MODULE - III

ALLOYS AND PHASE RULE

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3.1 Introduction

Metals are chemical elements that are typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity (e.g. iron, gold, silver, and aluminium, and alloys such as steel). They are insoluble in aqueous and non- aqueous solvents. However they are miscible in another metal in the molten state forming a homogeneous mixture. On cooling this mixture solidifies to form a solid mixture called alloys. Alloys, not only contain metals but also contains a few non- metals. Hence, it can be said that an alloy contains at least one metal.

Alloys often have properties that are different to the metals they contain. This makes them more useful than the pure metals. For example, alloys are often harder than the metal they contain. Compared to pure metals, alloys can be stronger, more resistant to damage and more versatile. Some are better than pure materials, while some are worse. Most alloys are formed for one or two specific properties, like strength and rust resistance.

3.1.1 Alloys – Definition

An alloy is defined as a **homogeneous mixture of two or more different elements one of which is essentially a metal.**

Examples: (i) Nichrome – an alloy of Ni, Cr, Fe

(ii) Brass – an alloy of Cu, Zn

(iii) An alloy containing mercury as one of the constituent is termed as amalgam. (e.g.) Sodium amalgam

3.1.2 Properties of alloys

The properties of alloys are as follows,

1. Alloys are harder and less malleable (cannot be beaten into sheet).
2. They have lower melting points than the component elements.
3. They have low electrical conductivity.
4. They have high corrosion resistance & chemical resistance.

3.1.3 Significance of Alloying

1. **To increase the hardness of metals.**

   Example:

1. Pure gold is soft, but when it is alloyed with copper, it becomes hard.

2. Addition of 0.5% of arsenic makes lead hard which is used in manufacturing of bullets.

2. **To lower the melting point of metal.**

Example:

Wood's metal (an alloy of lead, bismuth, tin and cadmium) melts at **71˚C**, which is much less than the constituent metals.

[Melting point of Pb – 327.5˚C, Melting point of Bi – 271.4˚C, Melting point of Sn– 231.9˚C, Melting point of Cd – 321.1˚C]

3. **To increases the corrosion resistance of the metal.**

Example:

Pure iron rusts easily, but stainless steel (alloy of Fe, Ni, Cr) is less sensitive to corrosion.

4. **To alter the chemical activity of the metal.**

Example:

Sodium amalgam is less active than sodium, but aluminum amalgam is more active than aluminum.

5. **To modify the colour of metal.**

Example:

Brass (alloy of Cu - **red** & Zn – **silvery white**) is **yellow** in colour

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3.1.4 Functions and effect of alloying elements

Alloying improves the properties of metals. Some alloying elements in steel and their functions are,

Metals	Properties	Uses
Nickel	Improves- ductility, tensile strength, toughness, elasticity & corrosion resistance.	For making balance wheels.
Chromium	Increases - Tensile strength, corrosion resistance, hardness	For making surgical instruments, connecting rods etc.
Manganese	Increases - strength, abrasion resistance, hardness, etc.	For making grinding wheels, spindles, rails etc. .

Vanadium	Increases - tensile strength, ductility, shock resistance and abrasion resistance.	For making axles, piston rods etc.
Molybdenum	Improves - corrosion and abrasion resistance. Becomes strong at high temperature.	For making high - speed tools.
Tungsten	Increases - red hardness, toughness, abrasion resistance and shock resistance	For making cutting tools, permanent magnets, etc.

Classification of alloys

1. **Ferrous alloys**
2. **Non – ferrous alloys**

Ferrous alloys (Alloy steels)

Ferrous alloys mainly contain **iron** as the **major constituent** along with **carbon, aluminium, boron, chromium, cobalt, copper and manganese** to improve the properties of steel. (e.g.) Nichrome, Stainless steel and Alnico.

3.1.5 Nichrome

Nichrome is **an alloy of nickel and chromium.**

Composition

Nickel – 60%

Chromium – 12%

Iron – 26%

Manganese – 2%

Properties

- Show good resistance to heat and oxidation.
- Possesses high melting point.

- Possesses high electrical resistance.
- It can withstand heat up to 1000 - 1100˚C.

Uses

- Used for making resistance coils, heating elements in stoves.
- Used for making parts of boiler, gas – turbines, aero – engine valves.
- Used for making electric irons and other household electrical appliances.

3.1.6 Stainless steel

It contains **chromium, molybdenum and nickel along with iron and carbon**. It **does not corrode** due to the formation of **dense film of chromium oxide. Hence i**t is otherwise called **corrosion resistant steel**.

