications than white cast irons?

6. (i) Draw a sketch of a foundry cupola and indicate the dimensions.

   (ii) What is a laddle?

   (iii) Draw a sketch of a sand mould used to mould an article of cast iron.

## AIMS AND OBJECTIVES :

(i) To explian in brief the main fabricat on processes used in engineering.

(ii) To explain the main uses and applications of structural steels.

(iii) To detail out the main applications of al oy steels and cast irons.

## 4.1 FABRICATION PROCESSES :

Dead mild steels and mild steels that is low carbon steels are structural steels. These account for nearly 80 - 90% of the steels used. These possess fair strength, high ductility and could be fabricated easily.

Some of the fabrication processes are Rolling, Drawing, Forging, extrusion and Welding.

### 4.1.1 ROLLING :

In rolling a piece of thicker guage is reduced to one of thinner guage by subjecting it to compressive forces between rolls, revolving in opposite directions but at the same peripheral speed.

This process is generally used to reduce cast ingots (which are prepared after extraction and refining) to billets, slabs, bars and sheets.

The process could be hot rolling or cold rolling.

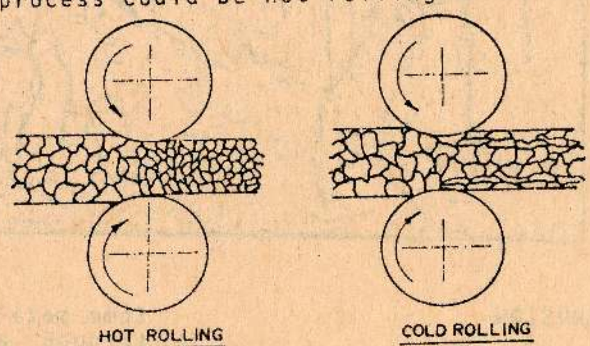



Fig 4.1 Schematic representation of hot and cold rolling. Hot rolling refines grain structure, and cold rolling distorts grain structure.

### 4.1.2 DRAWING :

In drawing (i) either tube drawing (ii) or wire drawing, a change similar to rolling is achieved but by a different method.

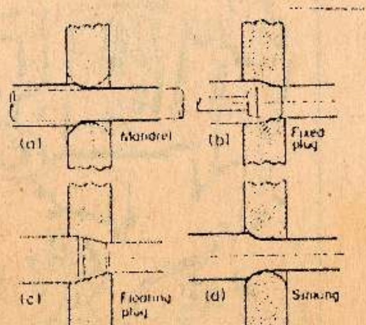



Fig. 4.2 (i) Tube elongation by drawing with internal support by (a) mandrel, (b) plug, (c) floating plug; and without internal support by sinking (d).

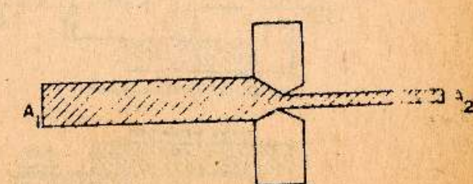
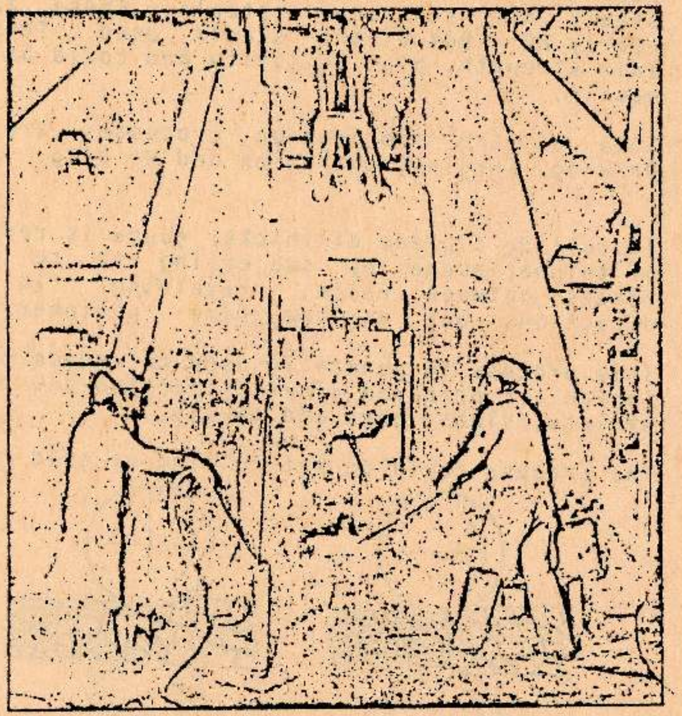



Fig.4.2(ii) Wire drawing

4.1.3 FORGING :

In this process compressive forces are appliec large pieces to be shaped as desired ι mechanically driven hammers or using presses. steam hammer is the principal type of hammer use hot forging. The hammer which may weigh from 5C 3000 kilograms, is fastened to the end of the p rod and travels between guides. The piece t forged rests on the anvil block, which is from 30 times as heavy as the hammer block and usua in concrete.



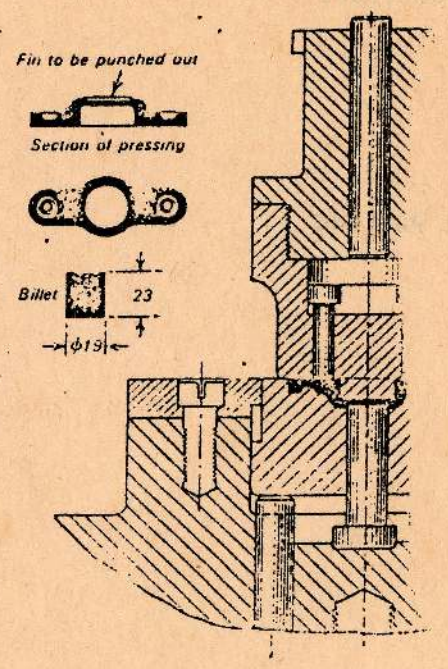



Fig.4.3 Tools for forgings

4.1.4 EXTRUSION :

Some metals lend themselves to forming by through an opening rather than by dra rolling. Soft metals like lead and its alloy be subjected to extrusion. Brass rods are obt this method. It has the advantage that perfectly round rods and are intricate sect as pinions.

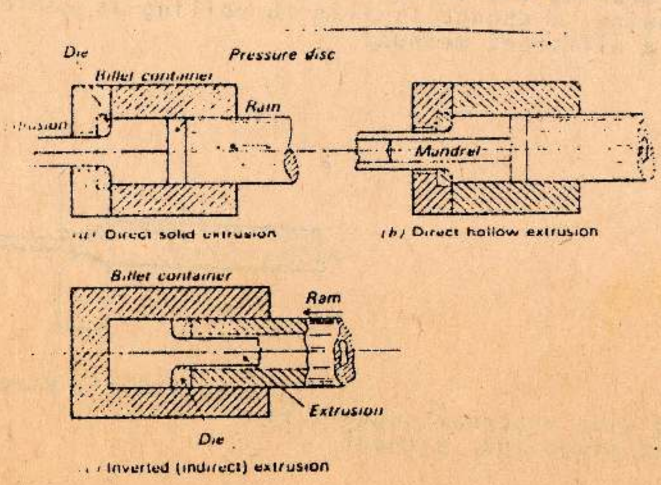



Fig.4.4 Modes of extrution

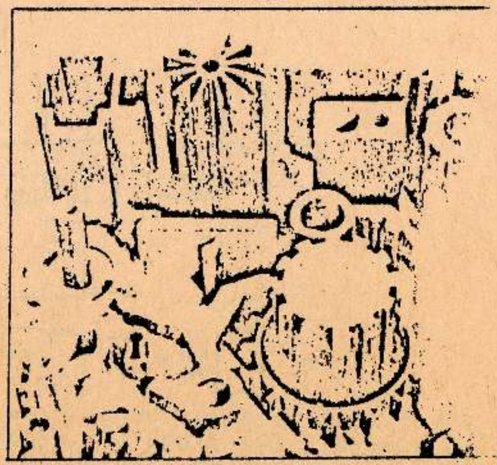


Fig.4.5 Extruded shapes

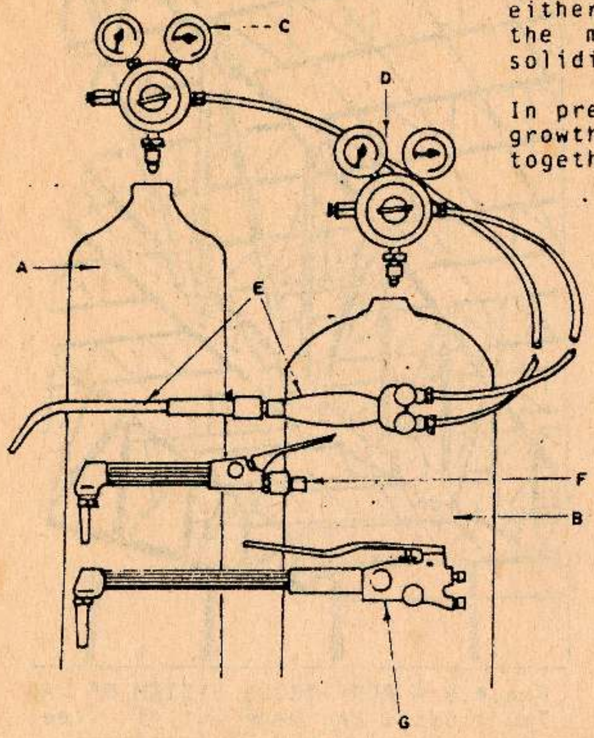
The picture indicates the intricate extruded shapes.

These fabrication processes could be applied for steels.

**4.1.5 WELDING** :

Welding of metals may be defined as uniting two pices of metal by crystallizing. This can be accomplished either by fusion or by pressure. In fusion welding the metal parts undergo melting and then solidification.

In pressure welding, recrystallisation and crystal growth occurs and the pieces of metal are welced together.




A- Oxygen cylinder.
B- Acetylene cylinder.
(gas cylinders shown diagramatically, cylinder valves omitted)
C- Oxygen pressure regulator.
D- Acetylene pressure regulator.
E- Welding torch shank and weldingtip.
F- Cutting attachment.
G- Cutting torch.
(F and G are alternatives to E)

Fig.4.6 Oxy-acetylene Welding/Cutting Equipment.

**EXERCISE 01** :

What is the difference between the processes hot rolling and cold rolling?
Is there a difference in grain structure of material obtained by these two methods.

**EXERCISE 02** :

In tube drawing, by looking at the picture given could you explain what the following components are (i) Mandrel (ii) Fixed plug (iii) Floating plug

**EXERCISE 03** :

In extrusion, what is a billet, a ram, and a die?

**EXERCISE 04** :

In welding why are the regulaters from the oxygen and acetylene cylinders necessary?

**4.2 APPLICATION OF STRUCTURAL STEELS** :

Structural steels are used for;
(1) Buildings (2) Bridges (3) Ships (4) Boilers
(5) Vehicles

4.2.1 BUILDINGS :

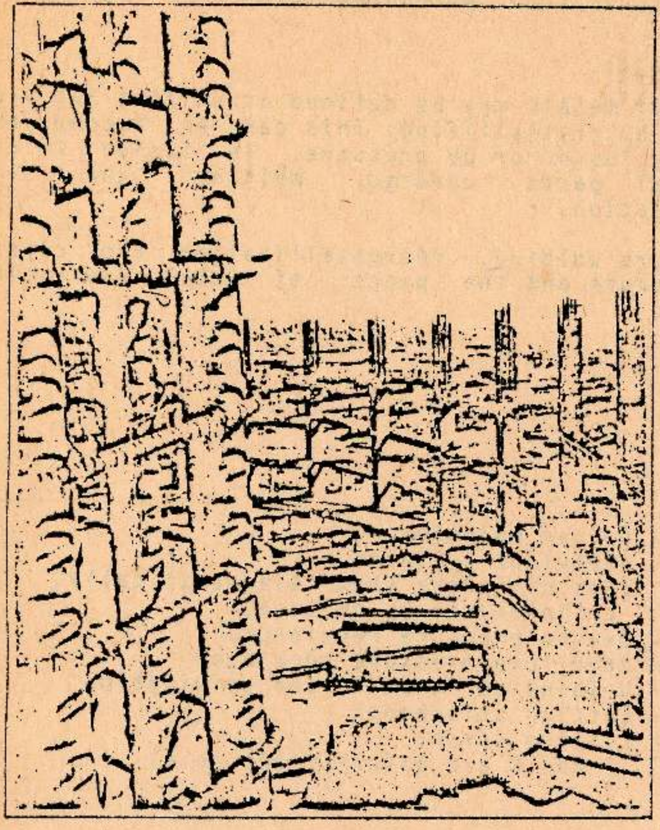


Fig.4.7 Construction of reinforced concrete columns for a domed stadium. Steel bars having a ribbed surface structure are used to reinforce the concrete columns. The bars are kept in vertical position by tieing them up with equally spaced horizontal loops formed by thies steel rods.

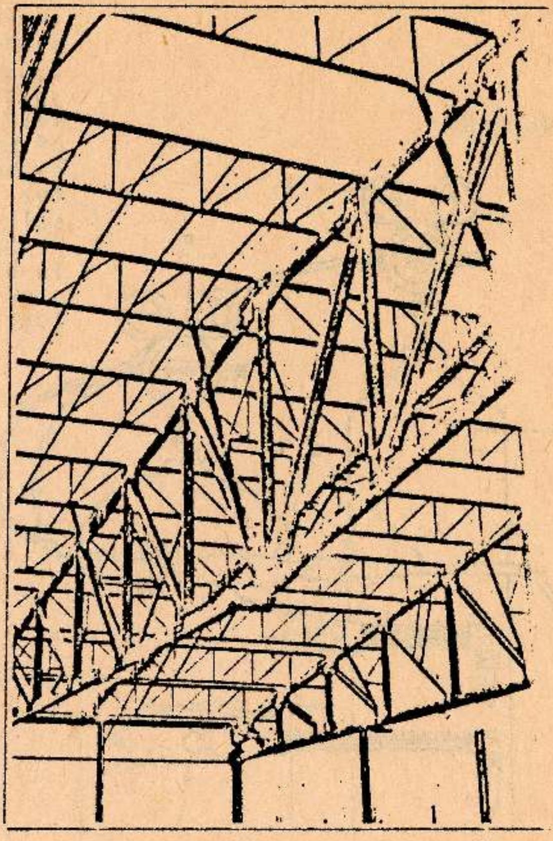


Fig.4.8 A ROOF TRUSS SYSTEM OF AN The trusses are made out of steel of I - section and T - sections.

4.2.2 BRIDGES :

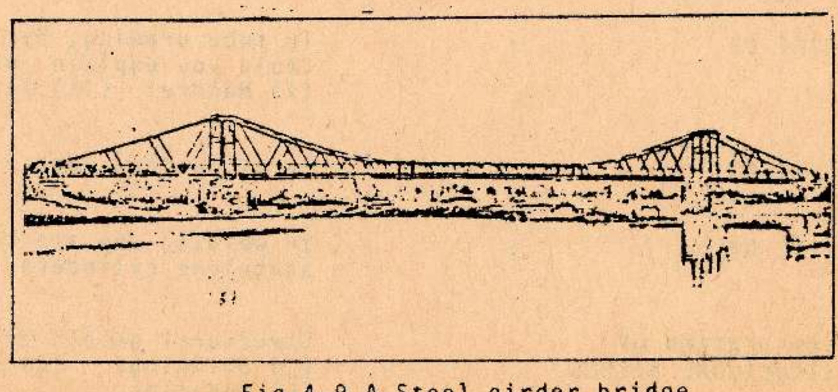


Fig.4.9 A Steel girder bridge

4.2.3 SHIPS :

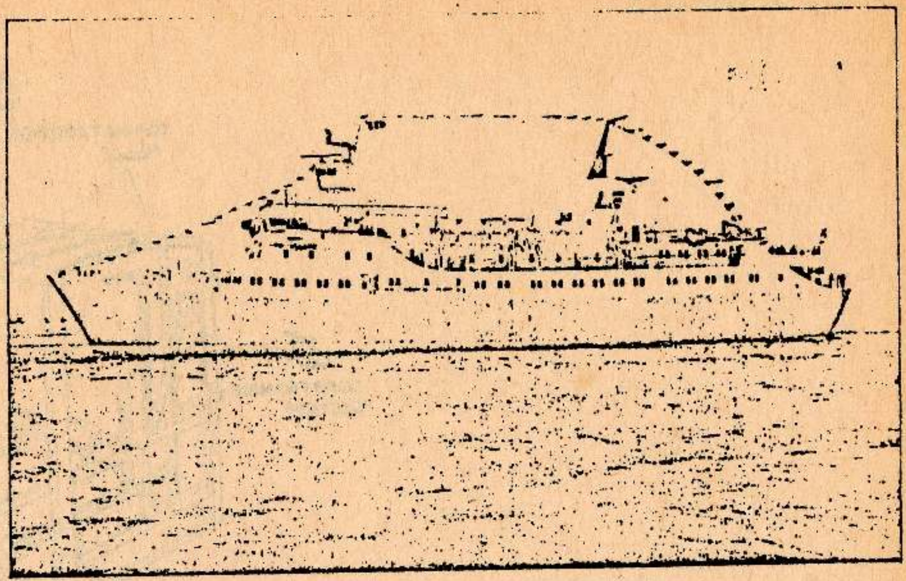


Fig.4.10 Antartic cruise liner linblad explorer

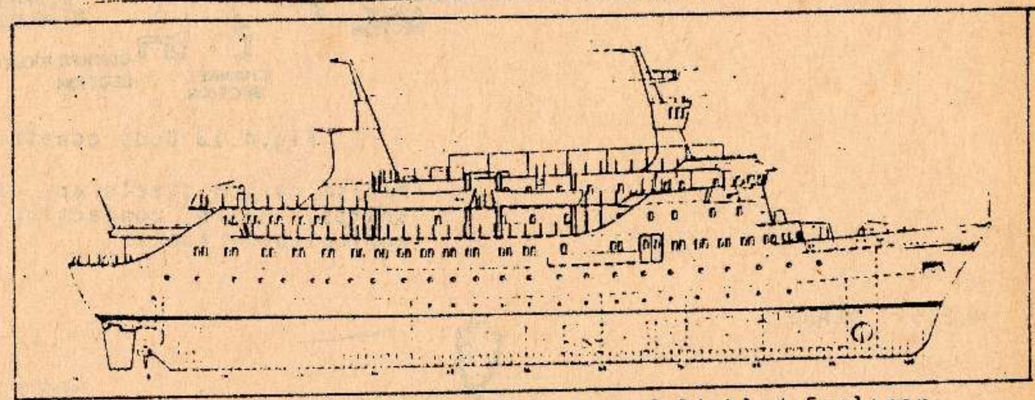
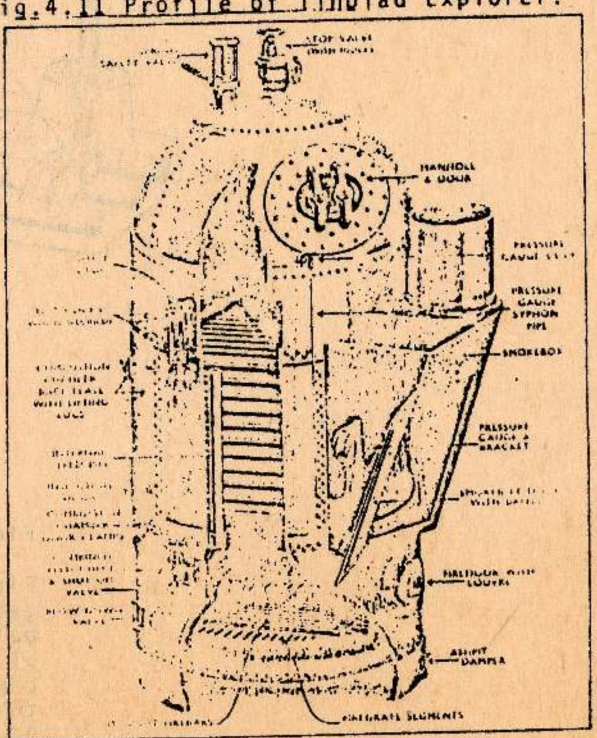


Fig.4.11 Profile of linblad Explorer.

4.2.4 BOILERS :




4.12 Sectional view of a Cochran vertical boiler

4.2.5 VEHICLES :

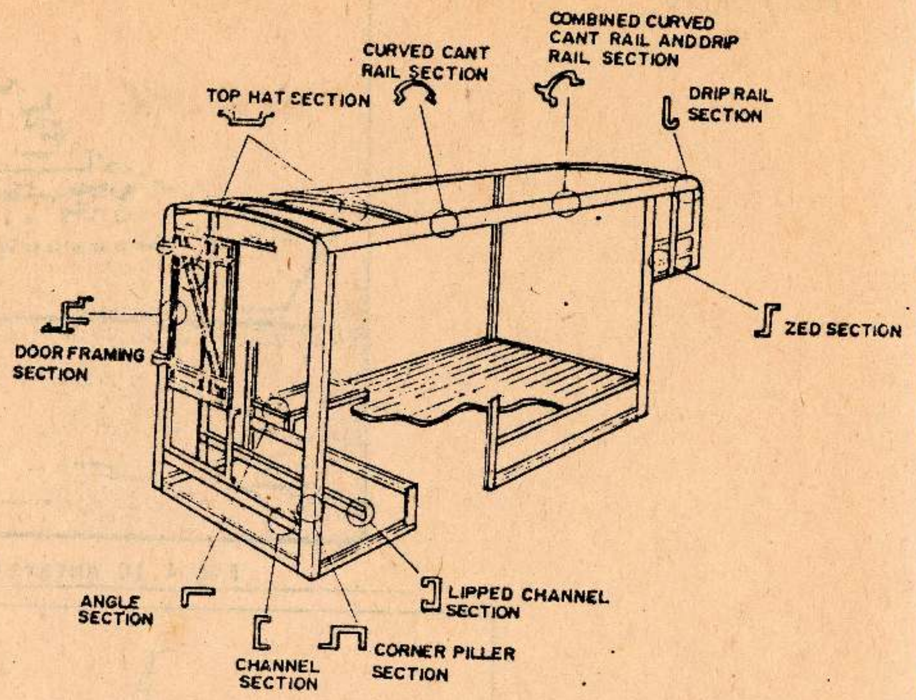



Fig.4.13 Body construction of a vehicle

Medium carbon steels are used for components such as shafts, gears, connecting rods, rail axles, dies and agricultural tools.

4.2.5.1 GEARS :

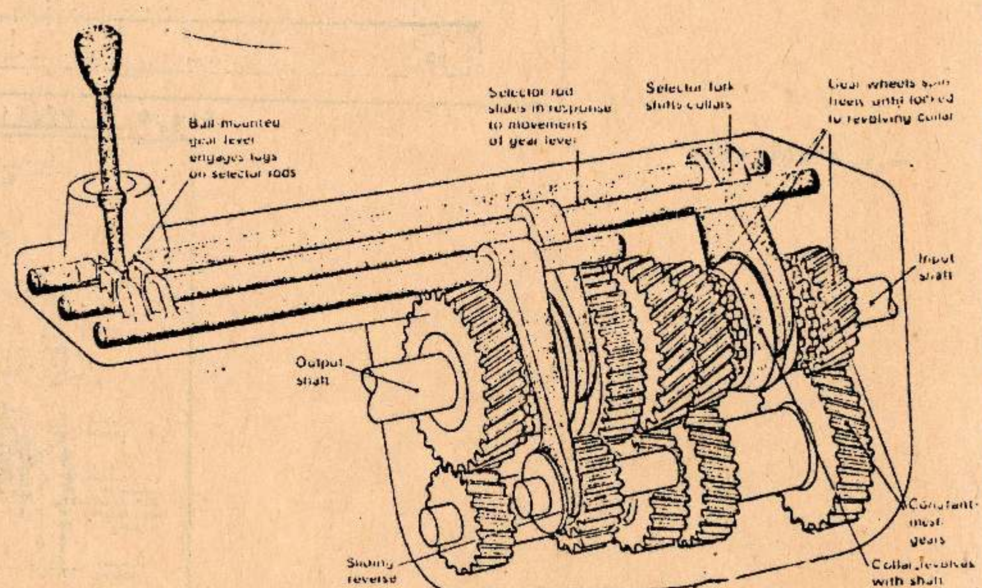



Fig.4.14 A typical 4-speed gear box

Fig 4.14 Shows a common four speed direct - top gearbox in neutral. The gear lever, pivoted at the ball-mounting, can be moved to engage the lugs on any of the three selector rods. The central rod slides to engage first or second gear, the back rod engage third and fourth gear and front rod shifts the reverse idler.

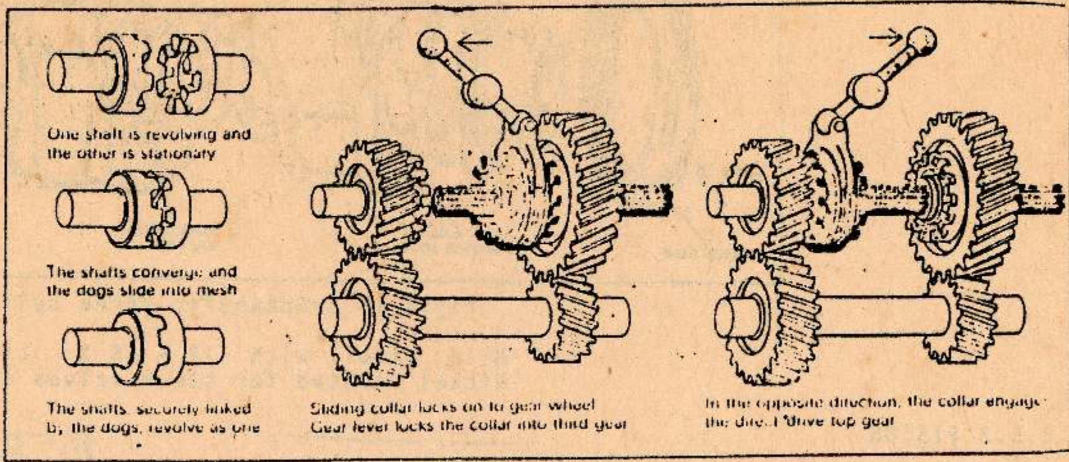
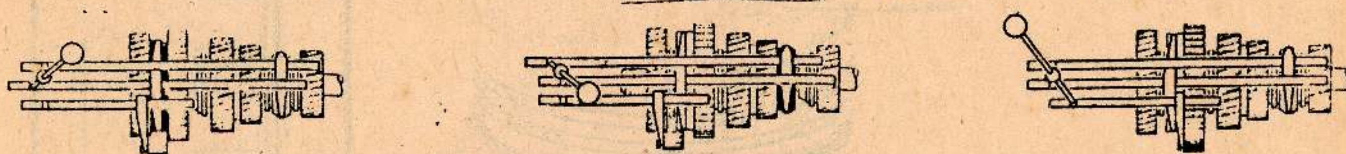



Fig.4.15 How dog clutches engage gears



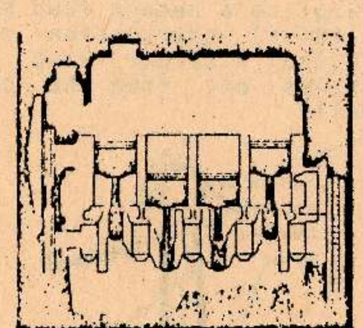
A selector rod moved to engage first gear -it moves the other way for second.

