SEMESTER 5

DISCIPLINE SPECIFIC ELECTIVE COURSES

DSE-B-1: INORGANIC MATERIALS OF INDUSTRIALIMPORTANCE

- **Alloys :**
- Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (Arand heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

ALLOY

- An alloy is a homogeneous mixture of two or more elements with metallic properties.
- Chemically alloys are solid solutions.
- Generally alloys are harder, less malleable and have low melting point than their component metals. They have low electrical conductivity and resist corrosion and action of acids.
- It is therefore certain physical and chemical properties such as hardness, tensile strength, resistance to corrosion of a metal can be changed by admixing a small quantity of one or more element into it.

PURPOSE OF MAKING ALLOY

- To increase the hardness of metal
- To lower the melting points
- To resist the corrosion
- To get good casting
- To modify chemical activity
- To modify colour

TYPES OF ALLOYS

- Alloys can be classified in a number of ways
- a) Based on metallurgical structure : Alloys are classified according to whether they consist of single phase or more than one phase. E.g. Brass (30% Zn, 70% Cu) , Monel metal (66.6% Ni, 33.3% Sn) , Transformer iron (96% Fe , 4% Si) are single phase alloys. Muntz metal (60% Cu , 40% Zn) is an example of two phase alloy.
- b) Based on the method of fabrication : Alloys are classified according to the type of fabrication, which is different for different alloys. E.g. wrought Cu-alloy contains 5-40% Zn, while casting alloy contains 5% Sn, 5% Zn & 5% Pb for getting easy machinability and pressure tightness.

TYPES OF ALLOYS

- c) Based on application of alloy : Alloys are also classified on the basis of the purpose for which they are used. E.g. bearing metal alloys, solder alloys (Sn=40-60% , Pb=60-40%)
- d) Based on the principal metal in the alloy : Alloys are also classified on the basis of the principal metal in them. E.g. Al-alloy, Mg-alloy, Cu-alloy, Pb-alloy, Sn-alloy, Fe-alloy.
- e) According to the base , alloys are grouped into three following classes
  - i) Iron base ferrous alloy
  - ii) Light Al based and Mg based alloy
  - iii) Cu base, Sn base, Pb base etc. non-ferrous alloy

FERROUS ALLOY :

FERROUS ALLOYS, WHICH ARE BASED ON IRON-CARBON ALLOYS, INCLUDE PLAIN - CARBON STEELS, ALLOY AND TOOL STEELS, STAINLESS STEELS, AND CAST IRONS.

- **Properties of Ferrous Metals**
- Ferrous metals may include a lot of different alloying elements. Some examples are chromium, nickel, molybdenum, vanadium, manganese. Those give ferrous steels material properties that make them widely used in engineering.
- A list of **ferrous metal properties** :
- **Durable ; Great tensile strength ; Usually magnetic ; Low resistance to corrosion ; A silver-like colour ; Recyclable ; Good conductors of electricity**
- These qualities make them usable in constructions of long-lasting skyscrapers. On top of that, they are utilised in making tools, vehicle engines, pipelines, containers, automobiles, cutlery etc.

NON-ALLOY STEELS

- Non-alloy steels are also known as **carbon steels** because carbon is the alloying element there. Although there are other elements also present, their content is low enough to not make an impact on the material properties. Those elements are sulphur, phosphorus, silicon and manganese. Sulphur and phosphorus can actually have a detrimental effect on the steel's quality but again, not with such low-level content.
- Non-alloy steels are classified by their carbon content as low, medium and high carbon steel. Each has their own uses and the characteristics vary. Also, different treatment methods are available accordingly.