Types of stainless steel

i) Heat - treatable stainless steel

ii) Non- heat treatable stainless steel

(1) Magnetic type

(2) Non- magnetic type

(i) Heat treatable stainless steel

Composition

- 1 .2% carbon
- less than 12 – 16% chromium.

Properties

Uses

- It is water and weather resistant.
- It can be used up to 800 ˚c.
- They are magnetic, tough& can be used in cold condition.
- It is used in making blades, scissors and surgical instruments.

(ii) Non – heat treatable stainless steel

Properties

- They possess less strength at high temperatures.
- They are more resistant to corrosion.

It is further classified into two types,

(1) Magnetic type

(2) Non – magnetic type

(1) Magnetic type

Composition

- 0.35% carbon
- 12 – 22% chromium.

Properties

- It is more resistant to corrosion than heat treatable stainless steel.
- It can be forged, rolled and machined.

Uses:

- It is used in making chemical equipments and automobile parts.

(2) Non – magnetic stainless steel

Composition

- 0.15% carbon
- 18 – 26% chromium
- 8 – 21% nickel.

Properties:

- It is resistant to corrosion which can be increased by adding a little quantity of Mo.
- It has resistance to oxidation.

Uses:

- It is used in making sinks, utensils, dental and surgical instruments.

18/8 STAINLESS STEEL

- It is also known as 302 or 304 grade stainless steel.
- This grade of stainless is generally regarded as one of the "workhorses" in stainless steel as it is widely available and cheap.

Composition

- 18% chromium
- 8% nickel and the rest is iron.

Properties

- Provides a great finish when electro polished.
- It is usually soft and prone to surface damage.
- It can be hardened by only cold working and isn't magnetic.
- Susceptible to corrosion in chloride solutions.
- It is resistant to corrosion which can be increased by adding a little quantity of Mo.

Uses

- Used in kitchen and food applications.
- It is also used in buildings, decor, and site furnishings.

3.1.7 Heat treatment of steel

The process of heating and cooling of solid steel article under carefully controlled conditions is known as heat treatment of steel.

Purpose of heat treatment of steel

a) Improves magnetic and electric properties.
b) Improves corrosion resistance.
c) Removal of thermal stress.
d) Removal of the imprisoned gases.
e) Refines grain structure.

The main heat treatment processes are,

i) Annealing
ii) Hardening
iii) Tempering
iv) Normalizing
v) Carburizing
vi) Nitriding
vii) Cyaniding

i) Annealing

- Annealing means softening of alloys.
- It is done by **heating** the metal to **high temperature**, followed by **slow cooling** in a furnace.

Purpose

- To increase machinability.
- To remove the imprisoned gases.
- To remove internal stress.

Types of annealing

1. Low temperature annealing
2. High temperature annealing

1. Low temperature annealing (process annealing)

Heating steel to a temperature **below the lower critical temperature** followed by **slow cooling**.

Purpose

- To increase machinability.
- To reduce hardness.
- To increase ductility.

2. High temperature annealing (full annealing)

Heating steel to a temperature **about 30 to 50˚C above the higher critical temperature** and **holding it** at that temperature for sufficient time and then **cooling** to room temperature.

Purpose

- To increase ductility and machinability.
- It makes the steel soft.

ii) Hardening(Quenching)

It is the process of heating steel **beyond the critical temperature** and **cooling it suddenly** either in oil orbrine water or any fluid.

Purpose

- To increase hardness.
- To increase abrasion resistance.

iii) Tempering

It is the process of **heating the already hardened steel** to a **temperature lower than its own hardening temperature** and then cooling it slowly.

Purpose

- To remove stress and strain.
- To reduce brittleness and hardness.

iv) Normalizing

It is the process of heating steel to a **definite temperature** and allowing it to **cool gradually in air.**

Purpose

- To remove the internal stress.
- To increase toughness.
- Normalized steel is suitable for the use in engineering works.

v) Carburizing

Mild steel article is taken in a cast iron box containing small pieces of charcoal. It is heated to **900 to 950˚C** and kept as such for sufficient time, so that carbon is adsorbed. Then the article is cooled slowly within the iron box itself.

Purpose

- To produce hard- wear resistance surface on steel article.

vi) Nitriding

It is the process of heating the metal alloy in presence of **ammonia at a temperature to about 550˚C.** Nitrogen combines with the surface of alloy to form hard nitride.

Purpose

- To get super hard surface.