Third gear. In the opposite direction this selector rod engages the direct top gear.

Revers is engaged by moving the spur idler wheel to mesh with the other spur wheels.

Fig.4.16 Selecting of gears

4.2.5.2 CRANK SHAFT :



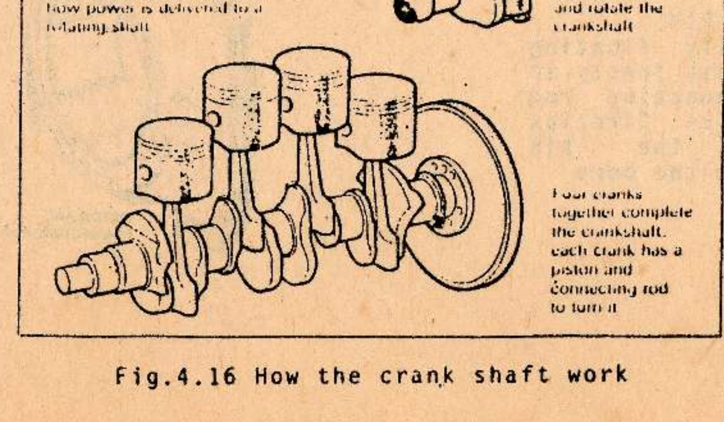



Fig.4.16 How the crank shaft work

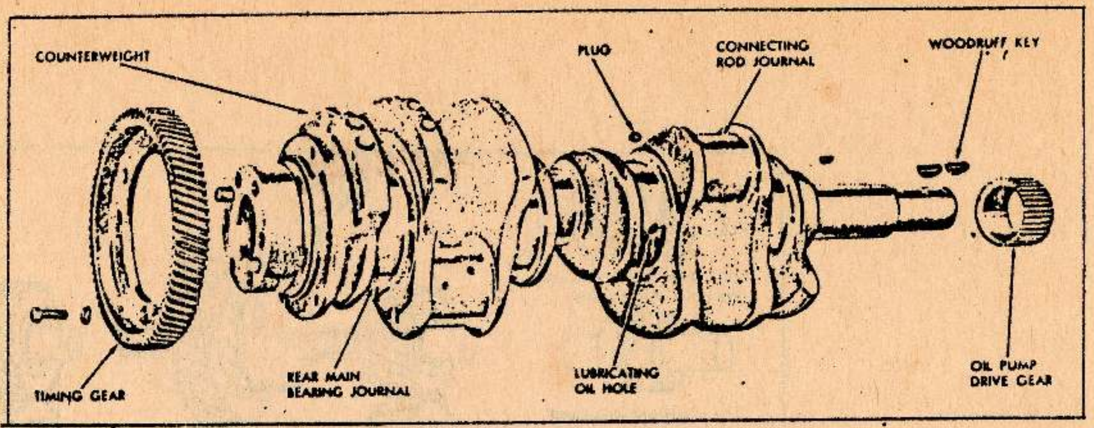
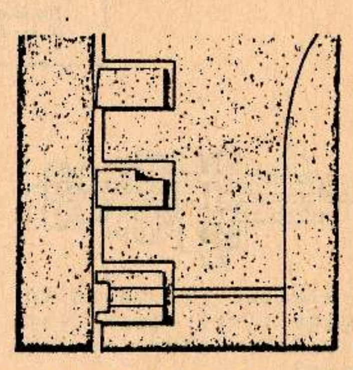
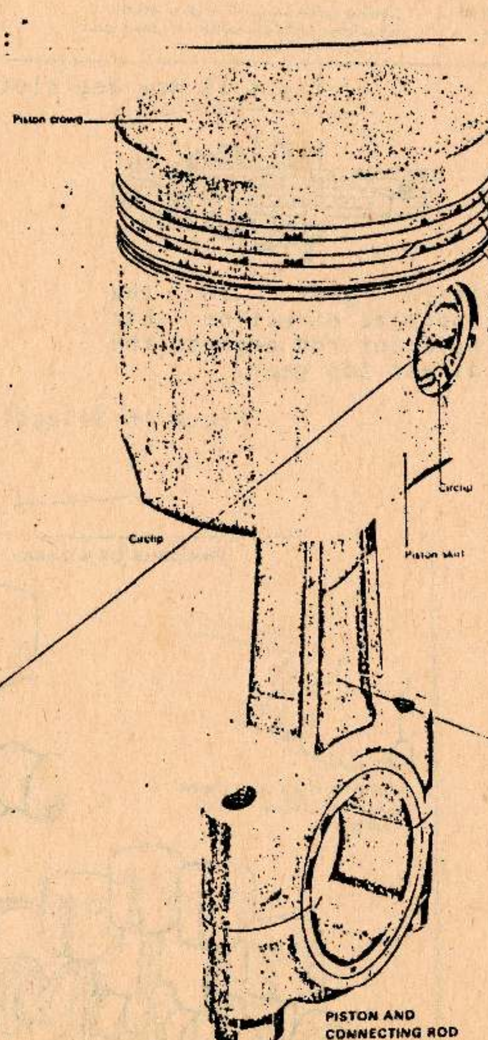



Fig.4.18 Crankshaft: three cylinder - four bearing

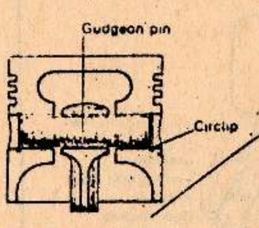
Mild steel with 12 - 15 % chromium and 0 - 8 % Nickel is used for steam valves and pistons.

4.2.5.3 PISTON :

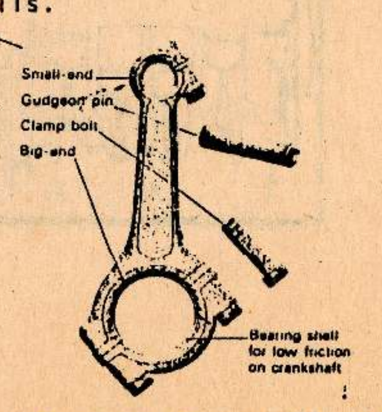





PISTON RINGS Blow-by, or gas leakage into the crankcase, is prevented by rings fitted in grooves in the upper portion of the piston. Gas passing down between piston and the bore forces a compression ring down in its groove and outwards against the bore. A small amount of gas will pass the top ring; so a second (and sometime a third) compression ring is fitted. A serper ring removes excess oil from the cylinder walls.




GUDGEON PIN
The fully floating pin pivots freely in the connecting rod and bosses. Circlips prevent the pin touching the bore




CONNECTING ROD The small-end is monted on a gudgeon pin carried in the piston, while the big-end encircles the crankpin.

Fig.4.19 Piston and connecting Rod

Medium carbon steels with the same contants of Chromium and Nickel are used for cutlery (spoons, table knifes, forks), springs and for machine parts used at high temperatures.

4.2.5.4 PROPELER SHAFT :

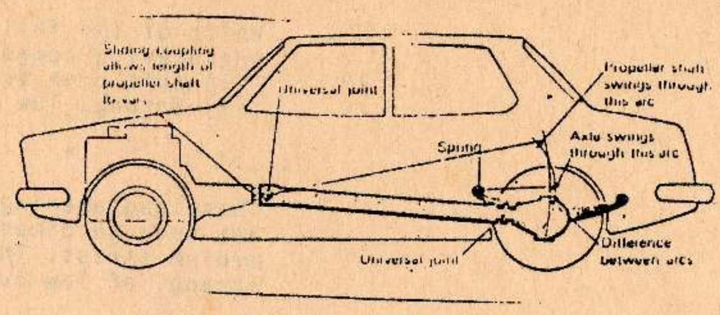



**Fig. 4.20 Allowing for movement**

As the axle rises and falls with the flexing of the springs, universal joint at each end of the propeller shaft allow its angle to change. The axel swings through an arc determaind by the rear springs. The propeller shaft moves through a different arc and its effective length has to vary, to compensate for the difference. A sliding coupling at one end of the shaft makes this possible.

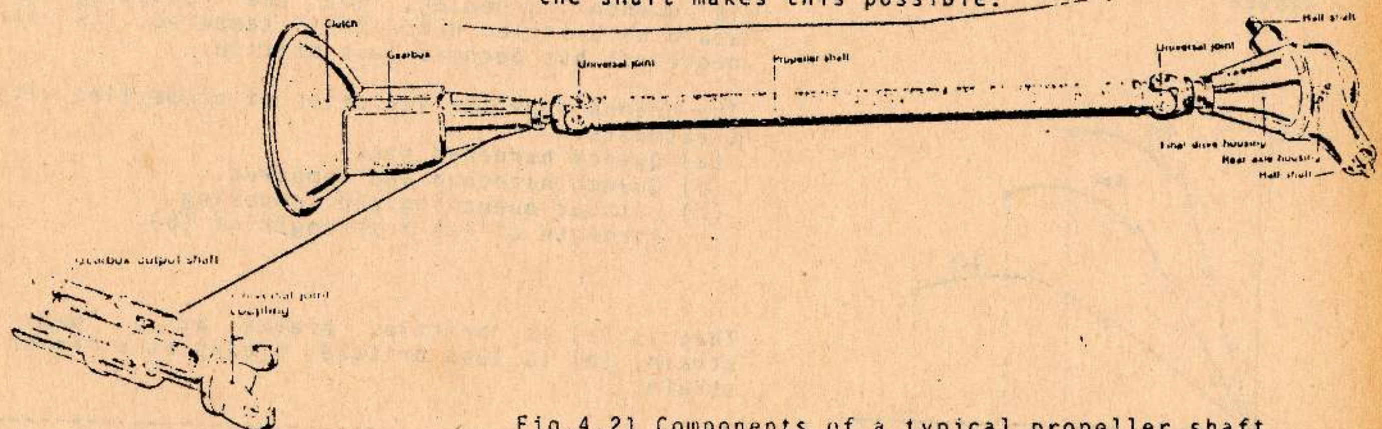



Fig.4.21 Components of a typical propeller shaft

THE UNIVERSAL JOINT
Coupling can slide backwords and forwords on splines on the output shaft as both rotate.

Universal joints at each end allow the angle of the propeller shaft to change, while the gear box output shaft and the final-drive shaft remain roughly parallel. The propeller shaft is balanced by the manufacturer so that its weight is evenly distrubuted about its axis. Any imbalance would cause vibration, damaging the gearbox and final-drive bearings.

---

S.A.Q. 1 : Mention why steels alloyed with Nickel and Chromium are used for steam valves and pistons of cars.

* * * * *

ANSWER : The high temperatures at which these components function would induce corrosion. Hence stainless steels are used.

---

S.A.Q. 2 : Why is the connecting rod so called?
What would happen if the connecting rod was made of dead mild steel and not of medium carbon steel.

* * * * *

ANSWER : Because of its ductility when subjected to the stress exerted on the piston in trying to turn the crankshaft, the dead mild steel connecting rod would tend to warp.

---

S.A.Q. 3 : Which of the following set of properties would an engineering component like a gear or shaft need?
(i) Soft high ductility, low toughness
(ii) Strong, low ductility, medium toughness

* * * * *

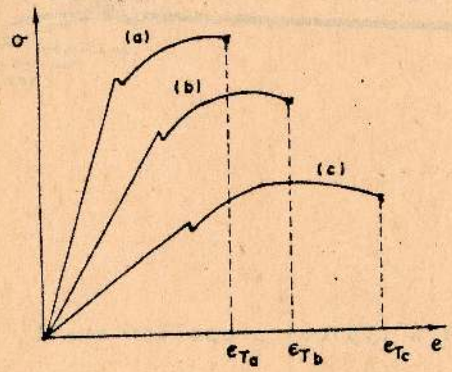
ANSWER : These engineering components need a steel that would not undergo dimensional changes when subjected to medium stress. That is these components should be strong, of low ductility and medium toughness.

---

S.A.Q. 4 : How would you obtain these properties, high strength, low ductility and medium toughness using a carbon steel.

* * * * *

ANSWER : To increase the strength of a steel the method used is quench hardening, but the resulting material would be brittle. Hence it is tempered. Its strength decreases but becomes less brittle.




The graphs show the variation of properties with heat treatments.
(a) Quench hardened steel
(b) Quench hardened and tempered.
(c) Without quenching and tempering
strength of (a) > strength of (b)

That is (a) is brittle, breaks at a lower total strain, (b) is less brittle, breaks at a higher total strain.

---

High carbon steels are mainly used for cheap cutting tools, such as saws, drills, chisels and axes and for rails, springs, dies and hammers. The great strength needed for these items is obtained by quenching and tempering at a low temperature of about 200°C.

Thus a quench hardened but tempered medium carbon steel is strong, has low ductility and is tough.

4.3 TEMPERING : A quenched steel is a non-equilibrium product. Martensite is formed. Thus the quenched steel because it has a non-equilibrium structure is dimensionally unstable. It is strong and brittle. To gain partial dimensional stability the material after quenching is heated to a temperature below the eutectoid temperature 723°C in order to convert some of the martensite ferrite and cementite (equilibrium product). This conversion increases the dimensional stability, decreases the strength and the steel becomes less brittle.

The extent to which martensite is converted to the equilibrium products ferrite and cementite depends on the temperature at which tempering is done (200°C, 400°C, 450°C, 500°C, or 700°C) and the time for which the specimen is held at the temperature at which it is tempered.

---

S.A.Q. 5 : Would tempering occur in a quicker time at a lower temperature or at a higher temperature.

*     *     *     *     *     *

ANSWER : Reactions and changes in microstructure take place at a higher rate at high temperatures than at low temperatures. These tempering would occur quicker at a higher temperature than at a lower temperature.

---

## 4.4 CAST IRON :

### 4.4.1 GRAY CAST IRON :

Grey cast iron has the advantages that it has a low liquidus temperature so that intricate castings could be poured. Moreover the presence of graphite makes it readily machinable and the overall cost is low. It has good wear resistance and is resistant to corrosion. Another important property is its damping capacity for vibrations. The tensile strength of graphite is low, because the flakes of graphite act as voids in the structure. These voids offer good damping effects towards vibrations that are set up during service. These properties cause them to be used for engine cylinder blocks, drain pipes, lamp posts and machine bases.

---

S.A.Q. 6 : What is the advantage of using a grey cast iron machine base?

*     *     *     *     *     *

ANSWER : Grey cast iron has good damping effects towards vibrations. These vibrations cause trouble in accurate machinery operations producing rough finishies and in accuracies in dimensions. Prevention of these vibrations would remove these in accuracies and give fine finishes in machining operations.

---

### 4.4.2 WHITE CAST IRON :

White cast iron has all its carbon in the form cementite (it is a hard and brittle compound.) Because of this high content of cementite the structure is hard and brittle. It has no graphite in the structure, that is the castings have to be ground to obtain the necessary shape.

80 - 90 % of the white cast iron is used to manufacture Melleable cast iron. Malleable cast iron is obtained by anealing the hard brittle white cast iron. Though it is titled malleable cast iron it is not ductile and hence not forgeable like steel or wrought iron, however it has higher toughness and ductility than other cast irons. Since it is softer than other cast irons it could be machined easily.

Hence malleable cast iron is used in applications where higher toughness and resistance to shock is needed.

Malleable cast irons find ready applications in farm implements, like plows, harrows, rakes etc. and also for automobile parts, small tools and other hardware.

TUTORIAL QUESTIONS :

1. Explain why the fabrication processes rolling, drawing, forging, extrusion, all use compressive forces and not tensile forces.

2. Structural steels are used for boilers and the infrastructure of vehicles (buses, lorries and ships) What are the special advantages of these steels to be used for these purposes.

3. Medium carbon steels are used for propeller shafts and gears. What difficulties would be encountered if cast iron or mild steel is used for these components.

4. If a quench hardened steel is held at 200 C for 10 minutes, would it be stronger or softer than when it is held at 400 C for 10 minutes.

5. What do you understand by the statement damping effects towards vibration? How does grey cast iron exhibit this property?

AIM : To introduce the type of welding. To explain the gas welding process.

OBJECTIVE : The student should learn the main type of welding processes.

After reading this lesson a student should be familiar with the oxy-acetyline welding apparatus, different flame conditions, methods of gas welding and gas welding practices.

The student should be able to make use of this knowledge in practical gas welding.

## 1.1 INTRODUCTION

Introduction to welding

: What do you understand by this term welding? Is it the same as processes like riveting and bolting? Welding is the joining of metal pieces or components by means of inter-atomic forces. The inter atomic forces causes the pieces which were separate to become one single item. This is different to riveting and bolting since the removal of the rivet or bolt causes the pieces to separate.

The art of welding dates back to the period in which hand welding (fire welding) was carried out at the forge. Have you seen at forge at the workplace of a blacksmith?

In fire welding also called smith welding the surfaces to be joined are heated to a pasty state and then hammered together. Developments in design and methods of production make use of the modern methods of welding to the full extent, so that welding now stands as an important method of production, which is closely related to other branches of workshop production.

Modern methods of welding can be classified into two main categories.

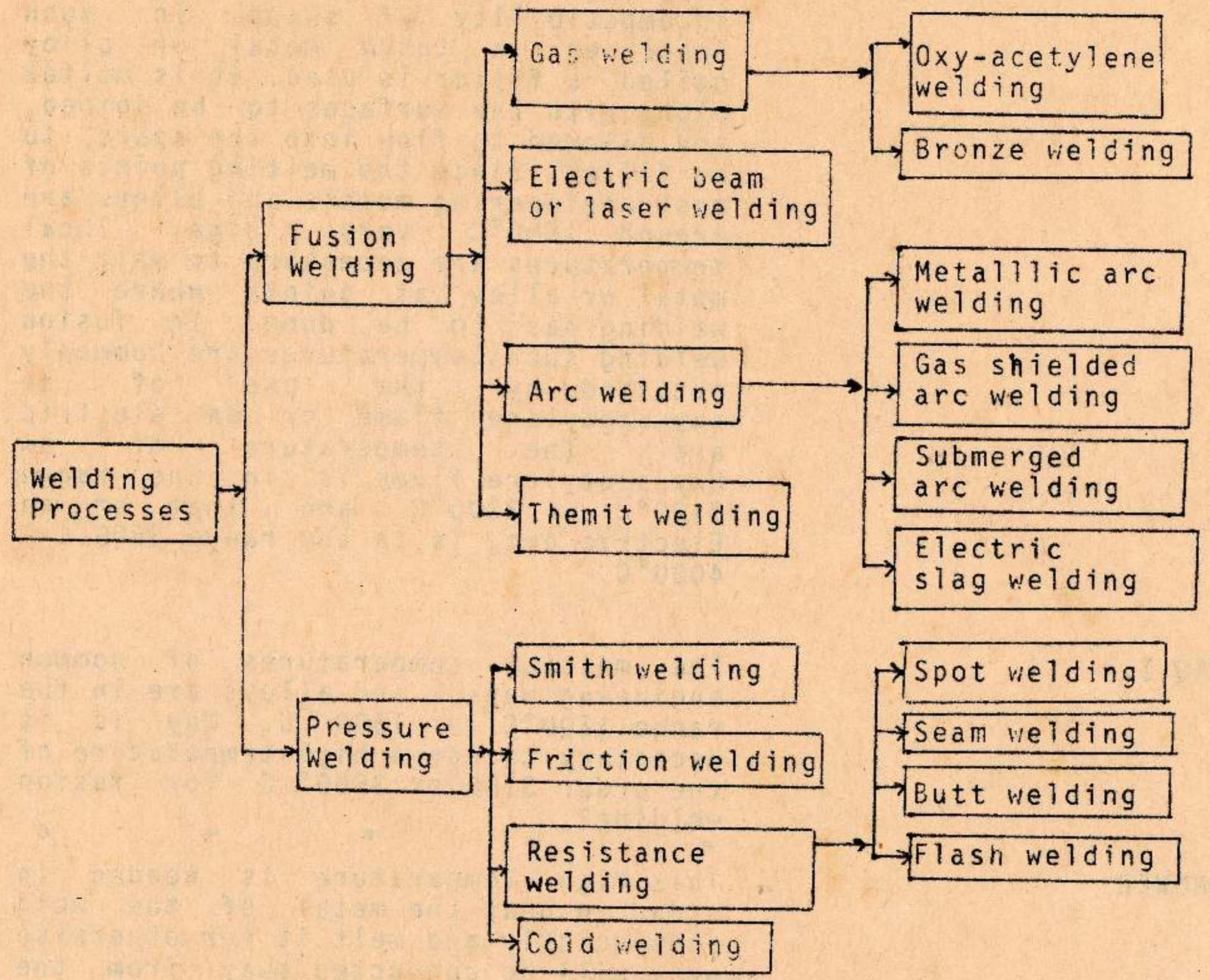
(a) Fusion welding
In fusion welding the parts to be joined are melted and fused together, often with the addition of a third metal or alloy to form the joint.

(b) Pressure welding
In pressure welding the parts are pressed together and heated to the necessary temperature to create the pasty state at which welding takes place. Fusion welding is used for depositing metals or alloys to make up for wear and to fill cracks.

In fusion welding processes the most commonly used techniques are gas welding and arc welding. In addition to these there are special welding processes used for special purposes and for special metals. They are metal arc welding, metal inert gas (MIG) welding, tungsten inert gas (TIG) welding and Submerged arc welding.

Pressure welding processes are also called solid state welding processes. They include processes such as forge welding, electric resistance welding (ERW) and friction welding. Of these processes electric resistance welding has found wide use in the form of spot and seam welding, specially in assembling processes involving sheet metal such as the fabrication of the body work of motor vehicles.

The following chart gives the full list of welding processes.



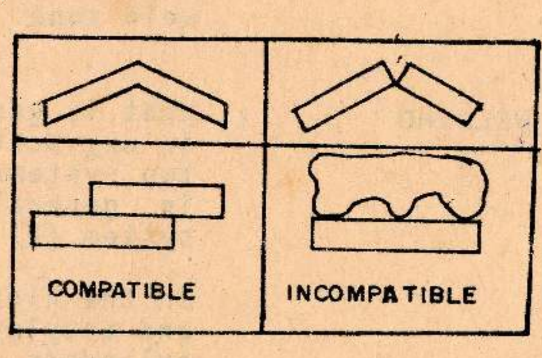




Fig. 1.1

In fusion welding the surfaces to be welded are heated until they melt and join together. But very often the surfaces to be joined cannot be brought together due to several reasons, such as due to incompatibility of shape. In such instances a third metal or alloy called a filler is used. It is melted along with the surfaces to be joined, and allowed to flow into the space to be filled. Since the melting points of most engineering metals and alloys are around 1500°C very high local temperatures are necessary to melt the metal or alloy at points where the welding has to be done. In fusion welding such temperatures are commonly obtained by the use of an oxy-acetylene flame or an electric arc. The temperature of an Oxy-acetylene flame is in the range 3100°C - 3300°C and that of an Electric arc, is in the range 3500°C - 4000°C.

SAQ 1. : The melting temperatures of common engineing metals and alloys are in the range 1200°C - 1800 °C. Why is it necessary to use a high temperature of the order 3100°or 3500° C for fusion welding?

* * * * *

ANSWER : This high temperature is needed in order to heat the metal of the weld zone quickly and melt it for otherwise heat will be conducted away from the weld zone.

## 1.2 GAS WELDING

What is generally meant by gas welding is oxy-acetylene welding. There are two systems of oxy-acetyline welding in general use, (1) high pressure system (2) low pressure system.

In the high pressure system the oxygen and actylene are supplied from steel cylinders in which they are stored under pressure. The gas is taken out by reducing the pressure as required by means of pressure reducing valves.

The gases are mixed in required proportions in the mixing chamber of the blow-pipe which is called the shank.

After mixing the mixture travels into the nozzle at the tip of the below-pipe, at which point the mixture is burnt.

In the low pressure system the acetyline is supplied from a generator at low pressure. The generator produces acetyline by the reaction of calcium carbide with water.

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

With use it is noted tnat the pressure of the acetylene decreases and when it is too low, blocks of calcium carbide and water are added into the tank, so that there is a pressure build up. The acetylene formed is purified, dried and passed into the below- pipe. The oxygen is supplied as in the high pressure system from high pressure cylinders through a reducing valve. In this system the blow-pipe is designed so that the high pressure oxygen injects and draws the low pressure acetylene, and the mixture is burnt at the tip of the blow-pipe. The low pressure system is widely used at small workshops and tinkers.

The oxygen in the cylinders is at a pressure of 12.16 MPa (120 atmospheres)

The maximum pressure allowed for the accetyline in the low pressure system is 62.06 KPa (9 $lb/in^2$) (0.6 atm) for special purposes generators which produce acetylene at a pressure of 138 KPa (20 $lb/in^2$) (1.36 atm) are available. After generation the acetylene gas can be blown by small compressors (boosted). This method gives a steady reliable supply which is useful especially for automatic welding. With this method many safety devices are necessary to prevent accidents.