LOW CARBON STEEL

- Low carbon, or mild steels contain **0.05…0.25% of carbon**. They are pretty low-cost and very well suited for bending operations. The surface hardness can be increased through carburising.
- The low cost and malleability low carbon steels are widely used. Some examples include bolts and nuts, forgings, medium-loaded details etc.
- Examples of low carbon steels: C10E/1.1121, C15E/1.1141

MEDIUM CARBON STEEL

- Medium carbon steels contain **0.25…0.6% of carbon**. The higher carbon content increases their strength and hardness compared to low carbon steels. At the same time, the ductility decreases. The increase of carbon and manganese allows tempering and quenching.
- Medium carbon steels are mainly used for making different automotive industry components like gears, axles, shafts but also bolts, nuts, screws etc. Steels ranging from 0.4…0.6% are also suitable for everything related to locomotives and rails.
- Examples of medium carbon steels: C40E/1.1186, C60E/1.1221

HIGH CARBON STEEL

- The carbon content numbers for high carbon steels vary according to different sources. Some have more sub-groups, while other stop with high carbon steels that start with **0.6% carbon** content and end around **1%.**
- These are the strongest of this group, making it suitable for applications where resistance against mechanical material wear is needed. Another quality of high carbon steels is their tendency to keep a shape. This is why tool steels have a lot of different applications in the field of engineering. The shape-keeping quality makes them useful as springs. Other use-cases include blades, rail steels, wire rope, wear-resistant plates, all kinds of tools etc.
- Examples of high carbon steels: C70U/1.1520, C105U/1.1545

ALLOY STEELS AND THE ALLOYING ELEMENTS

- Alloy steels make up another sub-group of ferrous metals. Steel's alloying elements are **chrome, nickel, silicon, copper, titanium** etc. Each has their own effect on material properties. Of course, they are usually combined, so the end products has a bit of everything.
- **Nickel :**
- Its main purpose is to **increase ductility and corrosion** resistance in combination with other elements, namely chromium. When chromium content is around 18% and nickel at 8%, we get an extremely durable stainless steels.

CHROMIUM & MANGANESE

- **Cr :** Chromium is the element responsible for creating stainless steel. Presence of chromium at levels above 11% make a metal corrosion-resistant. As discussed in the material wear article, the protection takes place through creating an oxidised chromium layer on top of the metal. This means that the base metal does not get into contact with oxygen and the danger of corrosion is greatly diminished.
- Therefore, it is ready for use without any protective coating. You can achieve a great aesthetic result by choosing the right stainless steel surface finish for your application.
- On top of that, chromium also increases tensile strength, hardness, toughness, resistance to wear etc.
- **Mn :** Manganese improves ductility, wear resistance and hardenability. The latter is done through quenching where manganese has a significant impact. It diminishes the danger of defect formation during the process by making it more stable.
- It also eliminates the formation of harmful iron sulfides, increasing strength at high temperatures.

SILICON ,TITANIUM ,VANADIUM , MOLYBDENUM

- **Silicon :** Improves strength and provides elasticity in springs. Another significant effect is increasing a metal's magnetic properties.
- **Titanium :** Improves strength and corrosion resistance, limits austenite grain size.
- **Vanadium :** The formation of vanadium carbides limits the grain size. This has an effect on increasing a material's ductility.
- It also increases strength, hardness, wear and shock impact resistance. Because of its effectiveness, the amounts must be held low. Otherwise, it can have a negative impact on material properties.
- **Molybdenum :** Molybdenum has a large effect on steel alloys at high temperatures. It improves mechanical properties but also resistance to corrosion and acts as an amplifier for the effects of other alloying elements.

CAST IRON

- Cast iron is an alloy of iron and carbon, with a carbon content somewhere between 1.5 and 4 percent. There are also other elements present – namely silicon, manganese, sulphur and phosphorus.
- Although it is brittle, its hardness makes it resistant to wear. The final form of a cast iron product is gained through casting. This process only needs minor after treatment, making it possible to form a needed shape.
- The properties of cast iron:
- Great castability
- Relatively cheap
- High compressive strength
- Good wear resistance
- Low melting point

NON-FERROUS METAL

- Non-ferrous metals do not contain iron. They are softer and therefore more malleable. They have industrial uses as well as aesthetic purposes – precious metals like gold and silver are both non-ferrous. Actually, all pure metal forms, except for pure iron, are non-ferrous.