SAQ 2. : Why is it that acetylene cannot be compressed to high pressures like oxygen?

* * * * *

ANSWER : In general organic compounds specially hydrocarbons tend to explode when compressed.

Since acetylene cannot be compressed, in the high pressure system, acetylene is supplied in cylinders in the form known as "dissolved acetylene". The cylinders are filled with a porous material in the form of a charcoal cement and then charged with acetone. Acetone has the property of absorbing about 25 times its own volume of acetylene for each atmosphere of pressure applied. The pressure of the acetylene supplied in this form is usually about 1.59 MPa (225 $lb/in^2$). Cylinder sizes vary from 1.41 to 7.05 $m^3$ (50 to 250 $ft^3$)

SAQ 3 : Name an important accessary to be used to control the gas flow into the blow-pipe.

* * * * *

ANSWER : The pressure regulators connected to the supply of oxygen and acetylene an important accessories to control the flow of oxygen and acetylene in the right proportion to the blow-pipe.

1.2.1 THE REDUCING VALVE OR PRESSURE REGULATOR : Figure 1.2 (a) shows the external view of a pressure regulator with the inlet and outlet end pressure gauges connected.

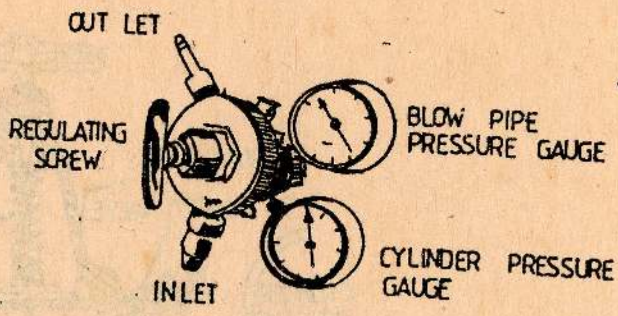



Fig. 1.2(a)

Figure 1.2 (b) shows the sectional view of an older type of the pressure regulator.

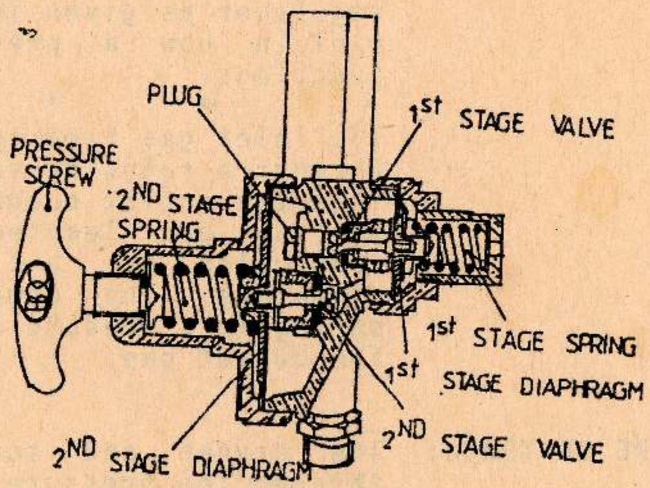



Fig 1.2 (b)

Figure 1.2 (c) shows a modern type of pressure regulator where reduction of pressure is obtained in two stages.

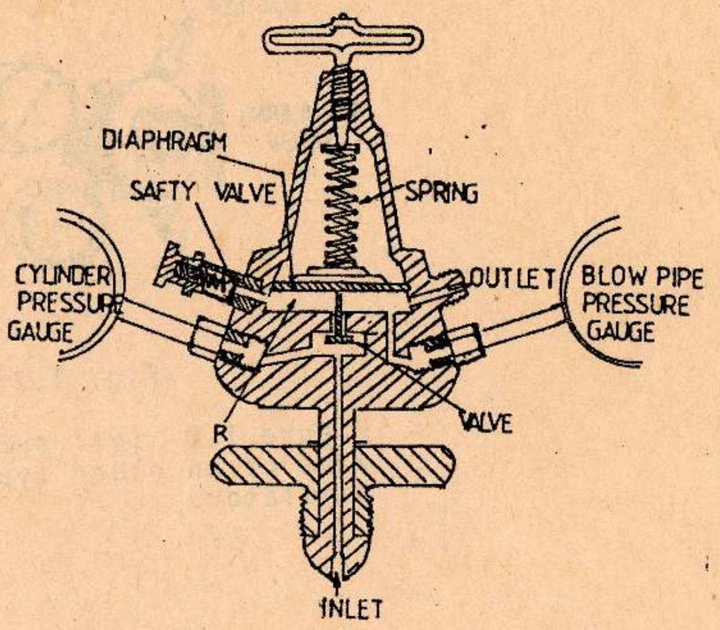



Fig 1.2 (c)

SAQ 4. : From sectional view of pressure regulator as given in figure 1.2 (b) explain how a pressure regulator functions.

* * * * *

ANSWER : The inlet gas from cylinder is taken through a reducing valve which screws into the outlet chamber. The pressure of the gas leaving the outlet is controlled by a spring loaded diaphragm. The compression on the spring is a measure of the pressure of the outlet gas.

### 1.2.2 BLOW-PIPE OR TORCH:

The oxygen and acetylene passing through the pressure regulating valves are carried to the blow-pipe by flexible tubes. The supply of gases is mainly controlled by the pressure regulating valves and minor adjustments are done at the regulating valves of the blow-pipe.

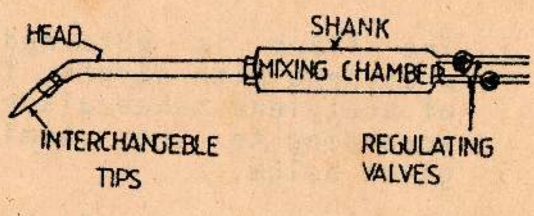
The main functions of the blow-pipe are

1. To mix oxygen with acetylene and eject one stream of mixed gases which is lit at the mouth of the blow-pipe to obtain the welding flame.

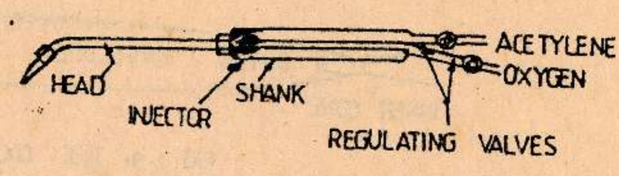
2. To regulate the quantities of oxygen and acetylene that are necessary to obtain different flames used for different welding conditions.

3. To direct the flame to the required position at the required angle.

There are two types of below pipe (1) high pressure type (2) low pressure type. Each type consists of a variety of designs used for different purposes the Figures 1.3 (a) and (b) indicate the design and structure of below-pipes used for general purposes.




(a) PRINCIPAL OF HIGH PRESSURE BLOWPIPE




(b) PRINCIPAL OF LOW PRESSURE BLOW PIPE

Fig 1.3

The high pressure blow pipe is simply a mixing device to supply a mixture of oxygen and acetylene in required proportions to the tip of the blow-pipe. The blow-pipe is fitted with regulating valves to vary the pressure of the gases as required. A set of nozzles or interchangable tips having orifices varying in size are supplied with each blow pipe. These interchangable tips together with the pressure of the gas in the shank enables the flame size to be changed as required.

SAQ 5 : Oxy-acetylene flames are sometimes used for cutting. What is the difference between the blow-pipe and the cutting torch.

* * * * * *

ANSWER : The oxy-acetylene blow-pipe is used for welding, whereas the cutting torch uses the oxy-acetylene flame to cut metal sections.

1.2.3 FLAME : The flame is obtained by burning acetylene with oxygen. The combustion of acetylene takes place in two stages according to the chemical reactions given below.

$$C_2H_2 + 2O_2 \text{ -----> } 2CO_2 + H_2 \quad \text{-----} \quad (1)$$
$$CO_2 + 2H_2 + O_2 \text{ ----> } CO_2 + 2H_2O \quad \text{----} \quad (2)$$

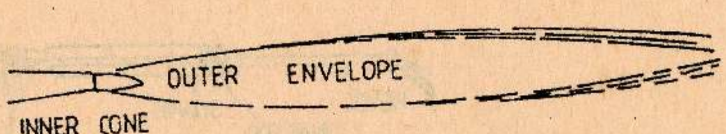



FIG 1.4 THE OXY-ACETYLENE FLAME

Reaction (1) takes place in the inner most blue luminous cone. Reaction (2) which completes combustion takes place in the outer envelope where the flame is in contact with atmospheric oxygen.

SAQ 6 : What happens to the flame if too much or too little oxygen is supplied?

* * * * *

ANSWER : There is a correct amount of oxygen that should be supplied for complete combustion of a given amount of acetylene. If too little oxygen is supplied then combustion of acetylene is incomplete and carbon is set free. The flame in this case is known as a carburising or carbonising flame. If too much oxygen is supplied, there is more oxygen than what is required for complete combustion, and hence the flame is an oxidising flame.

Welding flames:
Welding flames are of three types
(1) Neutral flame
-Figure 1.5 (a)
(2) Carburizing flame
-Figure 1.5 (b)
(3) Oxidising flame
-Figure 1.5 (c)

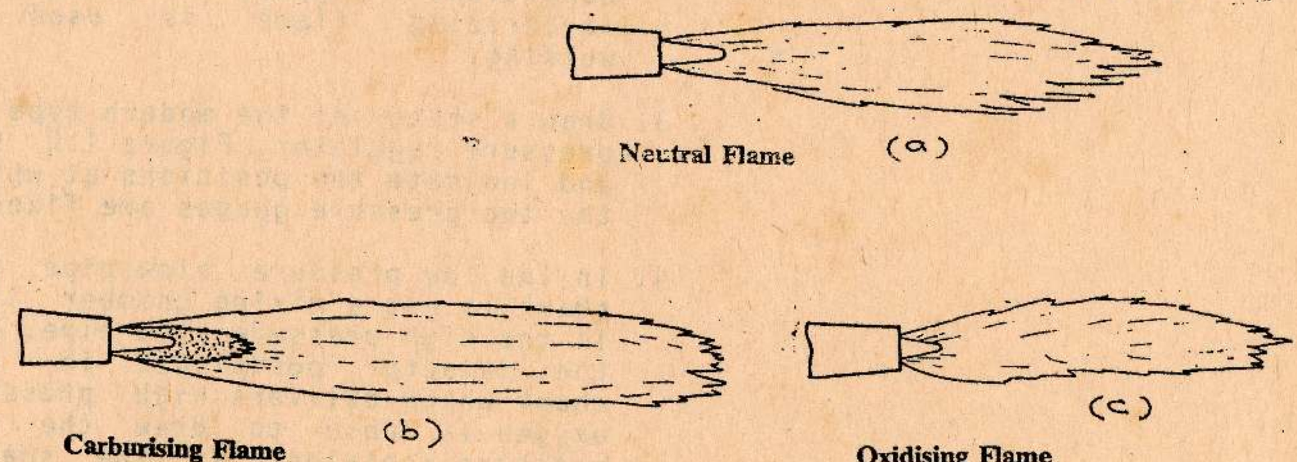



Fig. 1.5

In general, the neutral flame is used in gas welding. It is used for welding metals such as cast iron, copper, aluminium and steels. However for special work and for certain types of metal an oxidizing or a carburizing flame may be used.

- The correct adjustment of the flame is important to obtain reliable welds. An oxidising flame causes the weld to get oxidised. An oxidizing flame could be recognized by the small size of the inner blue cone. This is used for welding brass. A carburizing flame is recognised by the feathery white plumee around the inner blue cone. A carbourzing flame causes the content of carbon in the metal at the weld to be lighter than that of the parent metal. Carburizing flames are widely used in linde welding, a method used for welding pipes.

Questions:

1. In gas welding normally the welder at a small workshop uses a face guard, specially to protect the eyes. Why is this ncessary?

2. Name the advantages and the conditions under which a carburizing flame is used in welding.

3. Draw a sketch of the modern type of pressure regulator, Figure 1.2 (c) and indicate the positions at which the two pressure guages are fixed.

4. In the low pressure blow-pipe the shank is not a mixing chamber like in the high pressure blow-pipe. But the injector positioned in the shank which delivers high pressure oxygen is able to draw the low pressure acetylene in the shank. Explain how this high pressure gas is able to draw the low pressure gas.

5. If the correct proportions of acetylene and air are available and complete combustion occurs the flame temperature at the hottest point is about 3200° C. Would the temperature of a carburising or oxidising flame be higher than or lower than this value.

1.2.4 METHODS OF WELDING: We will now consider the following methods of welding.

1. Leftward (or forward) welding
2. Rightward (or backward) welding
3. Vertical & overhead welding
4. Linde welding

A description of (1) and (2) is given in your handouts on "Basic Training-Workshop Technology". They are called downhand methods since the position of the plate is horizontal below the operators hand.

Vertical Welding:

There are two methods of applying a weld to a vertical joint.
(a) Single operator method
(b) Two Operator method.

The single operator method is used for welding unprepared plates of thickness up to 3/16". This method requires more skill than the down hand method in controlling the molten metal.

Welding is performed either from the bottom upwards with the rod preceding the flame as in the leftward method or from the top downwards, in which case the molten metal is held in place by the blowpipe flame. This may be regarded as the rightward method of vertical welding since the flame precedes the rod down the seam. In the upward method the aim of the welder is to use the weld metal which has just solidified as a 'step' to hold in place the molten pool.

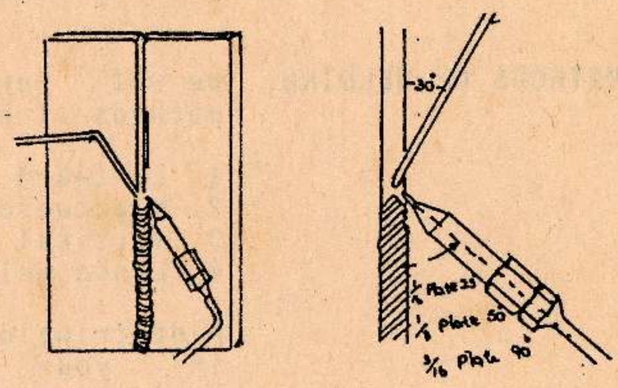



Fig. 1.6 Single operator vertical welding

When welding downwards it is important to select the correct rod type and the flame size, and also much experience is required to prevent the molten metal from falling downwards. This method is excellent in practice to obtain perfect control of the molten pool.

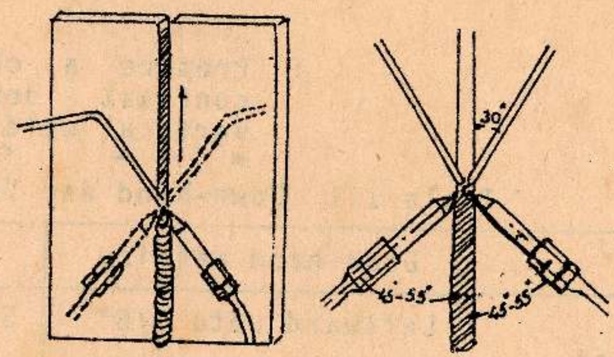



Fig. 1.7 Two operator vertical welding (for unprepared plates of thickness up to 5/8 in.)

In the two operator method the flames of the welders must be neutral in condition and equal in size. It is possible to use much smaller jets for this method so that the total gas consumption is less than that in downhand welding.

Positioning of blowpipes and rods with respect to the weld are shown in Fig. 1.7.

This method has the following advantages.

1. Plates of thickness up to 5/8 in can be welded without preparation.

2. Low consumption of gases and filler rod.

3. Low heat input as a result of reduced volume of molten metal and increased speed of flame travel which minimizes grain growth and cracking or warping due to expansion/contraction effects.

Combination of a left handed welder and a right handed welder makes the two operator method very efficient.

SAQ 7 : Prepare a chart to compare and contrast downward welding with vertical welding.

* * * * * * *

Table 1.1 Down-hand and Vertical Welding

| | Down-hand welding | Vertical welding |
|---|---|---|
| Plate thickness (without preparation) | Leftward upto 1/8"<br>Rigntward upto 5/16" | Single operator upto 3/16"<br>Two operator upto 5/8" |
| Operator skill | Less skill | Move skill (in controlling molten metal) |
| Welding metnod | Rightward or Leftward | Downward (equivalent to rightward) or upward (equivalent to leftward) |
| Operator Fatigue | Less fatigue since welding position is comfortable | High fatigue (requires lighter blow pipes and tubes and a sitting position to reduce fatigue |

For same thickness, lower gas and filler rod consumption in two operator verticle welding compared to downhand method.

Overhead Welding:

Over head welding is usually performed by holding the blowpipe at a very steep angle to the plate being welded. The molten pool is entirely controlled by the flame. Holding it almost at right angle to the plate enables the molten metal pool to be kept in position.

The most common defect in overhead welding is insufficient penetration. When more heat is supplied to obtain the required penetration, the molten metal pool becomes uncontrollable due to its high fluidity with the correct size of flame and rod, and correct practice, this difficulty can be overcome and sound welds made. Care should be taken to ensure that there are no undercuts along the edges of the weld.

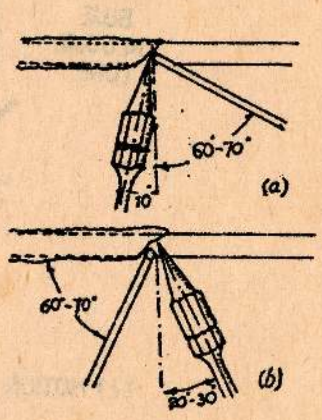
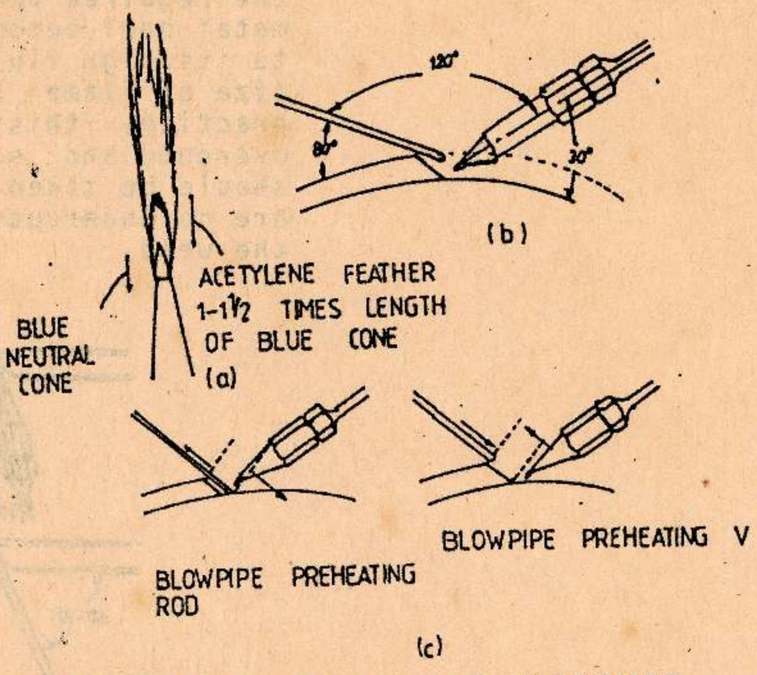



FIG 1·8

A comfortable position and a light blow-pipe and tubes are essential if the weld is to be made over a long length. Fatigue of the operator should be minimized by adequate resting.

Linde Welding:

This method of welding was devised by the Linde Co. of the United States for welding pipe lines (gas and oil). It is one of the most suitable methods of welding pipes.



(c) MOTION OF BLOWPIPE & ROD IN UNDEWELDING

Fig 1.9

Linde welding operation is based on the following facts.

1. When steel is heated in the presence of Carbon any iron oxide present may be reduced to pure iron by the reaction between carbon and iron oxide. The heated surface of the steel then readily absorbs any Carbon present.

2. The absorption of Carbon by the steel, lowers the melting point of the steel (Ex. pure iron melts at 1500°C, while 0.2% Carbon steel melts at 1300°C).

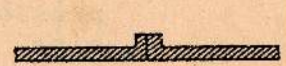
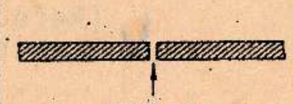
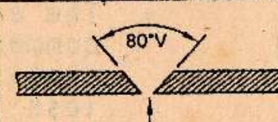
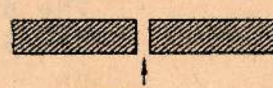
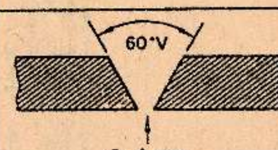
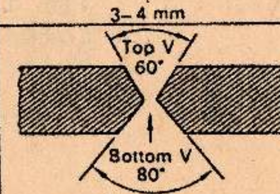
A carburising flame is used in linde welding. A part of carbon provided by the flame deoxidises any iron oxide present on the surface of the steel pipe. This make it easy for some carbon to be absorbed by the surface layers of the pipe thus lowering the melting point.
(Refer handout on Basic Training - lecture 16)

1.2.5 PRACTICE OF WELDING BUTT JOINTS : The execution of butt joints is a common part of welding practice. The plates or bars of any thickness not less than 1/32 in. can be joined by this method. There is a choice between the leftward and rightward methods. The preparation of edges (V- grooving) takes a considerable time and energy.

Edge preparation is not essential up to a certain thickness. It is 1/8" for leftward welding and 5/16" for rightward welding.

The table 1.2 gives the most suitable combination of parameters for downhand butt welds in steel.

Edge preparation, technique and speed – underhand butt welds in steel

| Thickness of metal | Diameter of welding rod | Edge preparation |
|---|---|---|
| Less than 1 mm | 1·5 mm |  |
| 1–3 mm | 1·5–3 mm |  |
| 3–5 mm | 3–4 mm |  |
| 5–8 mm | 3–4 mm |  |
| 8–15 mm | 3–6·5 mm |  |
| 15 mm and over | 6·5 mm |  |

| Technique | Speed mm/min | Thick-ness of metal |
|---|---|---|
| Leftward welding | 127–152 | 0·8 mm |
| Leftward welding | 100–127 | 1·5 mm |
| Leftward welding | 100–127 | 2·5 mm |
| Leftward welding | 90–100 | 3 mm |
| Leftward welding | 75–90 | 4 mm |
| Rightward welding | 60–75 | 4·8 mm |
| Rightward welding | 50–60 | 6·4 mm |
| Rightward welding | 35–40 | 8 mm |
| Rightward welding | 30–35 | 9·5 mm |
| Rightward welding | 22–25 | 12·5 mm |
| Rightward welding | 19–22 | 15 mm |
| Rightward welding | 15–16 | 19 mm |
| Rightward welding | 10–12 | 25 mm |

TABLE 1·2

Fillet Welding:

Sometimes construction requires joining of two plates in such a manner that a weld in the corner is the easiest way of making the joint. Such welds are called fillet welds. (See Fig. 1.10).

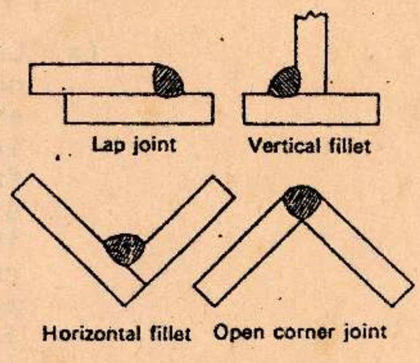



Fig 1.10

Usually the plates are first positioned and "tacked" or slightly fused together at suitable points to hold them in position. Welding is then carried out by building up the fillet with filler rod. In making welds of this type, precautions should be observed regarding fusion and penetration. The plates should not be allowed to form an under cut. Under cutting means the errosion of metal of the plate near the weld. This happens when the flame is kept too long at the same place.

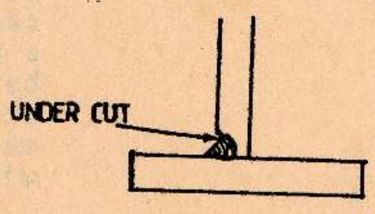





Fig 1.11

Cast-Iron Welding:

The welding of cast iron can be performed satisfactorily, but present problems which make it a more difficult undertaking than the welding of steel. Two of the main difficulties are;

(a) Cast iron never attains fluidity under the blowpipe in the same way as steel, but must be handled when in a pasty state. This makes fusion and penetration more difficult and promotes oxidation inside the weld as oxide cannot readily float to the surface of a pasty mass. For this reason a flux is necessary when welding cast iron. The welding flame also tends to burn the silicon out of the weld, allowing the carbon to assume the combined form and render the weld metal hard when cold. This is overcome by using a welding rod rich in silicon, so that the loss is compensated.

(b) Cast iron is a brittle material. The uneven expansion and contraction caused by local heating often results in cracks. This fault is often due to complicated shape of the cast component needing repair. This fault can be prevented by preheating the sections of the cast component liable to crack or the cast component as a whole, and then applying the weld in the heated state. This preheating of cast component is important and if a muffle furnace or a forge cannot be used, then a temporary structure of fire bricks shall be made around the casting and heated with gas burners or charcoal fire.

Malleable cast iron cannot be satisfactorily welded with cast iron filler rods, but may be joined with bronze rods. Bronze welding may also be applied to other cast iron and steels.

1.2.6 FLUXES USED IN OXY-ACETYLENE WELDING : Most metals in their molten condition become oxidised by the absorption of oxygen from the atmosphere. Fluxes are used to minimize the ammount of oxidation, to dissolve or float off any oxides formed and to make weld application easier. Fluxes, therefore are chemical compounds used to prevent oxidation and other unwanted chemical reactions. They help to make the welding process easier and ensure the making of good, sound weld. When welding wrought iron and mild steel the oxide which is formed has a lower melting point than the parent metal and, being light, it floats to the surface as a scale which is easily removed after welding. No flux may therefore be required when welding mild steel or wrought iron.

In the case of cast iron, oxidation is rapid at red heat and the melting point of the oxide is heigher than that of the parent metal. Therefore, it is necessary to use a flux, which will combine with the oxide and also protect the metal from oxidation during welding. The flux combines with the oxide and forms a slag which floats to the surface and prevents further oxidation. For brass and bronze welding a good flux is required (borax type flux). Aluminium and its alloys should be welded with a flux. Copper may be welded without a flux.

1.3 SUMMARY : This block of lessons explain to you the welding practice. We have started with explaining the purpose of welding and the main methods of welding. The two main methods of welding are

a) Fusion welding (eg. Gas welding and arc welding)

b) Pressure welding or solid phase welding.
(eg. Electric Resistance welding and friction welding)

Next we have introduced you to gas welding. We said that there are two main processes of gas welding. They are

(1) high pressure gas welding
(2) Low pressure gas welding

The major difference between these two processes is in the pressure of the acetylene supplied. Therefore two different welding torch systems are used to accomodate the pressure difference.

Next you have learnt about the equipment used in gas welding. They are the gas cylinders, the pressure regulators and the welding torch.

Then the oxy-acetylene flame was described to you. You have learnt about;

1) the chemical reactions involved in burning acetylene

2) What happens when supply of one of the gases is reduced or increased.

3) the types of flames obtained and

4) how to adjust the flame.

Also you have learnt about the methods of gas welding. Here you have learnt about different welding positions.

Finally you learnt about the different types of joints and fluxes used in welding.

# ELECTRIC ARC WELDING

AIM : To explain different methods of electric arc welding.

OBJECTIVES : The student should understand the principles of electric arc welding and different electric arc welding processes such as shielded metal arc welding, submerged arc welding, inert-gas-shielded arc welding.

## 2.1 INTRODUCTION : Introduction to electric arc welding.

Arc welding is a fusion process in which welding rod is cast into the space between the previously fused (melted) metal pieces to be joined of which the edges are fused along with the welding rod . The heat necessary to melt the metal and welding rod is obtained from an electric arc produced, between the rod (electrode) and the work piece. A temperature of 3500-4000°C is obtained near the crater of the arc.

In earlier arc welding processes where carbon electrodes are used where arc is produced between carbon electrode and metal edges to be welded, thus heating the metal to a fusible state. Developement of better and electrically more consistent carbon electrodes improved carbon arc welding tremendously. However, this method is almost completely replaced by newer welding processes.

Today, arc welding is done by producing an arc between the work to be welded and the tip of the welding rod (electrode). To protect the melting metal from oxidisation a flux coating is used with the electrode. Therefore it is called "shielded arc welding". This method of welding has the following advantages (i) less heat loss and (ii) less oxidation as compared to gas welding. Due to these reasons and rapid development in equipment which makes shielded arc welding suitable for a variety of purposes, practice of making welds electrically is increasing rapidly. Most of the shielded arc welding is done with metallic electrodes.

In order to produce high quality welds by an automatic mechanised process, the flux material can be used in powdered form as a heap along the welding path. Then the electric arc becomes submerged within the molten slag pool. This process is known as "submerged arc welding".

The welds produced by this method are of high quality since the contact between the atmosphere and the molten metal is eliminated.

More recently welding processes using inert gases as a shields from the atmosphere are being increasingly used. Helium and argon are the inert gases used. Following are the most widely used inert gas shielded arc welding processes.

(i) Inert gas metal arc welding with non consumable electrodes (TIG welding).

(ii) Inert gas metal arc welding with consumable electrodes (MIG welding).

2.2 ELECTRIC WELDING EQUIPMENT :

2.2.1 ELECTRIC ARC : An electric arc is an electric discharge in gases accompanied by high heat and a bright glow.

S.A.Q. 1 : Look at Fig. 2.1 and write down the components of the arc.

*   *   *   *

ANSWER : An electric arc is made of the following regions as shown by Fig.2.1: Cathode space, arc stream and the anode space. The electric arc used for welding is extremely bright, therefore it is harmful to the human eye. You must use protective shield to observe the welding process.

We must give the electrode's voltage potential. This potential depends on:

(i) The materials of the electrodes
(ii) The length of the arc
(iii) The gas in the gap
(iv) The current used for the arc.

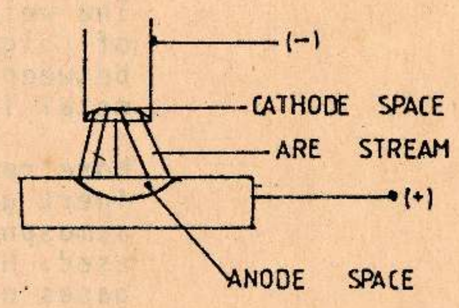



FIG 2.1

S.A.Q. 2 : What is the importance of the length of the electric arc in welding?

*   *   *   *

ANSWER : Arc length is an important variable in a welding process. It should be 3 to 4 mm. This is because the globules of the molten electrode metal, in the process of deposition, should have the smallest possible chance of coming in contact with the ambient air. And it should absorb as little oxygen from air as possible, since oxygen has an adverse effect on the mechanical properties of the weld.

2.2.2 EQUIPMENT : A station for manual arc welding should consist of:

(i) a source of current supply
(ii) flexible welding cables
(iii) An electrode holder and an eye gaurd
(iv) a clamp to attach the ground to the return cable.

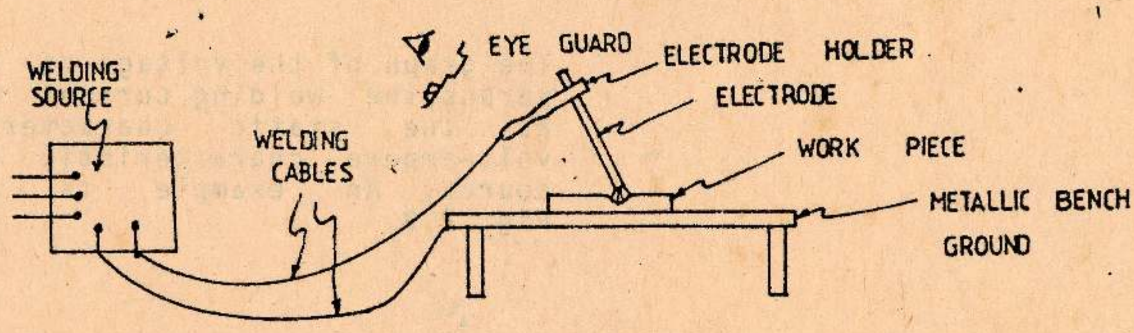



FIG 2.2 MANUAL WELDING STATION

We can get the welding current from the following sources of current supply.

(1) A d.c. generator or a rectifier (for d.c. welding)

(2) A welding transformer or a frequency changer (for a.c. welding)

S.A.Q. 3 : What are the requirements that a welding supply source should satisfy?

* * * *

voltage across the welding current source with the welding circuit open. It should be high enough to strike an arc, but not so high as to endanger the welder. For 2000 amp. transformers the no load voltage should not be over 90 volts.

(b) The power of the source should be sufficient to supply the required welding current.

(c) There should be a possibility to adjust the welding current within the desired limits.

(d) The current source should be light in weight, small in size, low in cost, and convenient in handling.

The graph of the voltage of a source versus the welding current is known as the static characteristic or volt-ampere characteristic of that source. An example is shown by Fig. 2.3.

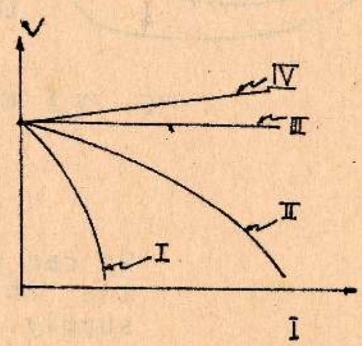



FIG 2.3 TYPE OF EXTERNAL WELDING CHARACTERISTICS

A d.c. welding generator usually has an electric motor or an internal combustion engine to drive it. Such a combination is called a "motor generator welder" or an "engine-driven welder" or a "d.c. arc-welding set". Electrically driven generators are usually used where we can install the set permanantly and a supply of current is available. Engine-driven sets are most commonly driven by a petrol or diesel engines.

Alternating current (A.C.) welding sets obtain their current from an electrical transformer. It takes in current at mains voltage (often 400 volts) and transforms it to the voltage necessary for the arc (80 - 100 volts).

S.A.Q. 4 : Compare AC and DC welding processes.

* * * * * *

ANSWER : Transformer sets are cheaper and simpler than generator sets. Since they have no moving parts, maintenence is almost nil. However, D.C. sets are superior in welding cast iron and non-ferrous metals. Also A.C. welding requires the use of covered electrodes.

The electrodes (welding rods) are made in various lengths from 8 in. to 18 in and in diameters from 1/8 in. upwards. Their composition varies according to the work for which they are required and they may be mild steel, cast iron, bronze or any other special composition to suit the work. Electrodes are coated with chemicals or fluxes. These chemicals or fluxes enable a steadier arc to be maintained and improve the quality of weld.

## 2.3 SHIELDED METAL ARC WELDING :

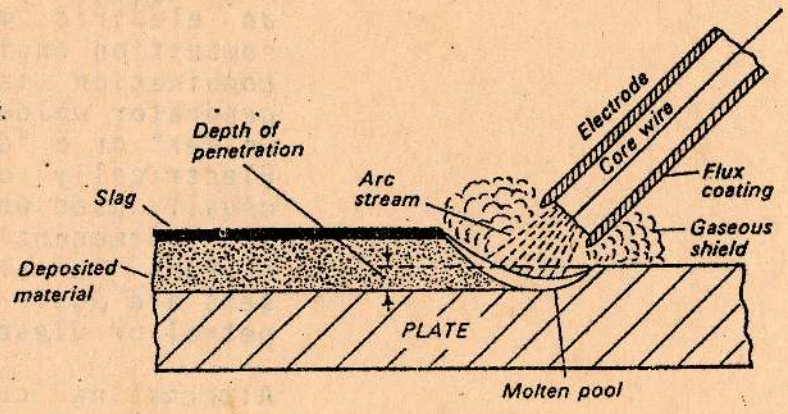



Fig. 2.4 Shielded Metal Arc Welding

Fig. 2.4 Shows the shielded metal arc welding process.

### 2.3.1 THEORY :

In the past, most electrodes were bare wire. With bare electrodes, it was difficult to control the arc and it cooled rapidly. Weld bead absorbed oxygen and nitrogen from the atmosphere, turning into oxides and nitrides, and producing a brittle, weak weld.

S.A.Q. 5 : You may have come across the welding rods, used in electric welding. Have you noted a coating on the metal wire?

What is the function of this coating?

*  *  *  *  *

ANSWER : Most modern electrodes are coated. Function of coating is to form a gaseous shield around the weld. This gas shield protects the molten metal from atmospheric contaminants.

Coating on the electrode burns as the electrode wire melts from intense heat of arc. As electrode wire melts, electrode covering, or flux, provides a gaseous shield around the arc, preventing contamination.

The force of the arc column when it strikes the work-piece, digs a crater in the base metal. This crater is filled up with molten metal. As the flux melts, part of it mixes with impurities in the molten pool and causes the impurities to float to the top of the weld. When this mixture of impurities and flux cools, slag is formed.

Slag improves the weld by protecting the bead from atmosphere and causing it to cool more uniformly; thus controlling the grain size. It also helps to control the contour of the weld bead by acting as an insulator.

Arc welding circuit consists of:

(i) Power supply
(ii) electrode cable
(iii) ground cable
(iv) ground clamp
(v) electrode holders
(vi) electrode rod as shown by fig. 2.2.

The only two items which can be adjusted are:

(i) Amperage or current setting and

(ii) Arc length between electrode tip and base metal.

Arc stream is formed when electrode is brought into contact with the work piece and then withdrawn slightly. The current will jump across this gap creating light and heat energy, which melts the electrode tip and the portion of the base metal directly under it.

The amount of current to be used depends on many variables. Some typical current values are given by the following table.

| Electrode diameter (mm) | Flat position (Amps) | Vertical and overhead position (Amps) |
|---|---|---|
| 2 | 30 - 80 | 30 - 80 |
| 3 | 80 - 135 | 80 - 120 |
| 4 | 120 - 175 | 120 - 160 |
| 4.5 | 140 - 250 | 140 - 185 |

S.A.Q. 6 : What factors do you consider in selecting the amount of current for a particular welding operation?

* * * *

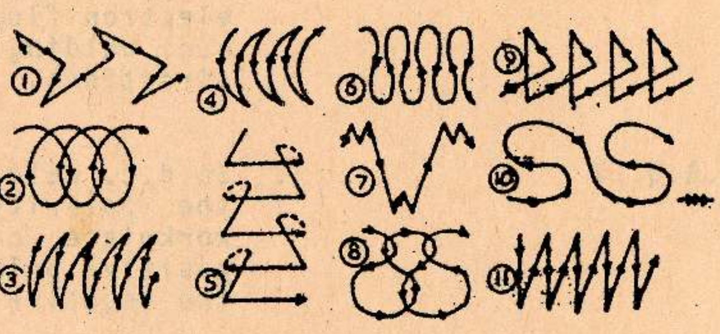
ANSWER : Some of the factors determining the amount of current are;
kind of material used,
size and shape of material,
type of joint,
position of weld,
skill of operator,
equipment available,
type of electrode,
speed required.

| | | |
|---|---|---|
| 2.3.2 PRACTICE | : | The two basic power suppliers for arc welding are the d.c. generator and the a.c. transformer.<br><br>Each of the two power supplies has distinct advantages. In d.c. welding, electron flow is in one direction; in a.c. welding, electron flow is in both directions. |
| S.A.Q. 7 | : | In d.c. welding what is the effect of the polarity ? For example the workpiece can be connected to the positive polarity and the electrode to the negative polarity or vice versa. |

* * * *

| | | |
|---|---|---|
| ANSWER | : | With d.c. welding if positive ground is used you will get the following effects ;<br>penetration will be greater due to the impact of electrons striking the work piece.<br>heat on the work surface is higher and the electrode burns away slowly.<br>If poles are reversed and if the work is negative,<br>the penetration is lesser<br>the work is more cooler and metal deposit is heavier.<br><br>A.C. welding combines the characteristics of both and provides intermediate penetration depths. Work and electrode are evenly heated in arc welding.<br><br>In depositing weld metal very often you may want to make the width of the deposit wider than that obtained by a string bead. In such cases, you must apply a weaving motion to the electrode as it advances along the line of the weld. By weaving, you can deposit more metal at a single pass. You may want a wider weld in welding a Vee groove on heavy plates, in making |

a fillet weld or in building up a pad. The weaving motion should be uniform, otherwise there is the danger of poor fusion at the edges of the deposit.



Typical Weaving Motions (Arrows show direction of advancement).

Fig. 2.5 Shows the weaving patterns that you can apply

S.A.Q. 8 : Can you describe the different welding positions and their problems in arc welding.

* * * *

The normal welding positions are

(a) flat or downhand
(b) horizontal
(c) vertical
(d) overhead

Vertical, horizontal and overhead welding require a shorter arc than flat welding. In the flat position, the normal arc voltage may range from 15 to 25 volts for 3 to 6 mm for bare or lightly coated electrodes and from 20 to 38 volts for covered electrodes.

The voltages for the other welding positions are 2 to 5 volts lesser than the above voltages.

When the welding is done in a flat position, the molten globules of filler metal drop into the molten base metal by the force of gravity. Whereas in horizontal, vertical and overhead welding, the molten globules are attracted to the molten base or weld metals into which they flow by surface tension.

Flat position is the most used for all shielded-arc welding. This position requires least skill to produce a sound weld.

Horizontal position is the second most popular position. Prefered movements are C, J and O. Major errors that happen is horiontal welding are undercutting and overlapping of weld zone.

Two types of vertical welds are uphill and downhill. Uphill weld is mostly used because electrode heat goes deaper into the metal, thus allowing deeper penetration of the weld. It is also stronger of the two. Downhill position is used for a sealing operation or for welding thin metal.

Overhead position is most hazardous. Instead of weld puddle beginning to stay, it will tend to drop from the work. By maintaining a short arc length and rapid electrode manipulation, you can over come this tendency.

2.3.3 APPLICATIONS : The preparation of the plates for welding is very similar to the method necessary for oxy-acetylene work.

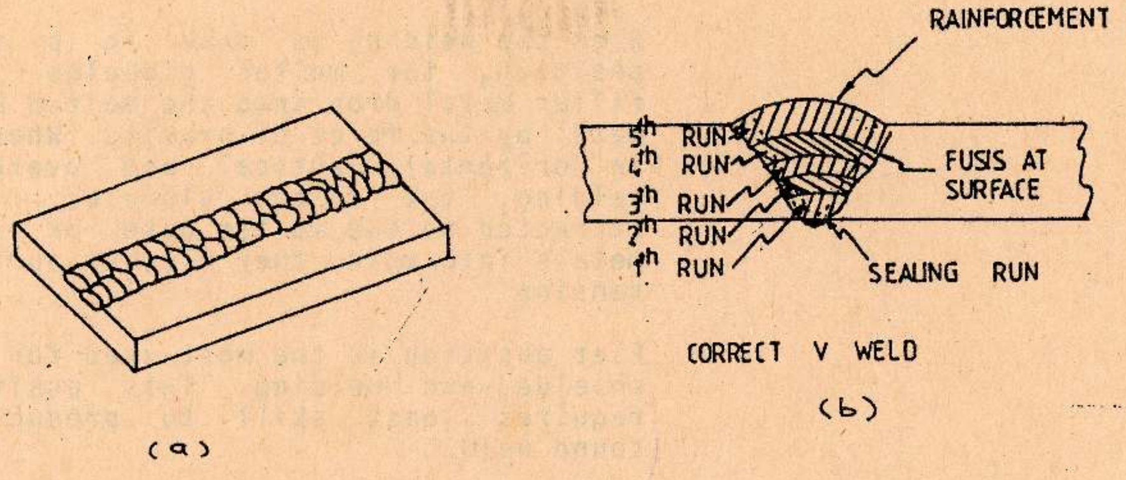



Fig 2.6

Fig. 2.6 shows beads on a flat plate and correct method of filling in a vee. The deposited bead of metal should be continuous and even, with good penetration into the parent metal. You can carry-out Fillet and lap welding with the arc method in the same way as the oxy-acetylene.

SAQ 9 : Is it possible to weld cast iron by arc-welding ?

* * * *

ANSWER : Yes.
When welding cast iron by the arc method the elctrodes used are either of a steel base with suitable alloying elements (e.g. silicon) or non ferrous such as phosphor bronze. The general method for the preparation of the weld is similar to that for oxy acetylene welding; But with arc welding no pre-heating is necessary unless the casting is very complicated in shape. This is because the heat is much

highly concentrated and localised in arc welding, a factor which often gives the arc method a great advantage over oxy-acetylene working.

2.4 SUBMERGED ARC WELDING :

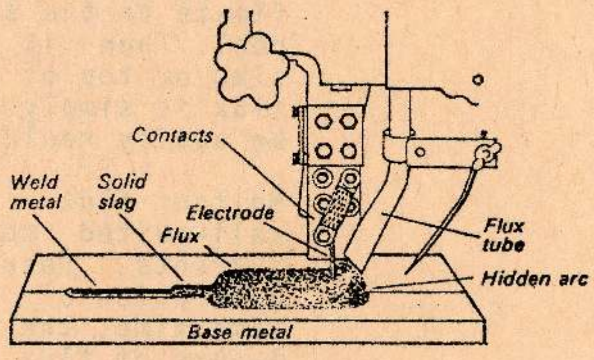



Diagram of the submerged-arc weld process

Fig 2.7

2.4.1 METHOD : Submerged arc welding process is an arc welding process where the welding area is shielded by a blanket of granular, fusible material on the work. Therefore the arc, electrode end, and the molten weld pool become submerged in a finely divided granulated powder containing appropriate deoxidizers, cleaners and any other necessary flux.

Fluxing powder is fed from a hopper, which is carried on the welding head. The tube from the hopper spreads the powder continuously in front of the electrode along the line of weld. This flux is of sufficient depth to submerge completely the arc column.

S.A.Q. 10 : What is the purpose of submerging arc by the flux ?

* * * *

ANSWER : when the arc is submerged by the flux the weld is shieled form effects of all atmospheric gases. Due to this unique protection, weld beads are exceptionally smooth.

Flux, adjacent to arc column melts and floats to the surface of the molten pool. Then it solidifies forming a slag on top of weld metal. Rest of flux is simply an insulator, which can be easily reclaimed.

Molten flux provides conditions well-suited to the use of large currents, resulting in the rapid generation of intense heat. At the same time, the molten and granulated layers of flux act as good insulators. Thus concentrating the intense heat in a relatively small welding region. This cause the base metal and the electrode to become thoroughly fused. And also it makes possible high welding speeds and deep penetration or fusion in the base metal.

Flux also acts as cleaners, absorbing impurities from the molten weld metal.

Since deep penetration is obtained by the submerged arc process, you can use narrow welding grooves. Such grooves require only small additions of filler metal.

Submerged arc process is characterized by high welding currents. Current densities range from 3200 to 11200 amp/cm. as compared to 480 to 1600 amp/cm. need in shielded arc welding. The high current density gives the deep penetration and welding speeds. Plates 15 mm thick can be square butt welded without special edge preparation. You can use currents as high as 1000 amps with 4.5 mm filler wire. You can weld base metal as thick as 40 mm in a single pass.

In submerged arc welding, distortion is minimum. Minimized distortion is a result of

high speed,
narrow weld zone concentrated heat,
and reduced number of passes.

2.4.2 PRACTICE : You can use either D.C. or A.C. supplies. Voltage across the welding zone normally ranges from about 20 to 45 volts. Currents generally used are much higher than other arc welding processes, upto 1200 amp.

You can control the welding process either mechanically or manually. The mechanical method is much widely used.

In mass production industries, the submerged arc welding is utilized in almost completely automatic setups. The function of the operator is to load and unload the work into the jig or fixture and closing the jig after loading.

Because of the nature of the process, submerged arc weld must be deposited in a downhand position. Types of welds that can be made by submerged arc weld are the butt welds, fillet welds and the plug welds.

You can make butt welds in one pass in any thickness upto 75 mm. However for better welding, thicknesses over 19 mm are done by multiple passes.

Fillet welds can be smaller than other welding methods. This is because of the greater depth of penetration obtained.

Plug welds can be made very effectively. To make plug welds the machine is stationery, with the welding rod centrally located in the

hole. The time required to complete the plug weld depends on
- the welding current used,
- the thickness of the backing member
- the size of the hole.

S.A.Q. 11 : Why is the submerged arc welding process better suited for automatic processes than manual welding processes?

* * * * * * * *

ANSWER : Submerged arc welding process requires spreading of flux powder on the welding work. In the first place this is difficult to be done by the welder, while he is engaged in the welding. Therefore certain mechanisation is required.

Submerged arc welding can be carried out at high speeds producing sound welds. Therefore maximum use of it is obtained by an automated process than manual process. Further attention required during welding is lesser, therefore manual intervention can be kept to a minimum.

* * * *

2.4.3 APPLICATIONS : Submerged arc welding can be applied to the welding of all weights of metals, from light gauges to heavy thicknesses. Welds can be made in one pass in thick sections, which might require several passes by other welding processes. It is also capable of joining low and medium carbon steel, heat resistant steel, corrosion resistant steel and many high strength steels. Also, it is adaptable to Nickel, Monel and many other non ferrous metals.

Submerged arc welding process has many industrial applications. e.g.

fabricating pipes, boiler pressure vessels, railroad tank cars, structural shapes.

S.A.Q. 12 : The equipment for the submerged arc welding can take different forms, according to the welding motion. What arc the different methods of motion that can be used?

* * * *

ANSWER : Many applications of this process have created three general types of equipment:

(a) stationery electrode with work moving
(b) electrode mounted on a moving carriage with work stationery.
(c) submerged arc mounted on a self propelled tractor with work stationery. This of course is a manual process.

Submerged arc welds, in the gas-welded condition are strong and ductile. The weld metal can be normalized and recrystallized readily.

## 2.5 INERT-GAS-SHIELDED ARC WELDING

To protect the weld from the attack of the atmospheric oxygen and nitrogen a shield of gas can also be used with the arc welding process. This technique is known as the gas-shielded arc welding. The gas used can be an inert gas or an active gas.

S.A.Q. 13 : Name some inert gases and active gases that can be used in welding?

* * * *

ANSWER : Inert - gas - shielded arc welding uses an inert gas such as Helium or argon as the gas shield. Active- gas -

shielded arc welding can use a variety of gases such as $CO_2$, $N_2$ and even steam as the shielding gas. Most widely, active gas process is known as MAG. (Metal Active Gas process). It uses $CO_2$ and is suitable for the welding of carbon and some high alloy steels. Steam is suitable for welding non critical weldments.

Argon is used as the shielding gas in the welding of easily oxidizable and active metals (aluminium, magnesium and titanium), and also high - alloy chromium and chrome - nickel steels.

Welding with the shield of carbon dioxide uses a consumable electrode. While argon shielded arc welding may use both consumable and non consumable electrodes. Non-consumable electrodes are made of either carbon or tungstan. The arc between the electrode and the work melts the parent metal and the tip of the filler rod. In welding with a consumable electrode, the welding electrode is continuously fed into the welding zone as it melts.

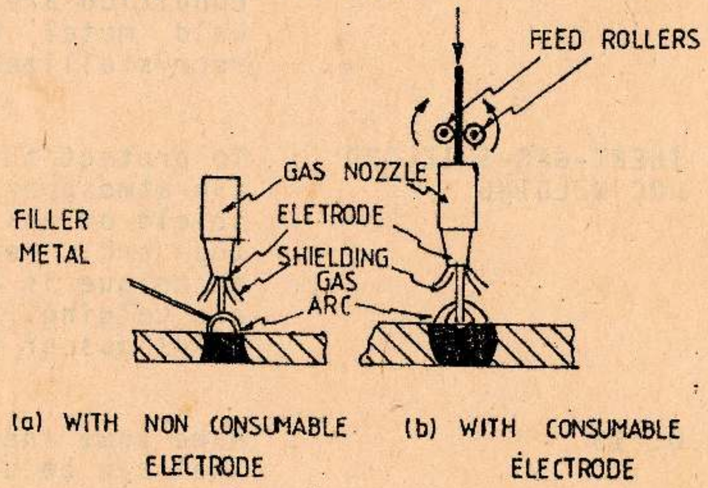



Fig. 2.8 Gas Shielded Arc welding

S.A.Q. 14 : What are the main applications for inert gas and active gas welding techniques?