NON-FERROUS METALS' PROPERTIES

- Non-ferrous metals' advantages make them usable in many applications instead or iron and steel.
- The properties of non-ferrous metals:
- High corrosion resistance
- Easy to fabricate – machinability, casting, welding etc
- Great thermal conductivity
- Great electrical conductivity
- Low density (less mass)
- Colourful
- Non-magnetic

COPPER

- Copper is pretty widely spread in the industrial sphere. Add the alloys brass (copper and zinc) and bronze (copper and tin), and you may already see the many uses of copper. If not, we can help you out. For mechanical engineers, slide bearings and bushings may be the most known uses.
- Still, copper and copper alloy properties allow more applications:
- High thermal conductivity – heat exchangers, heating vessels and appliances etc
- High electrical conductivity – used as an electrical conductor in wiring and motors
- Good corrosion resistance – beautiful but expensive roofing
- High ductility – makes the material very easily formable and suitable for making statues

ALUMINIUM

- In engineering terms, a very special and important metal. May not be so useful in everyday application because of the price but its combination of low weight and great machinability make it the go-to metal in yachts, planes and many automotive parts.
- Aluminium is also the base metal in many alloys. The best known aluminium grades are probably duralumin, Y-alloy and magnalium.
- Aluminium properties include:
- Corrosion resistant
- Good conductor of heat and electricity (but less than copper) – in combination with ductility and malleability replaces copper in some instances
- High ductility and lightweight
- Becomes hard after cold working, so needs annealing

LEAD

- For the average person, lead may ring a bell related with bullets (which are now without lead) and gas (which has a sign "unleaded"). Although at first added to fuel to decrease motor knocks, it turned out to be heavily unhealthy when vaporised into the atmosphere.
- The same goes for bullets and shooting range employees who got health problems because of it. But why add it in the first place? Because lead is the heaviest common metal. As it doesn't react easily with other substances, they are still used in batteries and power cables, acid tanks and water pipes.
- Lead properties are:
- Very heavy
- Resistant to corrosion – doesn't react with many chemicals
- Soft and malleable

ZINC

- Zinc on its own doesn’t mean much to the average person. As an alloying element, on the other hand, it has a wide range of purposes. It is mainly used for galvanising steel in all kinds of fields. Galvanising makes a material more durable against corrosion.

MANUFACTURE OF STEEL

- **Primary Steelmaking**
- **Principles**
- In principle, steelmaking is a melting, purifying, and alloying process carried out at approximately 1,600° C (2,900° F) in molten conditions. Various chemical reactions are initiated, either in sequence or simultaneously, in order to arrive at specified chemical compositions and temperatures. Indeed, many of the reactions interfere with one another, requiring the use of process models to help in analyzing options, optimizing competing reactions, and designing efficient commercial practices.

RAW MATERIALS

- The major iron-bearing raw materials for steelmaking are blast-furnace iron, steel scrap, and direct-reduced iron (DRI). Liquid blast-furnace iron typically contains 3.8 to 4.5 percent carbon (C), 0.4 to 1.2 percent silicon (Si), 0.6 to 1.2 percent manganese (Mn), up to 0.2 percent phosphorus (P), and 0.04 percent sulfur (S). Its temperature is usually 1,400° to 1,500° C (2,550° to 2,700° F). The phosphorus content depends on the ore used, since phosphorus is not removed in the blast-furnace process, whereas sulfur is usually picked up during iron making from coke and other fuels. DRI is reduced from iron ore in the solid state by carbon monoxide (CO) and hydrogen (H_2). It frequently contains about 3 percent unreduced iron ore and 4 percent gangue, depending on the ore used. It is normally shipped in briquettes and charged into the steelmaking furnace like scrap. Steel scrap is metallic iron containing residuals, such as copper, tin, and chromium, that vary with its origin.