* * * *

ANSWER : Inert gas welding techniques are mainly used for welding active metals like aluminium, magnesium, titanium, stainless steel.

Active gas welding techniques are used for non-active metals like carbon steels.

Following are the Inert - gas - shielded arc welding processes:

(i) Inert - gas metal - arc welding with non consumable Tungstan electrodes (TIG welding).

(ii) Inert-gas carbon - arc welding.

(iii) Inert - gas metal - arc spot welding.

(iv) Inert - gas metal - arc welding with consumable electrodes (MIG welding).

S.A.Q. 15 : What are the advantages of gas-shielded arc welding over other welding methods?

* * * *

ANSWERS : Advantages of gas - shielded arc welding over other welding methods.

(i) No fluxing required

(ii) Welding operation becomes very simpler and easily visible.

(iii) Provides sound welds in the protective atmosphere of the gas.

(iv) Can use an inert gas shield or an active gas shield.

(v) Suitable for mechanisation and automation as well for manual Welding.

Disadvantages:

(i) Needs a gas supply and the welding setup is more complicated than other.

(ii) A particular type of gas - shielded welding is suitable for a particular range of applications.

(iii) Expensiveness of gases.

* * * *

2.5.1 TIG WELDING : Tungstan Inert Gas (TIG) welding is an electric arc welding process. It makes use of ;

a non consumable tungstan thoriated tungstan electrode and
an inert gas to provide the shield for the molten metal and the electrode.

Inert gas is sent by tube directly to the weld zone, where it surrounds the tungstan. Electrode does not melt and will not form part of the weld metal. Therefore a filler metal rod has to be applied. The weld can also be the result of pure fusion of the base metal without the use of a filler metal.

The inert gas can be helium or argon. Gas is fed through a nozzel surrounding the electrode to completely envelope the electrode and the work, displacing atmospheric air from the welding area. Total shielding of the puddle from air contamination prevents the formation of oxides, nitrides and other compounds which reduce the strength of the welded joint.

S.A.Q. 16 : What are the advantages of TIG welding?

* * * *

ANSWER : Advantages of the TIG process are;

(i) Main advantage is the elimination of flux, even with rapidly oxidizing hard-to-weld materials like magnesium, aluminium etc.

(ii) TIG welds are stronger, more ductile and more corrosion resistant than welds made by shielded arc welding.

(iii) As no granular flux is required, it is possible to use a wide variety of joint designs.

(iv) There is little weld metal splatter or weld sparks, which damage base metal surface, as in shielded arc welding.

Applications of TIG process are;

TIG welding is principally used on aluminium, magnesium and stainless steel.

However fusion welds can be made in nearly all commerical metals e.g. aluminium and its alloys, stainless steel, magnesium alloys, nickel base alloys, copper base alloys, carbon steel and low - alloy steels.

TIG welding can also be used for combining dissimilar metals, hard facing, and surfacing of metals.

Hot rolled steel cannot be welded very satisfactorily with this process, either with or without filler metals.

Same is true for zinc and high - zinc alloys.

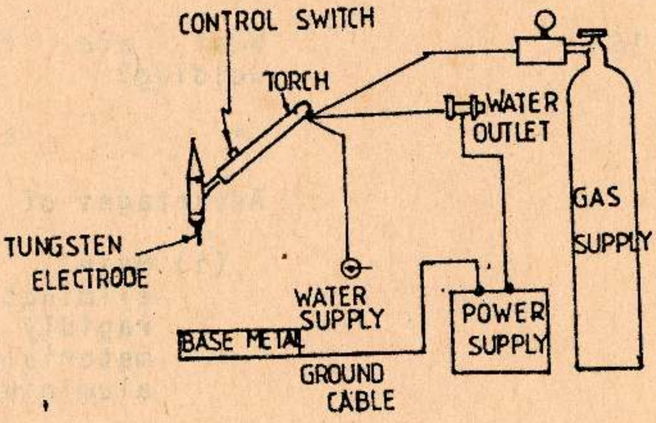



Fig. 2.9 TIG WELDING SETUP

For manual TIG welding following equipment is required (See Fig. 2.9).

(a) Holder for the electrode (TIG torch)

(b) Supply of inert gas

(c) gas regulator (flow meter) and electrical controls

(d) Welding current source (generator or transformer)

(e) Cooling water source

(f) suitable hose and cable connecting this equipment.

Basic types of equipment used;

1. Manual equipment

2. Semi Mechanized equipment

3. Mechanized equipment

4. Automatic equipment.

S.A.Q. 17 : What is the purpose of water cooling?

* * * *

ANSWER : All four types of equipment are water cooled so as to handle great quantities of heat generated by the higher currents employed for high speed, deep penetration and heavy materials. The main differences in the four types of equipment are their relative capacities and the way in which they are positioned and/or moved in relation to the work.

Some of the additional advantages of TIG welding are,

the reduction in the heat - affected area resulting from the high concentration of heat,

elimination of any necessity for preheating the metal minimising warpage and shrinkage.

One of the outstanding advantages of TIG welding is the excellent penetration produced. If the joint is backed up, the penetration will be smooth and clean and will need very little grinding or finishing.

The manual TIG process may be used in all positions. e.g. flat, horizontal, vertical and overhead.

2.5.2 MIG WELDING : Inert gas consumable electrode process (Metal Inert Gas - MIG), is a refinement of the TIG process. In this process, tungstan electrode is replaced by a consumable electrode. Electrode is driven through a collete, which holds the consumable electrode by a set of driving wheels.

This process consists of continuously feeding a bare or covered filler metal in wire form through a suitable holder. This filler metal, which serves as the electrode, carries the welding current and maintains a welding arc between the wire end and the wire.

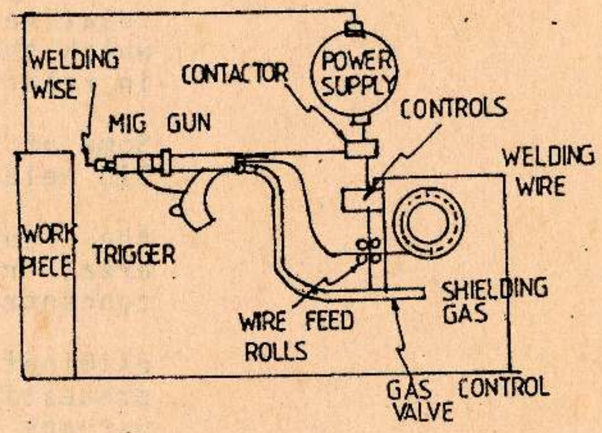



FIG 2.10 MIG WELDING SETUP

In TIG process, tungstan electrode acts as the source of arc column. In MIG process, consumable electrode acts as the source of arc column and as the supply of filler metal.

Three basic processes are employed in MIG welding process,

(i) Bare - wire electrode process

(ii) Magnetic - flux process

(iii) Flux - cored electrode process.

All three processes use shielding gases. However only process, (i) uses inert gas whereas (ii) and (iii) uses $CO_2$ as the shielding gas. Therefore

(ii) and (iii) are MAG processes.

Also the magnetic flux and flux cored processes give a slightly different weld bead. Weld bead deposited by these two processes has a slag coating as in conventional stick electrode welding. These processes need post weld cleaning.

Bare wire MIG process was principally developed for the welding of aluminium and stainless steel. But it can readily be adapted for welding many commonly welded non ferrous metals like magnesium, silicon - bronze, aluminium - bronze, copper base metals, Nickel alloys, plain carbon and low alloy steels.

Magnetic flux MAG process is used mostly for medium and high - carbon steels. In addition, magnetic flux and flux cored electrodes can also weld many of the metals, which can be done by a standard consumable electrode.

2.6.5 SUMMARY : This lesson explained to you the electric arc welding. First you have learnt how an electric arc is formed, and what factors effect the arc quality.

Then you have learnt about the equipment used in arc welding. That is the current supply source, welding cables, electrode holder, eye gaurd, electrical earth.

Next you were taught the theory, practice and applications of two of the main welding processes.

They are;

1. Shielded metal arc welding

2. Submerged arc welding

We have described
what these processes are (theory) and how these welding are carried out (practice) and
where these welding can be done (applications).

Next you were introduced to two specialised welding techniques in inert-gas-shielded arc welding.

They are,

1. Tungsten Inert Gas (TIG)

2. Metal Inert Gas (MIG)

You are given the advantages and the applications of these special arc welding techniques.

# CASTING

: INTRODUCTION TO CASTING

AIM : To introduce the casting processes.

OBJECTIVES : In this lesson, the student should get to know what is casting. He must get familiar with the casting terms. He should learn about the different casting methods.

## 1.1 INTRODUCTION

: Do you know what casting is? Casting is done with metal. Therefore it is referred to as metal casting. Metal casting is done by pouring liquid into a mould or cavity and allowing it to freeze. The frozen metal will then take the form of the mould. The finished metal part is also called as a metal casting. This is the fastest and often the most economical method that you can obtain a part of any desired shape. But don't think that it is a new technique, because the chinese have casted coins by using a mould as far back as 2000 B.C.

You can manufacture very intricate shapes by casting. And they are produced very cheaper by casting method than by other methods. Further dimensions of cast components are always nearer to the finished sizes of the product. If you take a different alternative production method like forging, it is costly and time consuming to finish it by machining. However you must remember that casting also has disadvantages. It is economical only for medium scale and large scale productions. Further strength of a cast component is not strong as a forged component. It is brittle and can break if subjected to heavy impact.

As you have learnt earlier casting is done for metal. When we speak of metals, there are mainly two types of metals. That is

(i) Ferrous metals, containing iron as the main metal. Iron, and steel foundaries belong to this group.

(ii) Non ferrous metals, containing metals other than iron.

Both these types can be casted, because of the wide difference in technology in casting, ferrous casting technology is different to non ferrous casting. Therefore we have ferrous founderies and non ferrous foundries. You will later learn what a foundry is.

The more widely casted metals are, Gray cast iron, cast steel, malleable iron, brass and bronze, aluminium and alloys, zinc-base alloys, magnesium alloys. Next section will introduce you the terms used in casting technology.

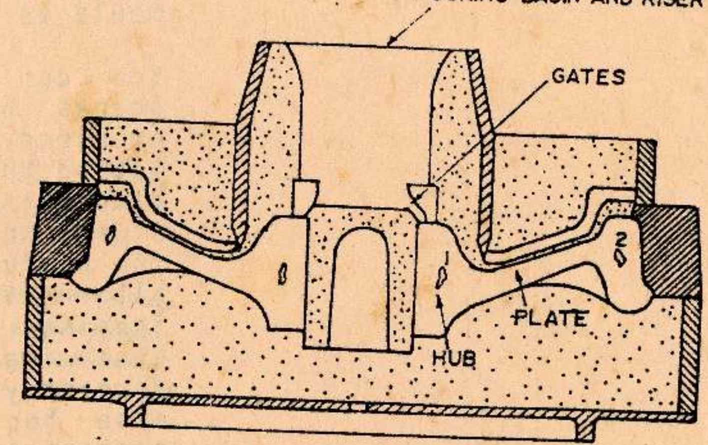



FIG 1.1 RAILROAD WAGON WHEEL

Fig. 1.1 shows you a mould to cast railroad - wagon wheel.

1.2 CASTING. TERMINOLOGY : Terms used in casting and their meanings are listed below.

| | |
|---|---|
| **Anchor.** | Appliance used to hold cores in moulds. |
| **Arbor.** | A device to reinforce or lift a mass of sand. |
| **Bedding in.** | Sinking a pattern into the sand by excavating a "bed" in which the pattern is placed for ramming up. |
| **Binders.** | Materials used to hold moulding sand together. |
| **Blow hole.** | Hole in the casting caused by trapped air or gases. |
| **Bottom board** | The board that the mould rests upon. |
| **Casting.** | The metal shape, exclusive of gates and risers, that is obtained as a result of pouring metal into a mould. |
| **Chaplet.** | A metal support used to hold a core in place in a mould. Not used when a core print will serve. |
| **Cheek.** | The portion of a flask placed between the cope and drag when a mould has more than two sections. |
| **Chill.** | A metal object placed in the wall of a mould, causing the metal to solidify more rapidly at such a point. |
| **Close over.** | The operation of lowering a part of the mould over some projecting portion such as a core. |

| | |
|---|---|
| Cold shut. | The imperfect junction where two streams of metal meet but do not fuse. |
| Contraction | Decrease in size due to cooling of the metal after it is poured. Shrinkage is the term applied to the decrease in volume of metal from liquid to solid stage. Contraction immediately follows it. |
| Cope. | The upper or topmost section of a flask. |
| Core. | A separate part of the mould, made of sand and generally baked, which is used to create opening and various shaped cavities in the casting. |
| Core box. | A mould in which a core is formed. |
| Core dryer. | A metal form in which the core is baked. |
| Core rod | Irons or bars imbedded in a core to strengthen it. |
| Crushing. | The pushing out of shape of core or mould when two parts of the mould do not fit properly. |
| Dowel. | A pin used between the sections of parted patterns or core boxes to locate and hold them in position. |
| Draft. | Slight taper given to pattern to allow drawing from the sand. |
| Drag. | The bottom part of a flask or mould. |

| | |
|---|---|
| Drawback. | A part of the mould made of green sand, which may be drawn back to clear overhanging portions of the pattern. It is rammed up on a plate or arbor so that it can be lifted away. |
| Drawing. | Removing the pattern form the sand. |
| Drop or drop out. | The falling away of a body of sand when the mould is jarred or lifted. |
| Feeding | Supplying additional molten metal to a casting to make up for volume shrinkage during solidification. |
| Flask. | A metal or wood frame, without fixed top or bottom, in which the mould is formed. |
| Flask pins | Pins to fit corresponding sockets on the joint of a flask to permit separation. |
| Feed head | A reservoir of molten metal from which the casting is fed as it solidifies. Also called a riser. |
| Fin | A thin projection on a casting due to an imperfect joint in the mould. |
| Fillat. | A concave corner piece used at the intersection of two surfaces to round out a sharp corner. |
| Follow board | A board shaped to the parting line of the mould. |

| | |
|---|---|
| **Gate** | A channel through which the molten metal enters the casting cavity. |
| **Gaggers** | Metal supports shaped like the letter "L" that are used to reinforce the sand in the mould. |
| **Green sand** | Moulding sand tempered with water to proper consistency for foundry use. |
| **Green-sand core.** | A core that is made of moulding sand but not baked. |
| **Head** | The pressure exerted by a column of fluid, such as molten metal, water, etc. |
| **Hot spots** | Areas of extra mass usually found at the junction of sections. |
| **Hot tears.** | Cracks in metal castings formed at elevated temperatures by contraction stresses. |
| **Jarring machine** | A moulding machine that packs the sand by jarring. |
| **Jig.** | A device arranged to expedite a hand or machine operation. |
| **Loam mould** | A mould built up of brick, covered with a loam mud, and then baked before being poured. |
| **Loose piece** | Part of a pattern that remains in the mould and is taken out after the body of the pattern is removed. |

| | |
|---|---|
| **Machine finish** | Allowance of stock on the surface of the pattern to permit machining of the casting to the required dimensions. |
| **Master pattern.** | An original pattern made to produce castings which are then used as metal patterns. |
| **Match plate** | A plate to which the pattern is attached at parting line. |
| **Mould** | A body of moulding sand or other heat-resisting material containing a cavity which forms a casting when filled with molten metal. |
| **Moulding sand** | A sand which binds strongly without losing its permeability to air or gases. |
| **Nowel** | The lower section of the flask; commonly called the drag. |
| **Overhang.** | The extension on the vertical surface of a core print, providing clearance for closing the mould over the core, also known as "shingle." |
| **Parting** | Joint where mould separates to permit removal of pattern. |
| **Parting Sand** | A bondless sand dusted on the parting to prevent the parts of the mould from adhering to each other. |
| **Pouring.** | Filling the mould with molten metal. |

| | |
|---|---|
| **Ramming up** | The process of packing the sand in the mould or core box with a rod or rammer. |
| **Rapping** | Loosening the pattern from the mould by jarring knocking. |
| **Rechucking** | Reversing a pattern upon a face plate to permit turning composite face to the required shape. |
| **Riser** | A riser is a passage of sand made in the cope during ramming the cope. |
| **Rolling over** | Operation of turning flask over to reverse its position. |
| **Runner** | The channel through which the molten metal is carried from the sprue to the gate. |
| **Shrinkage** | The decrease in volume when molten metal solidifies. |
| **Shrink hole** | A cavity in a casting due to insufficient feed metal. |
| **Sizing** | A primary coating of glue applied to the end grain of wood to seal the pores. |
| **Skeleton pattern** | A framework representing both the exterior and interior shape of the casting. |
| **Slab core** | A plain flat core. |
| **Snap flask** | A flask that has hinges and latches so that it may be removed from the mould prior to the pouring. |

| | |
|---|---|
| Soldiers | Wooden pegs used to reinforce a body of sand. |
| Split pattern | A pattern that is parted for convenience in moulding. |
| Strike or strickle | A template or straight edge used for removing excess sand from a mould or core box. |
| Sprue | The opening into which the metal is first poured. |
| Stock cores | Standard cores of common diameters which are kept "in stock" for general use. |
| Stopping off | Closing off a part of the mould that is not wanted. |
| Stripping plate | A plate, formed to the contour of the pattern, which holds the sand in place while the pattern is drawn through the plate. |
| Sweep or skree | A board shaped to a required profile. It is used to remove excess material from a mould or core. |
| Sweep work | Forming moulds or core by the use of jigs or templates instead of patterns. |
| Tacking | Pressing the sand in place with the hands. |
| Vent | Small opening in mould to facilitate escape of air and gases. |
| Vibrator | A mechanical device used to loosen pattern from mould. |

## 1.3 METHODS OF METAL CASTING :

SAQ 1 : Can you write down the procedure followed, when making a casting?

* * * * * *

ANSWER : The procedure followed in casting can be mainly divided to four general parts.

1. The design and making the pattern.
2. Production of the mould.
3. Melting, refining and pouring of the liquid metal.
4. Shaking out, cleaning and snagging castings.

The method of casting will be different mainly due to the first part. That is design and the production of the mould. In the following, the main methods of casting is introduced to you. More details will be given in the next lessons. There are other casting methods that are not given here. They are used for special castings.

### 1.3.1 GREEN SAND AND DRY SAND CASTING :

This is the most common and cheapest casting. The name green sand has nothing to do with the actual colour of the casting sand. Also the name dry sand is also not true in its sense. Because water has to be added to the sand, otherwise sand will not bind together to form the mould.

In this method of casting the mould is formed using a suitable casting sand. A wood or metal pattern is used to make the impression cavity in the sand. After forming the impression the pattern is removed. The mould is done inside wooden or metal boxes, called as flasks. Use of flasks enable the pattern to be withdrawn. For very large castings, the mould is formed on the foundry floor, without using flasks.

After making the mould, the molten metal is poured into the cavity. Then it is left to cool for sometime. Once cooled the casting is taken out by breaking the mould.

Therefore sand cast moulds can be used only once, because they have to be broken each time. Since for each casting a new mould is to be made, it is a littel time consuming.

Sand casted parts have the least accuracy in dimensions, when comparing to other casting methods. However, this is widely used for iron and steel castings, because the temperature of molten iron and steel is around 1500°C to 1700°C. and no other cheap material can withstand that temperature. Further sand casting is the cheapest and easiest. Brass and bronze is also mainly sand cast.

1.32 DIE CASTING : Die casting uses a permanent mould made out of a metalic mould. Therefore it is mainly suitable for low melting point metals like lead, zinc, alluminium and their alloys.

Die casting is the fastest in casting processes, since the mould need not be made each time, and it is required only to pour the metal into the mould. However initial cost is high, to make the permanent mould.

There are two types of die castings.

(i) **Gravity die casting: Where molten** metal is allowed to run into the cavity freely.

(ii) Pressure die casting: where molten metal is fed under pressure to the mould.

The pressure die casting gives the highest dimensional accuracy. The second accuracy is given by the method known as investment casting, the third accuracy is obtained by gravity die casting.

Further the product of pressure die casting has more uniform structure and is stronger.

### 1.3.3 INVESTMENT LOST-WAX CASTING

The term "investment" refers to the layer of refractory material with which the pattern is covered to form the mould. The shell moulding process, that is described in the following is also an investment casting. Investment casting has one thing common with sand casting. That is each time a casting is made, the mould is destroyed. However investment casting gives more precision in the product than sand casting.

In the investment lost-wax casting method, the refractory material is made to a mould by using wax. We call it lost-wax because, once the mould is made the wax is melted off. The casting is done in three stages.

1. Making the wax pattern.
2. Investing the pattern to make the mould.
3. Pouring and stripping the casting.

In the first stage a split master die is used to make the wax pattern.

The investment material used is fine silica sand with a binding material to make a slurry. In the second stage this slurry is coated on to the wax pattern to a thickness of about 1/32 inches to form a precoating. Once this precoating is dry the main investment is poured over the wax, completely submerging it. Then the flask is put in a drying oven and dried up for about 48 hours at low temperature. Then it is heated more to completely melt the wax inside. Finally the molten metal is poured into the cavity and let cool. The mould has to be broken to take out the casting.

1.3.4 SHELL MOULDING : Shell moulding is also an investment casting process. However in this method instead of wax, a permanent metal pattern is used. The investment material is sand with a binder. The metal pattern is heated to a suitable temperatute. Then it is coated with a shell of sand containing a plastic binder. The pattern and shell are then heated sufficiently to cure the shell into a rigid state. Once it is dry the pattern is parted and the shell is removed from the pattern. Then the two halves of the shell are clamped together and molten metal poured into it. Once the casting is cool, it is removed by breaking the shell mould.

Shell moulding has an accuracy better than sand casting. But less than other better casting methods.

Investment casting serves as an alternative to sand moulding to produce better accuracy with steel castings. Also it is used for brass and bronze. Investment casting is the only casting process for jewellery and dental industry, and for metals that is hard to be machined. Therefore it is also known as "precision investment casting".

1.4 SUMMARY : In this lesson you were given an introduction to casting.

Casting is the technology of obtaining a product with a desired shape by pouring molten metal into a mould.

You were given a complete list of words that is used in the casting technology. Now you can easily find the meaning of any word in the following lessons.

Next, four methods of metal casting were generally introduced to you. They are,

1. Green sand and dry sand casting
2. Die casting
3. Investment lost-wax casting
4. Shell moulding.

Pattern making and Core making

**AIM** : 1. To explain the technique of pattern making

2. To explain the technique of core making

**2.1 INTRODUCTION** : You are realising now that casting can be divided to a series of five separate processes. They are;

1. Designing
2. Drafting
3. Pattern making
4. Foundry practice
5. Machine shop practice

These processes are closely related and dependent on each other. Therefore one process will not function efficiently without the others.

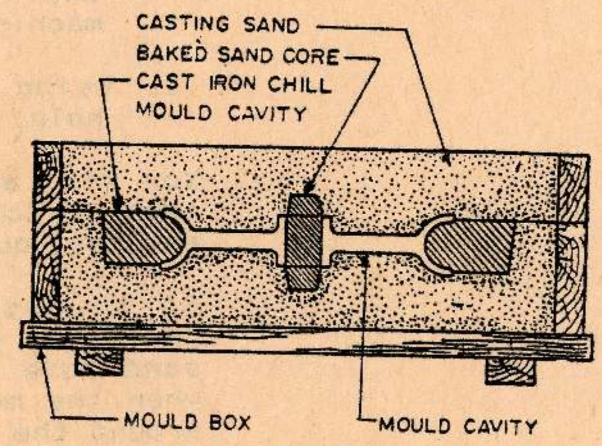



FIG 2·1

Designing and drafting happen in the design office and we will discuss the main qualities for a good pattern and core design.

To introduce to you the difference between the pattern and core, we will make use of the Fig. 2.1
In fig. 2.1 you will note five things.

a) Mould cavity
b) Baked sand core
c) Cast iron chill
d) Casting sand
e) Mould box

Mould cavity is the hollow space formed within the core sand. You will note that this hollow space has some shape. While casting,the metal will flow into this cavity and get formed to a casting of this shape. Therefore this is the shape of the object we want. And to make the hollow space to this shape, we should have a 'pattern' of the same shape. The pattern is imbedded in the casting sand to form the impression. Then the pattern is taken out of the sand leaving the hollow shape.

Now lets say, that in the casting you require some holes. To get these holes you can do two things.

1. Make the casting as a solid body and later make these holes by machining.

2. Using a sand core to make the hole, during the casting itself.

You will agree when there are lot of casting to be done, method 2 is the easiest, quickest and cheapest.

So to get a hole or other hollow cavity in a casting we place a baked sand core in the mould cavity. So when the metal is poured it will run around the core. Once the casting is finished the sand core is broken, leaving the hole we require.

In this lesson you will learn about these two things, pattern making and core making. You will learn how to design them and what material is used to make them.

We will not explain in this lesson about the cast iron chills. It will be explained in another lesson.

2.2 PATTERN MAKING : Pattern making is the process of making forms or models of desired castings. These are called patterns. They are used for forming moulds or impressions in damp sand or in some other suitable material. These moulds, when filled with molten metal, form the same shape of the patterns and are called castings.

2.2.1 PATTERN DESIGN : The fundamental requirement of patterns is that they be used for the best advantage by the moulds.

In order for you to understand the principles of good pattern design, it is necessary to have a knowledge of the fundamental operations of moulding.

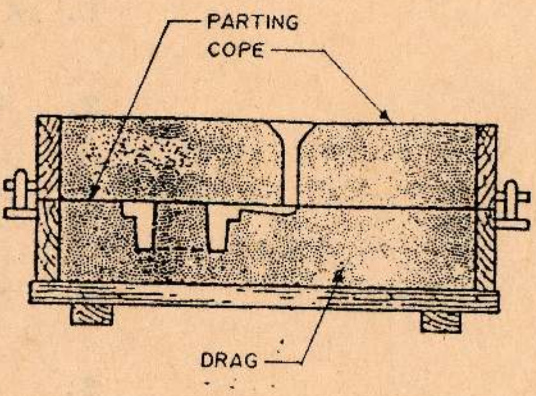



FIG 2.2(a)

Fig. 2.2 (a) shows a finished mould ready for pouring a casting.

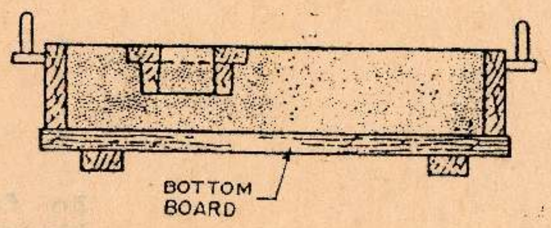



FIG 2-2(b)

Fig. 2.2 (b) shows the preparation of the bottom part of the mould. The bottom part is called the drag, and the top part is called cope.
In the making of the mould, the

pattern is placed on a mould board and the drag part of the flask is placed over it. Fine moulding sand is then rammed over the pattern. The remainder of the flask is filled with sand and rammed. Then a bottom board is placed on the top and the entire thing is turned around. After removing the mould board, the pattern is extracted from the cavity.

The pattern should be constructed, so that good castings are obtained at a minimum cost. To start with the shape, finished sizes and other details of the casting are obtained from a drawing. You have to consider the following factors in designing the pattern.

1. Kind of metal used for the casting.

2. Number of castings wanted from the pattern.

3. Possibility for repeat orders for castings.

4. Method of moulding - bench, floor or machine moulding.

5. Allowances to be made for draft, shrinkage, finish and machining provisions.

6. Warpage of casting or cooling effects.

7. Type of pattern to be made.

8. Use of standard or special cores.

9. Material to be used for pattern.

In fig. 2.2 (a) you will see that there is a parting line separating the cope and the drag of the mould. This parting line is the main design selection of a casting. And this line will determine how the pattern is to parted or divided.

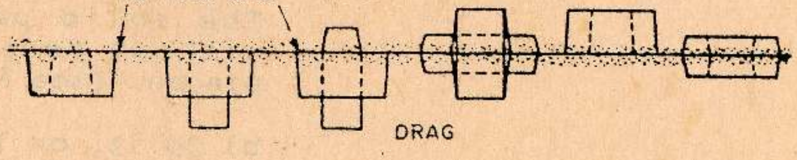



FIG 2-3

Fig. 2.3 shows you that, parting line can be selected at different levels for the same casting. The proper location for the parting line will depend upon the size and shape of the pattern, and no definite rule can be given.

Starting from the parting line the pattern should have a draft in either direction. You can refer your casting terminology to see what a draft is.

**SAQ 1** : If you do not need a draft in the finished casting what should you do ?

* * * *

**ANSWER** : Obviously, you have to machine this draft, after the casting is done. So you have to keep allowance for machining in your pattern.

Depending on how you select the parting line and other changes to facilitate the making of the mould, you can have several types of patterns. You can refer to fig. 2.4a for better understanding about the types. These types are pattern design that solve certain moulding problems resulting form the external or internal shape of the casting.

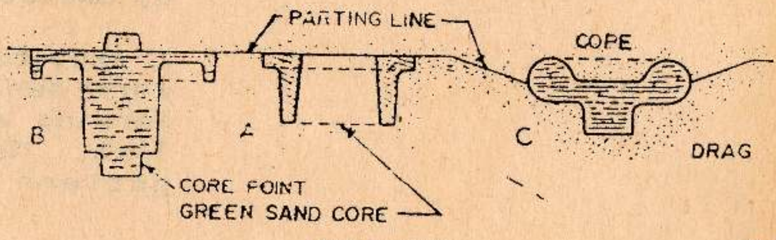



FIG 2-4 (a)

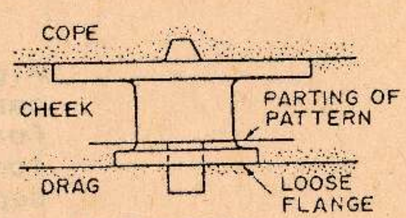
## Types of Patterns

a) Solid or one piece, pattern:

The solid pattern can be moulded without partings, joints or loose pieces. (see Fig. 2.4 a)

b) Split, or Two-piece, pattern:

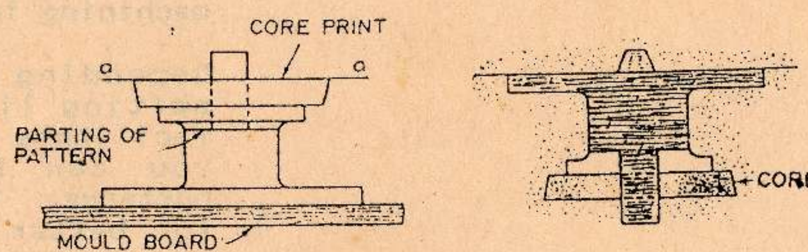
This is made in two sections and parted to mould one half in the drag and the other half in the cope. (see Fig. 2.4 b)




SPLIT PATTERN
FIG 2·4(b)

c) Three-part pattern:

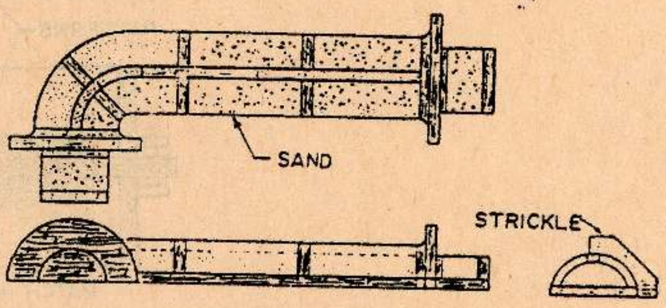
Actually a three-part pattern consists of two parts. But the shape is such that it cannot be drawn or made in a flask having one parting. It must be moulded in a flask having three or more sections. The parting line of the pattern may not correspond to a parting line of the flask, as shown in the fig. 2.4 c.




THREE PIECE PATTERN
FIG 2·4(c)

d) Skeleton patterns:

A skeleton pattern is a wooden frame work designed to aid the moulds in forming a part of pattern in sand or loam. This type of pattern reduce the pattern cost and is suitable for needing one or two castings. The complete pattern is formed by filling the skeleton with sand. Then it is used as a normal pattern to mould.

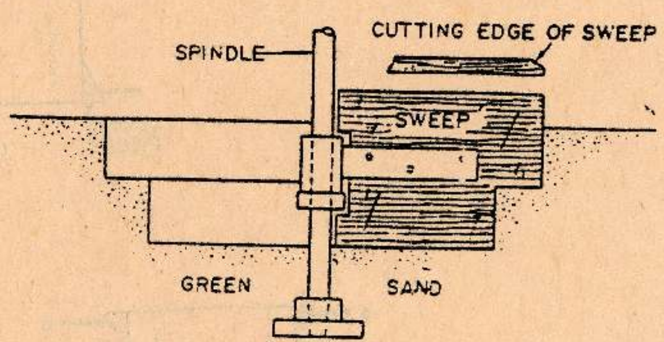



SKELETON PATTERN

FIG 2·4 (d)

e) Sweep patterns:

Sweep work is a method of forming moulds, usually of a circular shape, by means of a sweep attached to an arm. The arm may be pivoted or revolved around a spindle. The edges of the sweep have the desired contour.

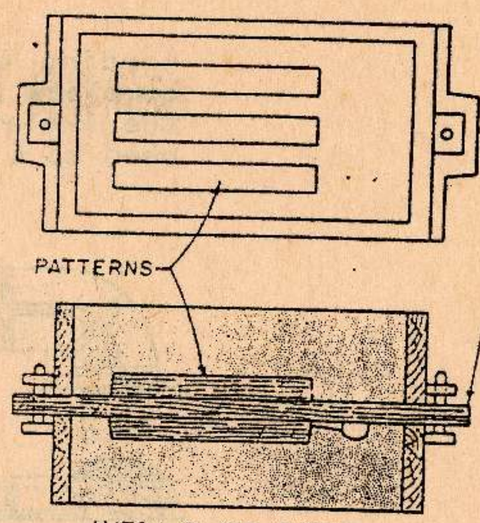



SWEEP PATTERNS

FIG 2·4 (e)

f) Match-plate:

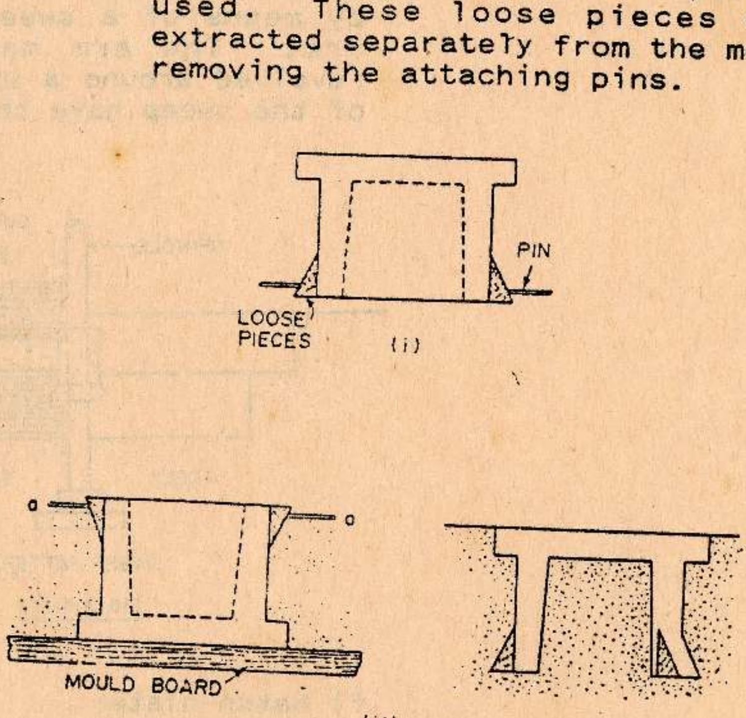
For speedy moulding work by manually or machine operations. Patterns are mounted on plates.




MATCH -PLATE PATTERN
FIG 2-4 (f)

g) Patterns with loose pieces:

For shapes that have projections which make the withdrawal of the pattern not possible, loose pieces are used. These loose pieces can be extracted separately from the mould by removing the attaching pins.




PATTERN WITH LOOSE PIECES
FIG 2·4 (g)

2.2.2 PATTERN ALLOWANCES: The following are the more common allowances used in patterns. These allowances have to be added to the required dimension of the final product. These allowances will get removed in various operations during and after casting, so that the final product will have the required dimensions. The following are the common pattern allowances.

1) Shrinkage allowance
2) Pattern draft allowance
3) Finish allowance
4) Machining provisions
5) Allowance to overcome warp
6) Allowance for rapping

These are explained below.

(1) Shrinkage allowance

When a molten metal solidifies, its volume shrinkes. Therefore the pattern should have extra allowance to compensate this shrinking. We call this allowance as shrinkage. The amount of shrinkage varies;

a) With different metals
b) With a change of composition of same metal
c) Under varying moulding conditions
d) With the shape and size of the casting.
e) The shrinkage of the diameter is restricted by the cores and internal parts of the mould.

Shrinkage allowances for some of the more common metals are as follows:

| | |
|---|---|
| Cast iron | 1/8 in. per ft. |
| Brass | 3/16 in. per ft. |
| Aluminium | 3/16 in. per ft. |
| Steel | 1/4 in. per ft. |

There is a special measuring rule used for the construction of the pattern. This is called the "Shrinkage rule".

The scale of the shrinkage allowances are divided to agree the shrinkage allowance of the metal. Therefore each type of metal will have a different shrinkage rule. These shrinkage rules must be used for both patterns and core boxes.

(2) Pattern Draft allowance

Draft is the term applied to the taper on all vertical surfaces of a pattern. The draft enables you to remove the pattern from the sand without excessive rapping and without any damage to the mould. The surface from where the draft starts is called the 'face' of the pattern. Fig. 2.5 shows you the purpose of the draft. There is no draft in A but there is a draft in B. The usual allowance for draft is 1/8 in per ft. However according to requirement it can vary from 1/4 in. to 3/8 in. per ft. Draft is kept on the dimensions on the drawing. Later on, it is removed by machining, if unnecessary.

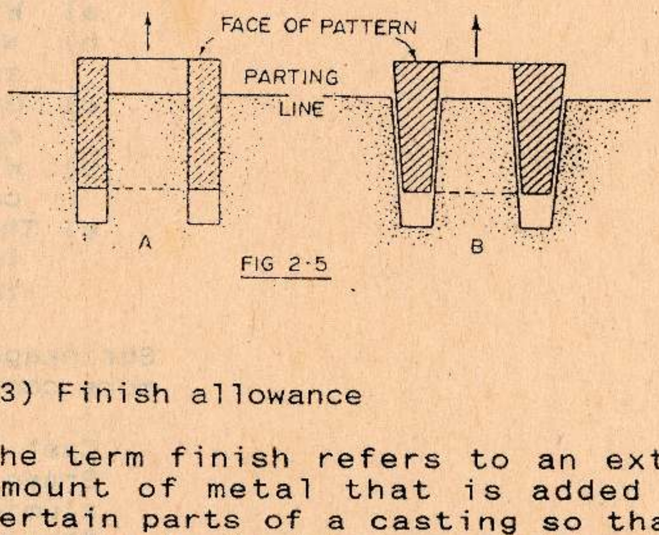


FIG 2·5

(3) Finish allowance

The term finish refers to an extra amount of metal that is added to certain parts of a casting so that, they can be finished or machined to the proper size. This finish allowance depends on;

a) Size of the casting
b) The method used in machining it
c) The kind of metal used
d) The degree of finish required.

In ferrous casting, a hard crust or hard scale get formed on the surface. This is due to the chilling effect when hot molten metal touches the cold sand. This hard scale has to be removed by machining. In non ferrous casting, this scale is not formed. Therefore finish allowance for non-ferrous castings is less than for ferrous. For ferrous casting usual finish allowance small and medium is 1/8 in, for large ferrous castings you have to keep 1/4 to 3/4 in. For non-ferrous castings such as brass and aluminium keep 1/32 to 1/8 in.

(3) Machining Provisions

Certain types of castings are more easy to handle when machining if extra bosses or lugs are casted to them. Such extra machining provisions will save hours or machining time and also will prevent distortion while machining. Their locations, will depend on the requirements of the machine shop.

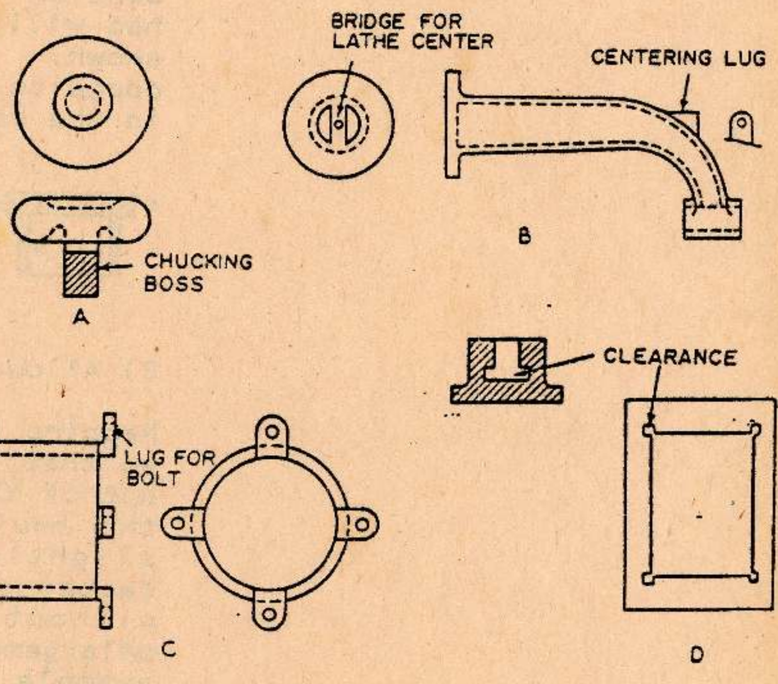



FIG 2-6

Figure 2.6 shows you some of the machining provisions. They are explained below.

A - A chucking boss is cast on to the piece. Otherwise it is difficult to hold the piece on the lathe chuck.

B - A bridge or a centering lug is added.

C - Piston rings are casted with additional lugs provided for bolting to a face plate.

D - Recess is kept in the casting as a clearance for the tool.

4) Allowance to overcome warp

Some castings tend to become distorted or warped when cooling. This is due to uneven metal thickness or to one surface being more exposed than another, and therefore cooling more rapidly. To overcome this equal and opposite warp or camber has to be kept in the pattern. For example look at fig. 2.7, the casting of a lathe bed. Since section "b" is thinner than section "a" when cooling the machine bed will warp in a concave manner as shown. To counter this an equal and opposite convex bend or camber is kept in the pattern.

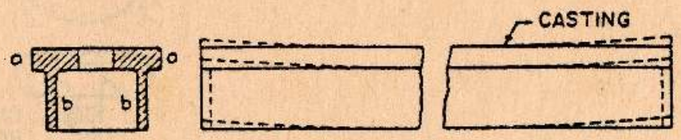


FIG 2·7

5) Allowance for rapping

Rapping is the tapping on the pattern, so that it will get loosened and come out of the sand easily. When rapping the mould, cavity will get enlarged slightly than the pattern. When casted parts are to be fit together without machining, this rapping enlargement has to be corrected. For example see fig. 2.8. Rapping will slightly increase dimension of part "a" and slightly decrease dimension of part "b". So if part "a" is to be

...ted to part "b", you have to keep an opposite rapping allowance as shown by the dotted lines

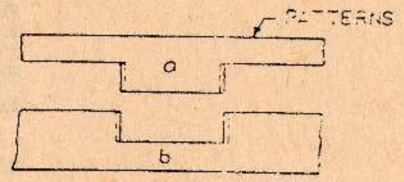


FIG 2·8

SAQ 2 : Can you think of a way, that the pattern can be withdrawn from the sand without rapping?

*　　*　　*　　*

**ANSWER** : When many castings are required by machine moulding, you can use a stripping plate. This stripping plate will allow the pattern to be withdrawn without disturbing the sand. Then keeping the draft and rapping allowance become unnecessary.

### 2.2.3 PATTERN MATERIALS

Durability of a pattern depend on the way it is made and the material used to construct it. All patterns will wear due to ramming and rapping and the abrasive action of the sand. Patterns also become alternatively damp and dry.

The material used to make the pattern depend on the number of castings wanted and how the pattern is used. The material should be hard enough to withstand the wear and tear of handling and moisture resistant.

The materials most commonly used in the order of their use, are wood, metal and plasters.

1. Wood

Wood is the most commonly used material for large and small patterns at a moderate cost. When you compare it with other materials, it is light and portable, strong, easy to work, and comparatively cheap.

The main disadvantage of wood is when exposed to moisture it can shrink and swell. Then the pattern can warp and the size and form will change. To overcome these defects, warp free wood should be used and the surface should be treated to resist moisture. The wood selected should be dried well before making the pattern.

White pine is a commonly used wood. Mahogany is a stronger wood used for more stronger pattern for many castings.

2. Metals

When you want to make a large number of castings, the pattern should be more durable and have strength than wood. Then you can use metals like cast iron, brass, aluminium and white metal for pattern. Then these patterns are called metal patterns.
Gray cast iron can be used in some cases for patterns. It is cheap, firm, not easily damaged and will not rust when properly protected. It is used for large patterns having hollow core inside.

Brass is a preferred metal for patterns. Brass can be easily finished, does not rust, is strong, and draws well from the mould. It is frequently used for small patterns.

Aluminium alloyed with zinc is used for general pattern work when you want hardness and lightweight in the pattern. It draws well from the sand, will not rust, and is not easily damaged.

White metal is an alloy that has little shrinkage. It is not so hard or so durable as the other metals. It is cheaper and used for various work.

**2.3 CORE MAKING** :

**2.3.1 CORES** : A core is a body of sand used in moulding when it is desired to form a hole, or recess, in a casting.

**SAQ 3** : What are the possible ways to keep a core so that a hole or recess is made in a casting ?

* * * *

**ANSWER** : There are two ways of keeping a core in a moulding;

i) The body of core sand may be formed to the mould by the pattern (Fig. 2.9 (a) )

ii) The core can be made in a core box and placed in the mould after the pattern has been drawn (fig. 2.9 (b))

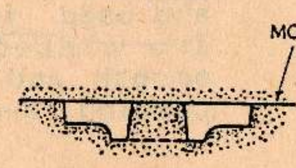



FIG 2·9 (a)

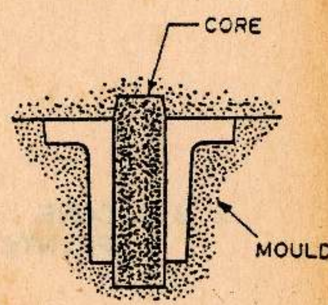



FIG 2·9 (b)

TYPES OF CORES

(a) Green sand core
(b) Dry sand core

When the pattern can be made to leave a core as a part of the mould, it is said to leave it's own core. Then the body of sand is known as a green-sand core. This is shown by fig. 2.9 (a). Green sand core is an economical and easy method of forming holes. And you must use it wherever possible. However it is possible only for vertical opening and limited to short length and not too small in diameter. For a green sand core the pattern should have a draft more than usual.

As in fig. 2.9 (b) when the depth of the same pattern increases, the green-sand core is no more practicable. Because the body of sand is too long and can break in the process of drawing. It also can get washed away by the molten metal. Therefore you have to use a dry sand core.

Dry sand cores are shaped in a wood or a metal moulds known as a core box. You have to use a special mixture of core sand and binder. The core is placed in an oven and baked until it is thoroughly dry. It should have following properties.

(i) It must be hard enough to withstand the pressure of the molten metal.
(ii) It must be soft enough to crush when the metal shrinks, to avoid cracking the casting.
(iii) The core must break up easily, so that it can be removed from the casting.

Cores are also sometimes made of metal and used in the form of chills. They are placed in the mould to get a smooth and accurate surface on the casting, avoiding machining.

**2.3.2 CORE PRINTS** : When a drysand core is introduced into a mould, there should be some way of hollowing it in position. This is done by projecting pieces called as core prints, made on the pattern. The core prints make an impression in the sand and form seat into which the cores can be set. The general types of core prints used are;

(i) Cope and drag prints
(ii) Horizontal or parting line prints
(iii) Balancing prints
(iv) Hanging or cover core prints
(v) Tail or drop prints

They are briefly described below:

(i) Cope and drag prints :

They are placed on the cope and drag sides of the pattern. The cope print has more taper. Because the cope has to be placed on the core.

(ii) Horizontal or parting line prints;

They are used to make the core seats when the core is placed in a horizontal position.

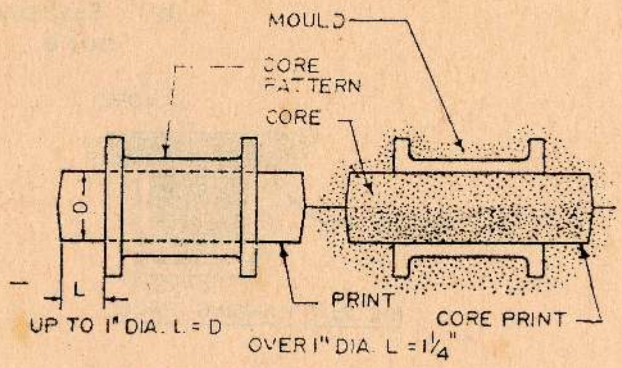


FIG 2-10 PARTING LINE PRINTS

(iii) Balancing prints:

This is used when the core is horizontal and it does not pass through the entire work. When core has to be supported on one end. Therefore you have to balance the core as shown by 2.1.1 (i) & (ii). In (i) the print is long enough to balance. In (ii) the print is enlarged to balance.

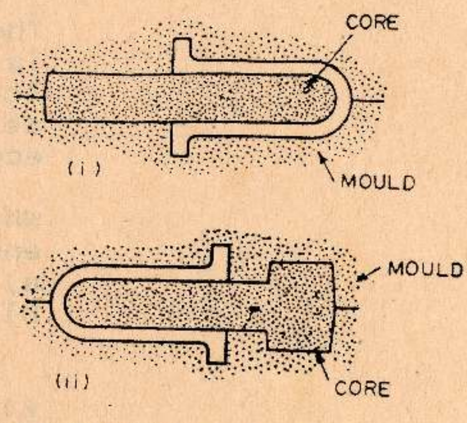


FIG 2-11 BALANCING PRINTS

(iv) Hanging or cover core prints:

This is used when a cored casting has to be entirely made in the drag. The core is hanged in the drag and will

a) Cover the mould.
b) Support for hanging the core.

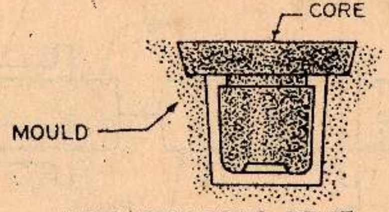



FIG 2-12 HANGING PRINT

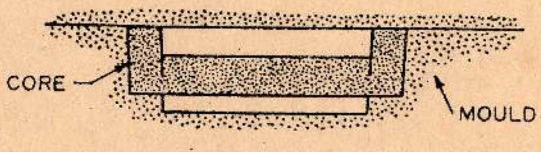



FIG 2-13 DROP PRINT

(v) Tail or drop prints:

This is used when a hole has to be cored above or below the parting off the mould. The sides of the print should have plenty of draft. This will enable the core to be placed readily in the mould.

**2.3.3. CORE BOXES** : To make any kind of dry-sand core you have to make use a wood or metal mould called as a "core-box". And you have to allow draft shrinkage and finish in the core box as in the pattern.

The first thing about making a core is deciding the method of holding and locating the core. Next step is deciding the most practical and economical method of making the core.

While making the core box you have to ensure following things;
a) Size and shape of the core
b) The way the core can be supported while drying.

All cores are soft when first made. It is important that they have to be supported while drying in an oven, so that shape will not change due to its own weight. Otherwise the core will not fit in the mould and the casting will not be perfect.

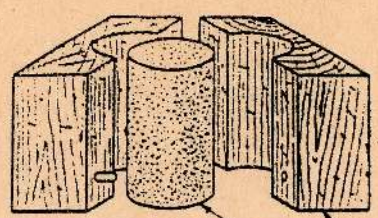


FIG 2-14

Fig. 2.14 shows you a core box and the core made from it. This core is kept vertical while drying and the core is made in this position.

There are several types of core boxes;

(i) Whole and half cores
(ii) Boxes of rectangular cores
(iii) Right and left hand boxes
(iv) Boxes with strickle
(v) Boxes for forming projections on cores.
(vi) Skeleton core boxes.

(i) Whole and half cores :

If the whole core can be dried up without deformation then the box is made as a whole. If the core is such that it will deform when drying, then it is made in halves in half boxes as shown in fig. 2.15

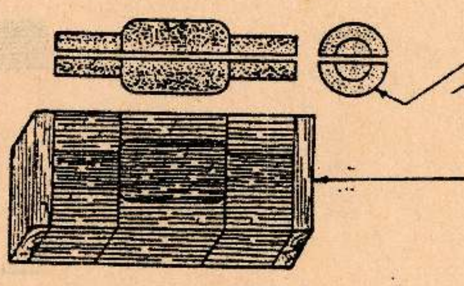


FIG 2-15 CORE BOX

(ii) Boxes for rectangular cores:

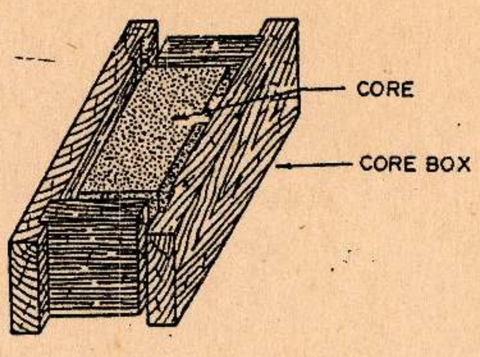



FIG 2-16 RECTANGULAR CORE BOX

As shown in fig. 2.16 rectangular cores has to be made in boxes, that can be parted to withdraw the core. The parting happens in diagonal corners.

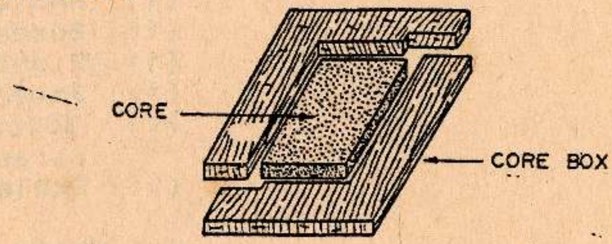



FIG 2-17 RIGHT & LEFT HAND BOXES

(iii) Right and left hand boxes:

Right and left hand core boxes are made for unsymetrical cores and where two half cores from the same box cannot be pasted to get the complete core.

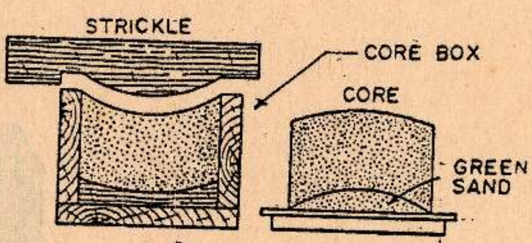



FIG 2-18 BOXES WITH STRICKLE

(iv) Boxes with strickles:

Some cores are of such irregular shape, that it is more economical to make it as shown by fig. 2.18. All the faces of the core except one are formed by the box. The other surface is made by a strickle.

(v) Boxes for forming projections on Cores:

Various methods are employed to form projections on a core. This depend on the shape of the core and the location of the projection. Generally projections are formed in the bottom of the box as in fig. 2.19. The openings should have plenty of draft, to allow the box to be readily lifted off the finished core.

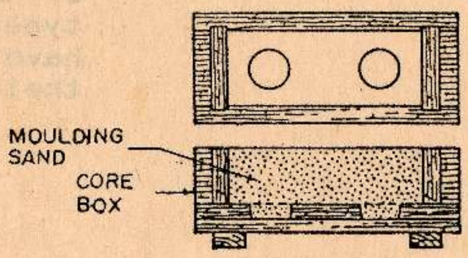



FIG 2.19 PROJECTIONS

(vi) Core boxes with loose pieces:

Loose pieces such as bosses, hubs, ribs and core prints are sometimes used in core boxes. There loose members are located in various ways. In fig.2.20 it is located by loose dowels or nails.

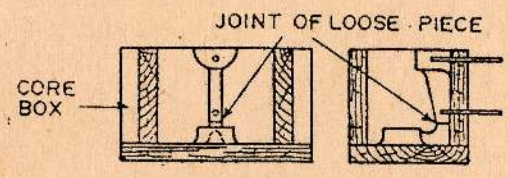



FIG 2-20 LOOSE PIECES

(vii) Skeleton core boxes :

These are constructed as same as the skeleton patterns.

**2.4 SUMMARY** : In this lesson you have learnt about the pattern making and core making.

Patterns are used to make the mould cavity. You have learnt how to design the pattern. Main types of patterns were introduced to you. And you also learnt the kinds of pattern allowances and their use. Now you know what are the materials used in pattern making and what patterns they are used.

Next you were given a description of core making. Cores are used to make holes in the casting. You know there are two types of cores green sand or dry sand cores. The importance of core prints and their general types were described. Finally you have learnt about the core boxes and their types.

LESSON : SAND CASTING TECHNIQUE

AIM : To describe the sand casting process.

3.1 INTRODUCTION : In the previous lesson we have discussed about the patterns and cores. They are essential in the sand casting process. In this lesson we will study about the entire sand casting process.

We can write down the steps involved in making a casting as follows:

(i) Make the pattern out of wood, metal or plastic.

(ii) In case of sand casting, select test and prepare the necessary sand mixtures for mould and core making.

(iii) With the help of patterns prepare the mould and necessary cores.

A mould is a container (of sand and metal, etc) having a cavity of the shape to be cast.

A core is a body (of sand etc) which is employed to produce a cavity in the casting.

(iv) Melt the metal or the alloy, that you want to make the casting.

(v) Pour the molten metal/alloy into the mould and remove the casting from the mould after the metal solidifies.

(vi) Clean and finish the casting.

(vii) Test and inspect the casting.

(viii) Remove the defects, if any.

(ix) Relieve the casting stresses by Heat Treatment.

(x) Again inspect the casting.

(xi) The casting is ready for shipping.

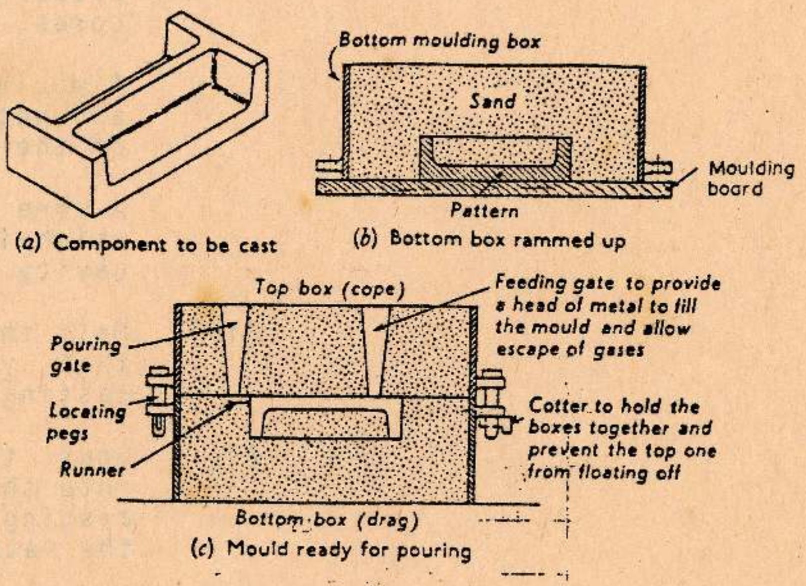
We will discuss the above mentioned different steps of metal casting in this lesson.

## 3.2 CASTING PROCESS

: We will take an example of a casting and follow the above mentioned steps in making the casting. Fig3·1(a) shows our component to be cast. It is a bracket.

S.A.Q. 1 : Can you describe the casting process for Fig.3·1?

* * * * *




(a) Component to be cast

(b) Bottom box rammed up

(c) Mould ready for pouring

Fig 3·1

(pouring gate, riser, runner) are cut away from the casting when the casting is cleaned up after solidifying. Then the casted component is machined at the required places.

We have discussed about the pattern making process in lesson 2. Therefore we will go on to the description of other material used in the sand casting process.

3.3 MOULDING MATERIALS : A mould material is one, out of which the mould is made. A mould material should be such that the mould cavity keeps its shape till the molten metal has solidified.

S.A.Q. 2 : Can you classify the moulds according to their durability ?

*  *  *  *  *

ANSWER : We can make castings in ;

(a) Permanent moulds made up of ferrous metals and alloys (steel, Gray C.I. etc).

(b) Temporary refractory moulds-made up of refractory sands and resins. You also can make moulds by wax, plaster of paris, carbon, ceramics etc.

Permanent moulds are normally employed for casting low melting point materials. Also the permanent moulds are costly. For the above mentioned reasons, most of the output of foundry industry is produced using refractory mould materials. That is chiefly Refractory sands: In this lesson we will consider the moulds made out of sand. In the next lesson we will consider the moulds made of other materials.

ANSWER : First we will make a drawing of this bracket. We will give this drawing to a pattern maker. He will make the pattern by a suitable wood, using a contraction scale.

On the pattern there will be contraction allowance. Further the pattern maker will keep 3mm to 5mm extra allowance on the faces to be machined. Therefore on our drawing, we have to show the faces to be machined.

At the foundry, the foundry men will use the pattern to prepare the mould in moulding boxes. They will keep the pattern face down wards on a moulding board and lay a moulding box-section over it. This is shown in Fig.3·1(b).

Then they will sprinkle a little smooth facing sand mixed with coal dust on the pattern. After that they will fill the box with moulding sand and ram-down very well. When the sand has been rammed sufficiently to make a good impression from the pattern, the box will be turned over. Then another box section is placed over it and rammed with sand as before.

Now a hole is formed through the sand in the top box for pouring the metal (called the "pouring gate") and the two boxes are parted again. The pattern is now carefully taken out from the bottom box. The impression (cavity) is touched up with smoothing tools, to give a good surface to the casting channels ("called runners") are made. They will take the liquid metal from the pouring gate to the cavity. Then the top box is placed back. Now the mould is ready for pouring. It will look like Fig.3·1 (C).

When casting take place, mettal is poured until it rises to the top of the pouring gate. These extensions

As compared to permenent moulds, we can use the refractory sand moulds, to cast high melting point materials and bigger objects. where as by permenent moulds we can produce small castings with better quality and dimensional accuracy.

3.3.1. REFRACTORY SAND : They are:

| | |
|---|---|
| (i) Silica Sand | (ii) Magnesite |
| (iii) Zircon | (iv) Dolomite |
| (v) Olivine | (vi) Sillimanite |
| (vii) Graphite/carbon | |

S.A.Q. 3 : Can you think why sand is a good moulding material?

* * * * *

ANSWER : Refractory sands (especially silica sands) are the best moulding materials because :

(i) They maintain their shape and other charctirstics even at very high temperatures while they are in contact with molten metals.

(ii) Even when packed as the mould cavity, they remain sufficiently porous or permeable to give vent to the mould gases.

(iii) They can be moulded into intricate shapes.

(iv) They are chemically immune to molten metals.

(v) They can be used repeatedly for making moulds.

(vi) They are inexpensive

(vii) They can be made available without much difficulty.

How ever silica sands have the disadvantage of high thermal

expansions or volume increase at 1063 °F.

S.A.Q. 4 : What are the main materials used in making sand moulds?

* * * * *

ANSWER : While making a mould we make use of the following materials;

(i) Refractory sands

(ii) Binders

(iii) Water

(iv) Additives

3.3.2 MOULDING SAND BINDERS : As compared to moulding sands, moulding sand binders are less refractory.

S.A.Q. 5 : What is the function of the moulding sand binders?

* * * * *

ANSWER : Binders produce cohesion between the moulding sand grains in the green or dry state. Binders give strength to the moulding sand so that it can keep its shape as mould cavity.

We should not add too much binder because too much binder will decrease the permeability of moulding sand. Also when you increase the binder content the compression strength will increase upto a limit. After that how much ever you increase binder, the strength will not change. Usually we use clay as a binder.

3.3.3 WATER :

S.A.Q. 6 : Why do you need water for a sand mould?

* * * * *

ANSWER : The amount of water can vary from 1.5 to 8%. As it has been explained above, water is responsible for the bonding action of clays. Water activates the clay in the sand and the clay-sand mixture develops strength and plasticity. Water added to the sand mixture, partly gets absorbed by clay and partly remains free and is known as free water. The absorbed water is responsible for developing proper bond and the green strengths.

The free water acts as a lubricant,

It increases plasticity
It improves mouldability, but,

It reduces strength of the sand mixture.

S.A.Q. 7 : What happens if too much water or too little water is used for making the mould?

* * * * *

ANSWER : For a given type of clay and its amount, there is an optimum water content required. Too little water will not develop proper strength and plasticity. Too much water will result in excessive plasticity and dry strength. You can find experimentally the amount of water required to develop the optimum properties.

3.3.4 ADDITIVES : The basic constituents of moulding sand mixture are sand, binder and water. Materials other thatn the basic ingradients are also added to moulding sand mixtures, in small quantites, in order to;

(i) enhance the existing properties,
(ii) to develop certain other properties,
(iii) to confer special qualities like resistance to sand expansion defects etc.

Some of the additive materials along with the specific functions performed by them are given below:

FACING MATERIAL : Facing material tend to obtain smoother and cleaner surfaces of castings and help the easy peeling of sand from the casting surface during shake out. Ex. Coal dust, graphite dust, silica flour.

CUSHION MATERIALS : Cushion materials burn when the molten metal is poured. And this give rise to space for accommodating the expansion of silica sand at the surfaces of mould cavity.

In the absence of cushion materials, large flat surfaces of castings may buckle due to thermal expansion of silica sand grains.

A few cushion materials are;
Wood flour, cereal hulls, cellulose etc.
Other special additives are:

(a) Cereals or finely ground corn flour.
It increases green and dry strength of the molding sand.
It minimizes sand expansion defects.
It improves collapsibility.
It lowers flowability and permeability
cereals may be added in amounts ranging from 0.25 to 2.0 percent.

(b) Fuel oil
It appears to improve mouldability of sand.
It may be added in amounts from 0.01 to 0.10 per cent.

(c) Iron oxide
It develops hot strength

(d) Dextrin and Molasses
They increase dry strength of the sand.
They add to edge hardness of moulds Molasses resist the mould tendency to drying out.

3.4 MOULDS AND MOULD MAKING : Prepared moulding sand is packed rigidly around the pattern and when the pattern is withdrawn, a cavity corresponding to the shape of the pattern remains in the sand. This cavity is known as (Mould or) Mould cavity. Therefore a mould is a sort of container. When molten metal is poured into it, a casting of the shape of the mould is produced. The process of making moulds is referred ta as mould making.

S.A.Q. 8 : Can you list down the characteristics, a mould should have to produce a good casting?

* * * * *

ANSWER : A mould must have the following characteristics:

(i) possess refractoriness to bear the high heat of the molten metal,
(ii) possess strength to hold the weight of molten metal,
(iii) Produce a minimum amount of mould gases,
(iv) Be able to resist the erosive action of the molten metal being poured,

(v) Resist metal penetration into the mould walls.

**3.4.1. TYPES OF MOULDS** : The types of moulds used in sand casting are;

(a) Green sand mould
(b) Dry sand mould
(c) Sking-dried mould
(d) Air dried mould
(e) Core-sand mould

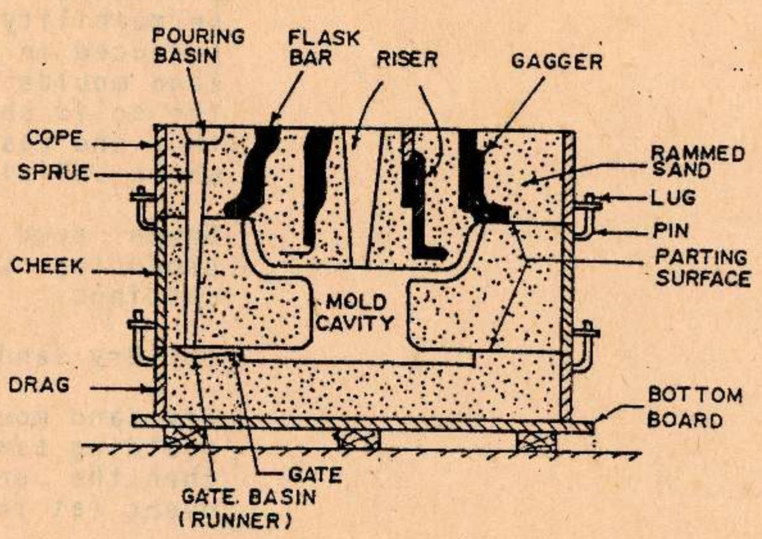



FIG 3·2 A THREE PART SAND MOLD

(a) Green sand mould

S.A.Q. 9 : What is meant by a green sand mould?

*    *    *    *    *

Green sand is a sand which is in damp condition and has free water. It also contains clay binder. In a green sand mold, molten metal is poured while it is in the green state i.e., the undried condition. A green sand mould possesses lower strength and lower permeability. Intricate shapes can be produced in green sand moulds. Green sand moulds offer less resistance to the solid shrinkage of castings and thus the castings do not crack or tear while solidifying.

Green sand moulds are suitable for producing small and medium sized castings.

(b) Dry sand mould

Dry sand moulds are actually made with moulding sand in green condition and then the entire mould is dried in ovens (at temperatures 300 to 650°F).

S.A.Q. 10 : When is a dry sand mould used?

*    *    *    *    *

ANSWER : In sand used for making dry sand moulds, certain binders are added which harden when heated. Dry sand moulds possess higher strengths as compared to green sand moulds. They are more expensive and consume more time in making, as compared to green sand moulds. They generate less mould gases than green sand moulds. They possess higher permeability than green sand moulds. They employ finer sands and hence produce smoother casting surfaces. They are preferred for large sized castings.

Dry sand moulds are used when green sand moulds prove to be unsatisfactory.

(c) Skin-dried moulds

Sands used for making sking dried moulds contain certain binders like linseed oil which harden when heated.

The mould is made with the moulding sand in the green condition and then the skin of the mould cavity is dried with the help of gas torches or radiant heating lamps. Unlike dry mould, a skin dried mould is dried only up to a depth varying from 6mm to 25 mm.

A skin-dried mould possess strength and other characteristics in between green and dry sand moulds. If a skin dried mould is not poured immediately after drying, moisture from green backing sand may penetrate the dried skin and make it ineffective.

(d) Air dried moulds

They resemble skin dried moulds in the sense that their skin is dried.

After the mould has been made in the green state, it is kept open to the atmospheric air for a certain period of time. During this time some of the moisture from the mould surfaces gets evaporated. Consequently the mould skin dries there by increasing the strength and hardness of mould surface.

Large pit moulds get dried in this manner because they remain exposed to atmosphere for quite some time while they are being made.

(e) Core sand moulds

A core sand mould is made by assembling a number of cores made individually in separate core boxes and baked. The cores are made with recesses and projections so that they can be fitted together to make the mould. A core sand mould is poured without a molding box surrounding it. As compared to green, dried and skin dried moulds, core sand molds possess high, collapsibility baked strength and hardness. Core sand moulds are more expensive (because of the cost of binders etc.) as compared to green and dry sand moulds.

S.A.Q. 11 : Did you understand, the difference between "core sand moulds' and 'sand core moulds?

* * * * *

ANSWER : 'Sand core moulds' are mostly wooden mould boxes used to make sand cores for the mould. 'core sand mould' is a sand mould made out of sand core mould boxes.

### 3.4.2 MOULDING METHODS

Various moulding methods are:

(a) Bench moulding
(b) Floor moulding
(c) Pit moulding
(d) Machine moulding

(a) Bench Moulding

Moulding is carried out on a bench of convenient height. Small and light moulds are prepared on benches. The moulder makes the mould while standing. Both green and dry sand moulds can be made by bench moulding. Moulds, both for ferrous and (especially) non ferrous castings are made on bench moulds. Both Cope and Drag are rammed on the bench.

(b) Floor moulding

Moulding work is carried out on foundry floor, when mould size is large and moulding cannot be carried out on a bench. Medium and large sized castings are made by floor moulding. The mould has its drag portion on the floor and cope portion may be rammed in a flask and inverted on the (floor) drag. Both green and dry sand moulds can be made by floor moulding.

(c) Pit moulding

Very big castings which cannot be made in flasks are moulded in pits dug on the floor. Very large jobs can be handled and cast easily through pit moulding.

The mould 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 moulding is much more than that in floor moulding. In pit molding, the moulder 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 moulding sand or binders connecting vent pipes to the floor level for the escape of mould gases. The cope (a separate flask) is rammed over the pit (drag) with pattern in position. Gates, runner, pouring basin, square etc. are made in the Cope.

The mould is dried by a stove placed in the pit. Cope and drag are then assembled. You may use a crane for lifting and positioning the cope over drag. Cope can be clamped in position.

Now the mould is ready for being poured.

S.A.Q. 12 : What is the difference between pit moulding and floor moulding?

* * * *

ANSWER : In floor moulding the drag part of the mold stands on the floor. In pit moulding, the drag part is embedded below the floor.

(d) Machine moulding:

In bench, floor and pit moulding, the different moulding operations are carried out manually by the hands of the moulder. In machine moulding, various moulding operations like sand ramming, rolling the mold over, with drawing the pattern etc. are done by machines.

S.A.Q. 13 : What are the advantages and disadvantages of machine moulding?

* * * *

ANSWER : Machines perform these operations much fast, more efficiently and in a much better way. Moulding machines produce identical and consistent castings. Moulding machines produce castings of better quality and at lower costs.

Moulding machines are performed for mass production of the castings where as hand moulding (bench, pit and floor) is used for limited production. But machine moulding is not a fully automatic process. Many operations can be performed by machines, but some others have to be carriec out by hands.

A few different types of moulding machines are listed below:

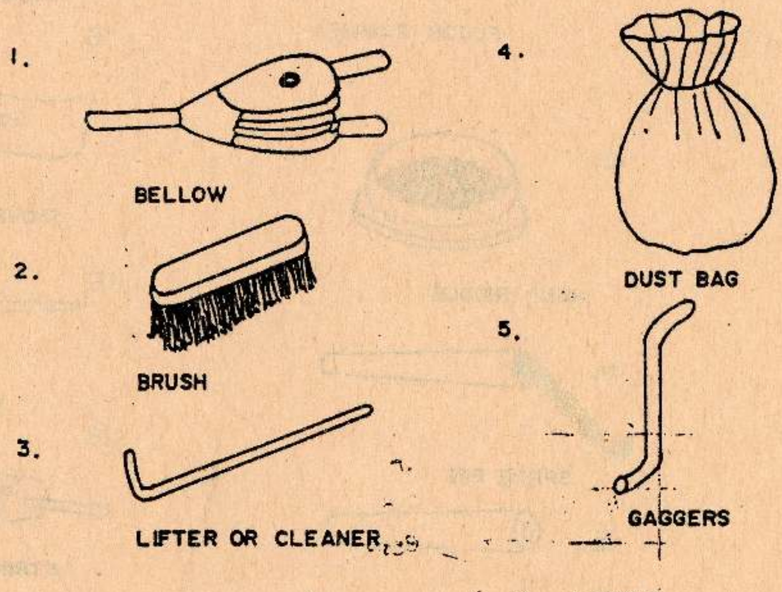
(a) Jolt machine
(b) Squeezer machine
(c) Jolt squeezer machine
(d) Sang slinger, etc.

At the Ceylon Steel Corporation, foundry shop you can see machine moulding.

### 3.4.3 HAND MOULDING TOOLS USED IN MOULD-MAKING

In hand moulding processes, all the moulding operations, such as ramming the sand, placing and drawing the pattern, turning over the moulding boxes, etc. are performed (manually) by hand.

A number of hand tools which are used by the moulder to perform above mentioned operations are shown in Fig 3.3




FIG·3·3· HAND MOULDING TOOLS

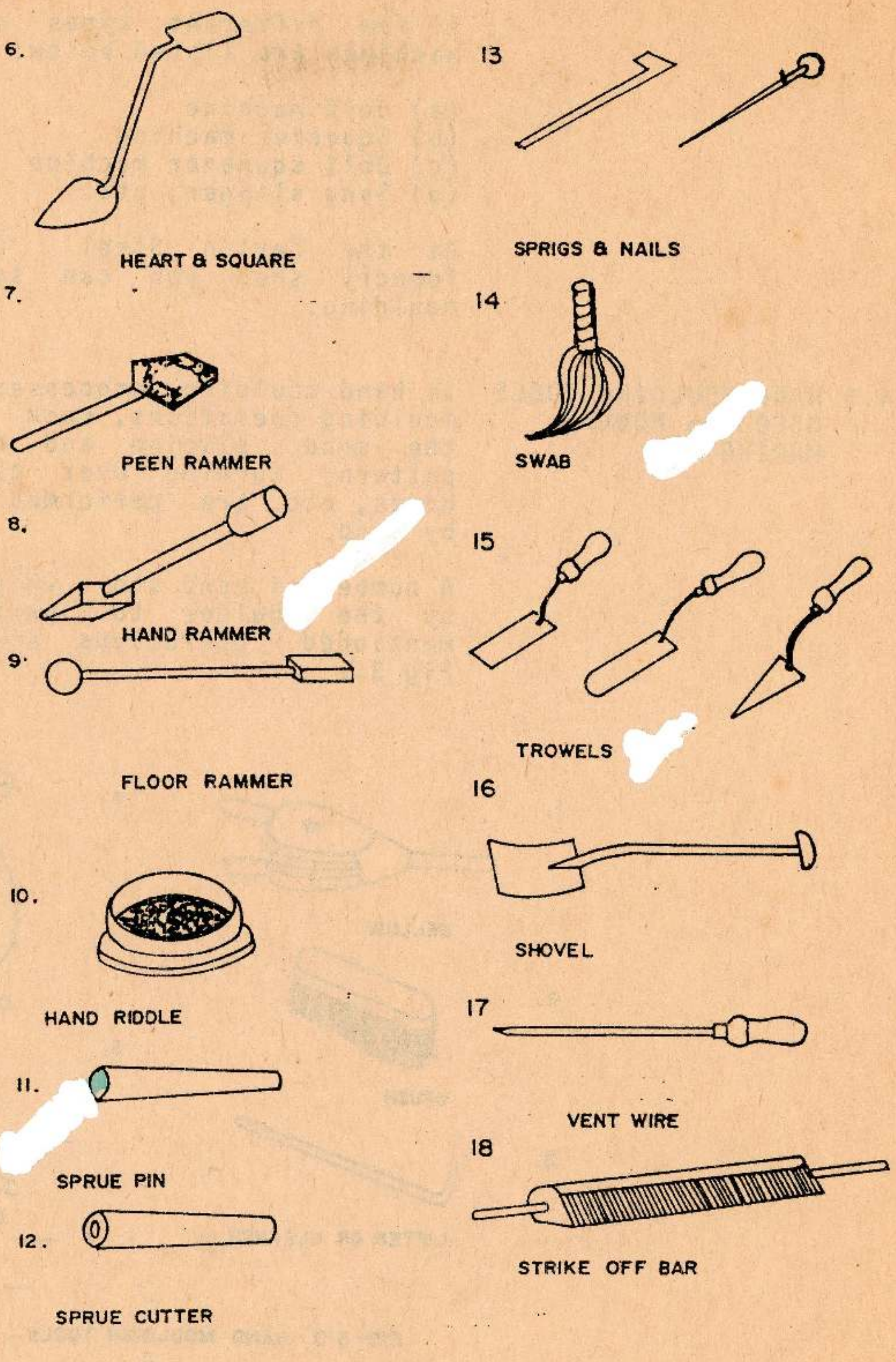



FIG · 3 · 3 · HAND MOULDING TOOLS

3.4.4 FORCES ACTING ON THE CORES AND MOULDS : When the mold cavity is filled with molten metal, it experiences high pressures.

S.A.Q. 14 : What is the effect of the forces due to pouring metal on the moulds?

* * * *

ANSWER : These large fluid forces tend to displace the cores, and distort the moulds.

S.A.Q. 15 : How can you prevent these distortions due to liquid metal pressure?

* * * *

ANSWER : We can eliminate the effects of these forces by;

(1) backing up the moulds,
(2) placing weights on the cope,
(3) clamping Cope and drag, properly.
(4) increasing the rigidity of (especially green) mould by using box bars or Coverplates to reinforce the sand mass.

A completely flat mould surface gives rise to maximum lifting force. We can calculate the forces acting on the cores or moulds. The upward force acting on a flat mould surface is equal to ph A; where
p is density of metal, $kg/cm^3$
h is head of metal, cm
A is superficial area, $cm^2$

Cores experience an up thrust due to the buoyant forces of the molten metal being poured. This force is equal to the weight of metal displaced. This force increases as the specific gravity of the molten metal increases. Brass, Bronze and ferrous alloys exert more upward thrust than light, Al and Mg alloys.

This upward force produced by molten metal can be easily withstood by the cores if they are constructed with reinforcing grids and irons.

## 3.5 PRINCIPLES OF GATING:

**3.5.1 GATING SYSTEM** : The term gating system refers to all passage ways through which the molten metal passes to the entire mould cavity.

**S.A.Q. 16** : Can you identify the parts of the gating system from Fig3.4?

*　　*　　*　　*

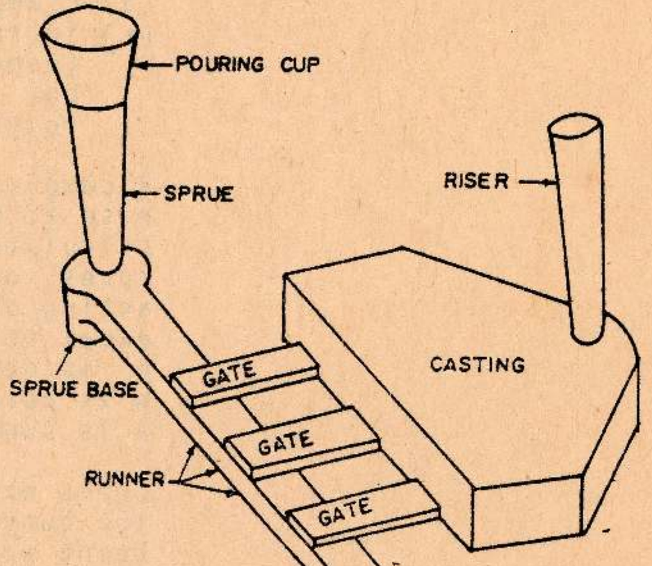



FIG 3·4 COMPONENTS OF GATING SYSTEM

ANSWER : The gating system has;

(a) Pouring cups and basins
(b) Sprue
(c) Runner
(d) Gates
(e) Risers

Fig 3·4 shows the various components of the gating system.

The way in which liquid metal enters the mold has an influence on the quality and soundness of a casting. Therefore different passages for the molten metal are carefully designed and produced.

A gating system should avoid sudden or right angle changes in direction. Sudden change in direction causes mould erosion, turbulence and gas pick-up.

If possible the gating system should form a part of the pattern. Because it;

1. avoids cutting a runner and gates,
2. allows sand to be rammed hard,
3. helps prevent erosion and washing away of the sand as molten metal flows into the mould.

S.A.Q. 17 : What is the purpose of having a gating system?

* * * *

ANSWER : Purpose of the gating system:

A gating system should fill the mould cavity completely before freezing. It should introduce the liquid metal into the mould cavity with low velocity and little turbulence, so that mould erosion, metal oxidation and gas pick-up is prevented.

The gating system should help to promote temperature gradients favourable for proper directional solidification.

It incorparate traps for the seperation of non-metallic inclusions which are either introduced with the molten metal or are dislodged in the gating system.

It also should regulate the rate at which liquid metal enters into the mould.

A good gating system should be practicable and economical to make and consume least metal. In other words (refer Fig.3.4) the metal solidified in sprue, runner, gates and risers should be minimum because gates, risers etc., are removed from the final casting. The gating system should provide for the maximum yield.

For proper functioning of the gating system, we have to control the following factors:

(a) Type of pouring equipment, such as ladles, pouring basin etc.
(b) Temperature/Fluidity of molten metal.
(c) Rate of liquid metal pouring.
(d) Type and size of sprue.
(e) Type and size of runner.
(f) Size, number and location of gates connecting runner and casting.
(g) Position of mould during pouring and solidification.

3.5.2 POURING CUPS AND BASINS : Fig.3.5 shows various pouring-cup designs.

(a) POURING CUPS : A pouring cup makes it easier for the ladle or crucible operator to direct the flow of metal from crucible to sprue. A pouring cup is a funnel shaped cup which forms the top portion of the sprue. The pouring cup may be cut out of the sand in the upper surface of the cope above the sprue.

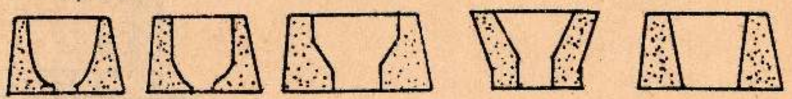


FIG 3-5 POURING CUPS

Fig.3·6 shows two pouring-basing designs. A pouring basin may be made out of core sand, metal or it may be cut or moulded in the cope of sand mould.

S.A.Q.18 : Why do you need a pouring basin instead of a pouring cup?

* * * *

(b) POURING BASINS : A pouring basin makes it easier for the ladle operator to direct the flow of metal from crucible to sprue. It helps maintaining the required rate of liquid metal flow, it reduces turbulence and vortexing at the sprue entrance. It helps separating slag etc., from metal, before the metal enters the sprue.

The metal is poured away from the sprue hole. Some times the down gate (sprue) is closed with a ball fixed on the end of a rod (fig3.6a) the ball is lifted when the pouring basin is full. This permits smooth filling of the mould cavity.

In another pouring basin design you may built a dam (fig3·6b) so that the ladle operator can acquire or optimum pouring speed before the liquid metal enters the sprue. Indirect pouring as above minimizes turbulence, vortexing. Therefore air is tapped at the sprue entrance.

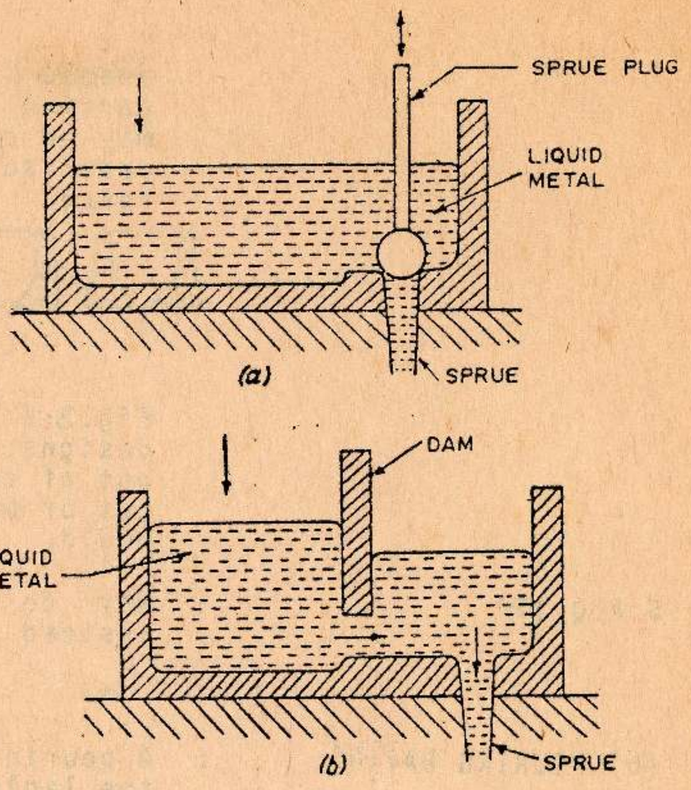



FIG 3·6 POURING BASIN DESIGNS

3.5.3 SPRUES : A sprue feeds metal to the runner which in turn reaches the casting through the gates. A sprue is tapered with its bigger end at the top, to receive the liquid metal. The smaller end is connected to the runner.

S.A.Q. 19 : Can you think why the sprue is constructed in a tapered shape?

* * * *

ANSWER : Since the larger section of the sprue is at the top, it will freeze after the smaller section at the bottom has frozen. Thus it will continue feeding liquid metal, to the mould cavity. Larger section compensates for shrinkage till the lower small end solidifies.

Sprues up to 20 mm diameter are round in section where as larger sprues are often rectangular. A round sprue has a minimum surface exposed to cooling. They also off the lowest resistance to flow of metal. There is less turbulence in a rectangular sprue.

3.5.4 GATES : A gate is a channel which connects runner with the mould cavity and through which molten, metal flows to fill the mould cavity.

S.A.Q. 20 : What are the important points in constructing the gate of a mold?

* * * *

ANSWER : A gate should feed liquid metal to the casting at a rate consistent, with the rate of solidification. The size of the gate depends upon the rate of solidification. A small gate is used for a casting which solidifies slowly and vice-versa. More than one gate may be used to feed a fast freezing casting.

A gate should not have sharp edges as they ( i.e edges) may break during pouring and sand pieces can get carried with the molten metal in to the mould cavity. Moreover, sharp edges may cause localized delay in freezing, thus resulting in the formation of voids and inclusions in the cast objects.

A gate basin (see fig3·2) may be used to act as a reservoir or store for molten metal. A gate basin traps loose sand and other undesirable particles and thus stops them from entering the mould cavity. A gate basin prevents turbulent liquid metal from entering the gate.

3.5.5 RISERS : A riser or a feeder head is a passage of sand made in the cope (mold) during ramming the cope. The molten metal rises in the feeder head after the mold cavity is filled up. This metal in the feeder head (or riser) compensates the shrinkage as the casting solidifies.

S.A.Q. 22 : What is the primary function of the riser?

* * * *

ANSWER : Metals and their alloys shrink as they cool and solidify. It creates a partial vacuum within the casting. Partial vacuum leads to a shrinkage void. This shrinkage void will grow and it will form shrinkage cavity. Therefore extra liquid metal from out side the mould cavity has to be supplied to prevent cavities. Therefore, the primary function of the riser (attached with the mould) is to feed metal to the solidifying casting so that shrinkage cavities are get rid of. Shrinkage is a very common casting defect.

S.A.Q. 22 : What are the other functions of the riser?

* * * *

ANSWER : A riser permits the escape of air and mould gases as the mould cavity is being filled with the molten metal. A riser full of molten metal indicates that the mould cavity has already been completely filled up with the metal.

The casting is provided with a metal pressure equal to the height of the riser. A casting solidifying under the liquid metal pressure of the riser is comparatively sound.

Risers also promote directional solidification.

## 3.6 FINISHING OF CASTING:

S.A.Q. 23 : What are the finishing operations of casting?

* * * *

ANSWER :

1. Pouring liquid metal into mould
2. Letting the liquid metal to freeze inside the mould
3. Breaking the mould and removing casting
4. Machine finishing

### 3.6.1 POURING

(a) POURING TEMPERATURE :

S.A.Q. 24 : Why is the pouring temperature important in casting?

* * * *

ANSWER : Pouring temperature is very important and should be specified along with the casting method. Selection of the pouring temperature depends upon the composition of the alloy and the type of casting being made. Both low and excessive pouring temperatures create defects in castings.

Metal poured at temperatures lower than the minimum would cause misrun and cold shuts. Where as excessive pouring temperatures tend to oxidise the metal, alloying elements get lost (by oxidation or vaporization), gas content of the melt increases and castings develop porosity. Therefore metal becomes more fluid at higher temperatures.

Higher pouring temperatures are required for castings with high surface area to volume ratio and short freezing time, in order to fill the mould satisfactorily. Lower pouring temperatures are preferred, where heavy, compact castings are to be produced.

Table 1 gives pouring temperatures for various metals and alloys.

| Metal/alloy | Pouring Temperature Range (°C) | Composition (%) |
|---|---|---|
| 1. Gray cast iron | 1510[1] - 1592[2] | - |
| 2. Steel | 1592 - 1760 | - |
| 3. Copper | 1130 - 1200 | 99 |
| 4. Cu-Ni alloy | 1220 - 1280 | 96Cu, 4Ni, |
| 5. Cupro-Nickel (castings) | 1375 - 1450 | 30Ni, 0.5Si, 1Mn, 1Fe, balance Cu |
| 6. Gun metal | 1100 - 1180 | 85Cu, 5Sn, 5Zn, 5Pb. |
| 7. Monel (normal) | 960 - 1050 | 1.5Si, 1Mn, 2.5Fe, 66Ni, balance Cu. |
| 8. Nickel bronze | 1180 - 1220 | 88Cu, 5Sn, 5Ni, 2Zn. |
| 9. Nickel (castings) | 1500 - 1590 | 1.5Si, 1.25Mn, 0.3C, balance Ni. |
| 10. Phosphor bronze | 1020 - 1100 | 11Sn, 0.25P, balance Cu. |
| 11. Tin bronze | 1080 - 1160 | 90Cu, 10Sn. |

N.B. 1. Heavy sectioned castings
2. Light sectioned castings

(b) POURING EQUIPMENT : Pouring equipments include (see Fig3·7)

(1) Pouring ladles.
(2) Ladle handles (shanks), trolley, (mono) rails, cranes, hand wheels, tilting levers etc.

LADLES : Ladles are used to carry molten metal from the furnace to the moulding boxes.

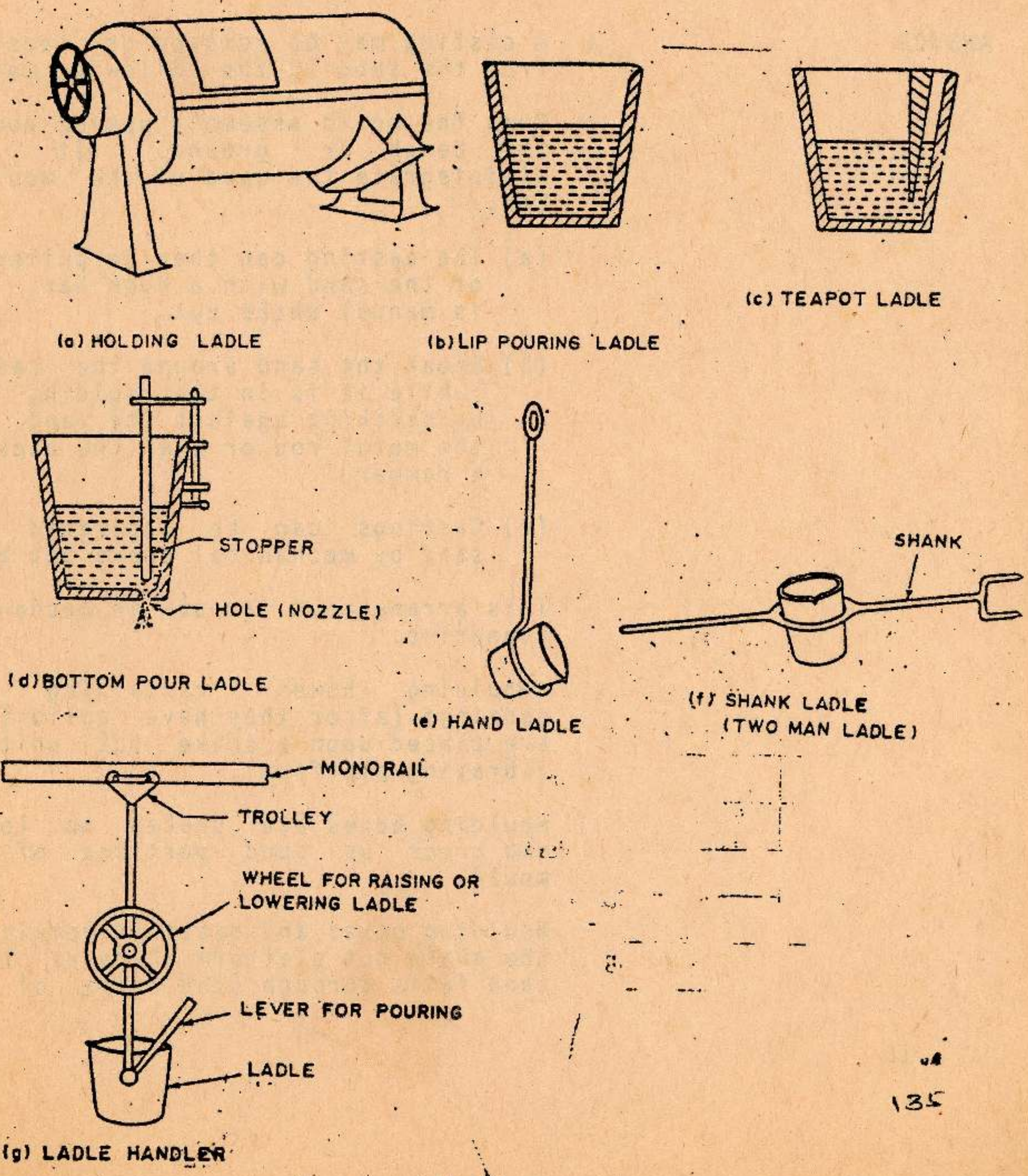



FIG 3-7 POURING EQUIPMENT

3.6.2 SHAKE OUT : After the molten metal has been poured into the mould, allow it to cool and solidify. When the casting has solidified it is removed from the moulding box. This operation is marked as shake out.

S.A.Q. 25 : Can you think of different ways of breaking a mould to get the casting out?

*  *  *  *

ANSWER : A casting may be removed or separated from the sand in the following ways.

Dump the mould assembly upside down on the bench or ground. It will disintegrate the sand of the moulding box.

(a) The casting can then be pulled out of the sand with a hook bar. This is manual shake out.

(b) Break the sand around the casting (while it is in the moulding box) by striking against the sand with the metal rod or even the back of a rammer.

(c) Castings can be separated from sand by mechanical shake out also.

This arrangement is used in mechanised foundries.

Moulding boxes containing the castings (after they have solidified) are placed upon a shake out unit (a vibrating platform).

Moulding boxes are shaken to loosen and break up sand portions of the mould.

Moulding boxes and castings remain on the shake out platform where as loose sand falls through (the holes of the flatform) into a hopper situated beneath the shaking platform.

3.6.3 FETTLING (CLEANING) :

S.A.Q. 26 : What do you mean by 'fettling'?

* * * * *

ANSWER : Fettling is the name given to cover all those operations which help giving the casting a good appearance after it has been shaken out of the sand mould.

By the fettling operation, we do the following:

(a) Removal of cores from the casting

(b) Removal of adhering sand and oxide scale from the casting surface. (surface cleaning)

(c) Removal of gates, risers, runners etc. from the casting.

(d) Removal of fins, and other unwanted projections from the castings.

(a) Removal of cores
It may be difficult to remove dry sand and hardened cores in the absence of suitable equipment. Hammering or vibrations imparted to cores does loosen and break them up.

You can remove sand portions sticking inside the castings by poking action using a metal rod. You can remove cores from larger castings effectively by pneumatic rapping and hydroblasting.

(b) Cleaning and casting surfaces
The outside and inside surfaces of castings are cleaned of adhering refractory (sand) particles and oxide scale.

The extent of surface cleaning required depends upon the metal / alloy of the casting and size of the casting. Steel castings require considerable more cleaning than those of iron and brass. Because of their high melting and pouring temperatures and consequent burning of the sand in contact with the molten metal. Aluminium castings are virtually free from burned on sand.

Since heavy castings suffer more than light castings from the burning of sand, their cleaning is more difficult.
Sand may be removed from the Surfaces of castings using hand methods or mechanical equipment.

S.A.Q. 27 : Can you name a few tools used for hand cleanning of castings?

*   *   *   *   *

ANSWER : Hand Methods;
(1) Wire brush
(2) File
(3) Pick
(4) Crow bar

Hand methods are slow, tedious and costly especially when the number of castings (to be cleaned) are large.

Mechanical Equipment (or methods)
(i) Tumbling
(2) Air blasting — sand blasting / shot blasting
(3) Mechanical blast cleaning
(4) Hydro blasting
(5) Chemical cleaning

3.6.4 FINISHING OF CASTINGS : Finishing of castings is a latter stage in cleaning of the castings. Once the embedded sand, gates, risers and other unwanted projections have been removed from the surfaces of a casting, we do the finishing.

S.A.Q. 28 : What is the result of the finishing operation?

* * * * *

ANSWER : Smoothen the areas of the casting from where gates and risers have been removed.

-remove any excess metal if left on the casting.
-improve surface finish and appearance.

Different finishing operations carried out on castings are described below.

(a) Grinding

Both grinding wheels and abrasive belts (of paper or canvas) are available in different sizes, shapes, grils, gril sizes and binders.

Gringding machines used on castings are of stationary or portable type. Portable machines are perferred for finishing large castings.

(b) Rotary filing

Softer metals (such as Al) are finished by rotary files instead by grinding.
A rotary file is actually a grinding wheel made up of hardened steel.

(c) Machining

As their requirements, castings may be given a finish treatment on lathe, shaper, milling machine etc.

(d) Chemical treatment

Both ferrous and non-ferrous castings may be given a chemical treatment to make their surfaces attractive.

A molten salt bath of sodium hydroxide (95%), sodium nitrates, and nitrites(5%) at 800°F is used for cleaning gray iron castings.

(e) Polishing

Castings may be polished in order to obtain smooth surface finish. Polishing can be carried out on abrasive belt machine using a finer grit (80 to 400 mesh).

(f) Brushing

Brushing imparts a smooth surface finish to castings. Rotary wire or fibre brushes may be used to remove burrs and grinding marks from the surfaces of a casting.

S.A.Q. 29 : What is meant by buffing?

* * * * *

(g) buffing

Buffing provides an exceptionally high luster on cast surfaces.

A buff is a disk of muslin sewn together and mounted on the axle of a buffing machine. A buffing machine resembles a grinder with the difference that a buff (disk) exsits in place of the grinding wheel.

The face of the buff is rubbed with a very fine abrasive mixed with a grease binder. The casting is fed (by hand or mechanically) to the buff wheel (rotating at high speeds) in order to acquire fine finish.

(h) Blasting or blast cleaning

In case castings that are not brushed nor buffed, they are blast cleaned or tumbled before shipping. This operation removes dirt, grease and grinding marks.

Blasting makes use of fine, sand or short grit. Castings produced in investment moulds already have a fine finish. Therefore they are blasted with grits such as rice hulls or ground walnut shells.

S.A.Q.30 : Why is painting important for the finished products?

* * * * *

(i) Painting

Many ferrous castings (such as base stands etc.) do not need fine finish. Rather they are painted after inital cleaning so that the objects get a suitable appearance for sale. And they are at the same time protected from dust etc.

S.A.Q. 31 : Is there any other surface treatment operations you can think of? (Excluding machining operations)

* * * * *

(j) Surface treatment of castings

You can give a number of surface treatments, to give special properties to castings: some of them along with the purpose they serve are named below:

| Treatment | Purpose |
| --- | --- |
| (A) (i) Painting | |
| (ii) Enamelling | |

(iii) Electroplating
(iv) Tinning and galvanising
(v) Polishing (Mechanical, chemical & electro chemical)
(vi) Anodising and pickling

For improving appearance and resistance to corrosion.

(B) (i) Carburising & Nitriding
(ii) Flame & Induction hardening
(iii) Chilling (C.I.)
(iv) Hard surfacing
(v) Shot peening

For improving wear resistance and mechanical properties (especially resistance to fatigue).

3.7 SUMMARY : In this lesson you have learnt about the sand casting process in detail. First we have taken an example of a casting and described the steps involved in carrying out the casting process.

To prepare a mould for the casting, we need moulding materials such as refractory sands, sand binders, water and additives. We have described the necessity of using these materials.

There are different types of moulds and moulding methods. We have given an introduction to them. You also learnt about the forces acting on the moulds during pouring.

To feed the mould cavity with molten metal, we have to make a gating system inside the mould. The gating system includes pouring cups and basins, sprues, gates and risers. You have learnt about the function of each of them.

Finally we have described the operations carried out to finish the casting. They are;

The pouring of molten metal,
Shaking out the casting from the mould,
Fettling operations,
Final finishing operations.