OXIDATION REACTIONS

- The most important chemical reactions carried out on these materials (especially on blast-furnace iron) are the oxidation of carbon to carbon monoxide, silicon to silica, manganese to manganous oxide, and phosphorus to phosphate, as follows:

$$2C + O_2 \longrightarrow 2CO;$$

$$Si + O_2 \longrightarrow SiO_2;$$

$$2Mn + O_2 \longrightarrow 2MnO;$$

$$2P + 2.5O_2 \longrightarrow P_2O_5.$$

$$2Fe + O_2 \longrightarrow 2FeO.$$

$$C + FeO \longrightarrow CO + Fe;$$

$$2P + 5FeO \longrightarrow P_2O_5 + 5Fe.$$

THE SLAG

- The products of the above reactions, the oxides silica, manganese oxide, phosphate, and ferrous oxide, together with burnt lime (calcium oxide; CaO) added as flux, form the slag. Burnt lime has by itself a high melting point of 2,570° C (4,660° F) and is therefore solid at steelmaking temperatures, but when it is mixed with the other oxides, they all melt together at lower temperatures and thus form the slag. A basic slag contains approximately 55 percent CaO, 15 percent SiO_2, 5 percent MnO, 18 percent FeO, and other oxides plus sulfides and phosphates. The basicity of a slag is often simply expressed by the ratio of CaO to SiO_2, with CaO being the basic and SiO_2 the acidic component. Usually, a basicity above 3.5 provides good absorption and holding capacity for calcium phosphates and calcium sulfides.

REMOVING SULFUR OR DESULPHURIZATION

- The majority of sulfur, present as ferrous sulfide (FeS), is removed from the melt not by oxidation but by the conversion of calcium oxide to calcium sulfide:
- $FeS + CaO \rightarrow CaS + FeO$.
- According to this equation, desulfurization is successful only when using a slag with plenty of calcium oxide—in other words, with a high basicity. A low iron oxide content is also essential, since oxygen and sulfur compete to combine with the calcium. For this reason, many steel plants desulfurize blast-furnace iron before it is refined into steel, since at that stage it contains practically no dissolved oxygen, owing to its high silicon and carbon content. Nevertheless, sulfur is often introduced by scrap and flux during steelmaking, so that, in order to meet low sulfur specifications (for example, less than 0.008 percent), it is necessary to desulfurize the steel as well.

REMOVING CARBON OR DECARBONIZATION

- A very important chemical reaction during steelmaking is the oxidation of carbon. Its gaseous product, carbon monoxide, goes into the off-gas, but, before it does that, it generates the carbon monoxide boil, a phenomenon common to all steelmaking processes and very important for mixing. Mixing enhances chemical reactions, purges hydrogen and nitrogen, and improves heat transfer. Adjusting the carbon content is important, but it is often oxidized below specified levels, so that carbon powder must be injected to raise the carbon again.

DEPHOSPHORISATION

- Dephosphorization of steels has become a very important metallurgical technique in steelmaking process to produce high quality steels.
- As the P content is controlled by the reactions in BOF, the double slag technique has generally been applied to obtain low P killed steels. However, this technique is accompanied by the increase in operating time and the decrease of the yield of the steel. In addition to the productivity problems with this technique, an enormous amount of BOF slag is also generated during the operation of the BOF (Basic Oxygen Furnace).

SURFACE TREATING OF STEEL

- The surface treatment of steel also begins during hot-rolling, because reheating conditions, in-line scale removal, rolling temperature, and cooling rate all determine the type and thickness of scale formed on the product, and this affects atmospheric corrosion, paintability, and subsequent scale-removal operations.
- Sometimes the final pass in hot-rolling generates specific surface patterns—for example, the protrusions on reinforcing bars or floor plates—and in cold-rolling a specific surface roughness is rolled into the strip at the temper mill to improve the deep-drawing operation and to assure a good surface finish on the final product—for instance, on the roof of an automobile.

PICKLING

- Before cold forming, hot-rolled steel is always descaled, most commonly in an operation known as pickling. Scale consists of thin layers of iron oxide crystals, of which the chemical compositions, structures, and densities vary according to the temperature, oxidizing conditions, and steel properties that are present during their formation. These crystals can be dissolved by acids; normally, hot hydrochloric or sulfuric acid is used, but for some alloy steels a different acid, such as nitric acid, is needed. In addition, inhibitors are added to the acid to protect the steel from being dissolved as well.

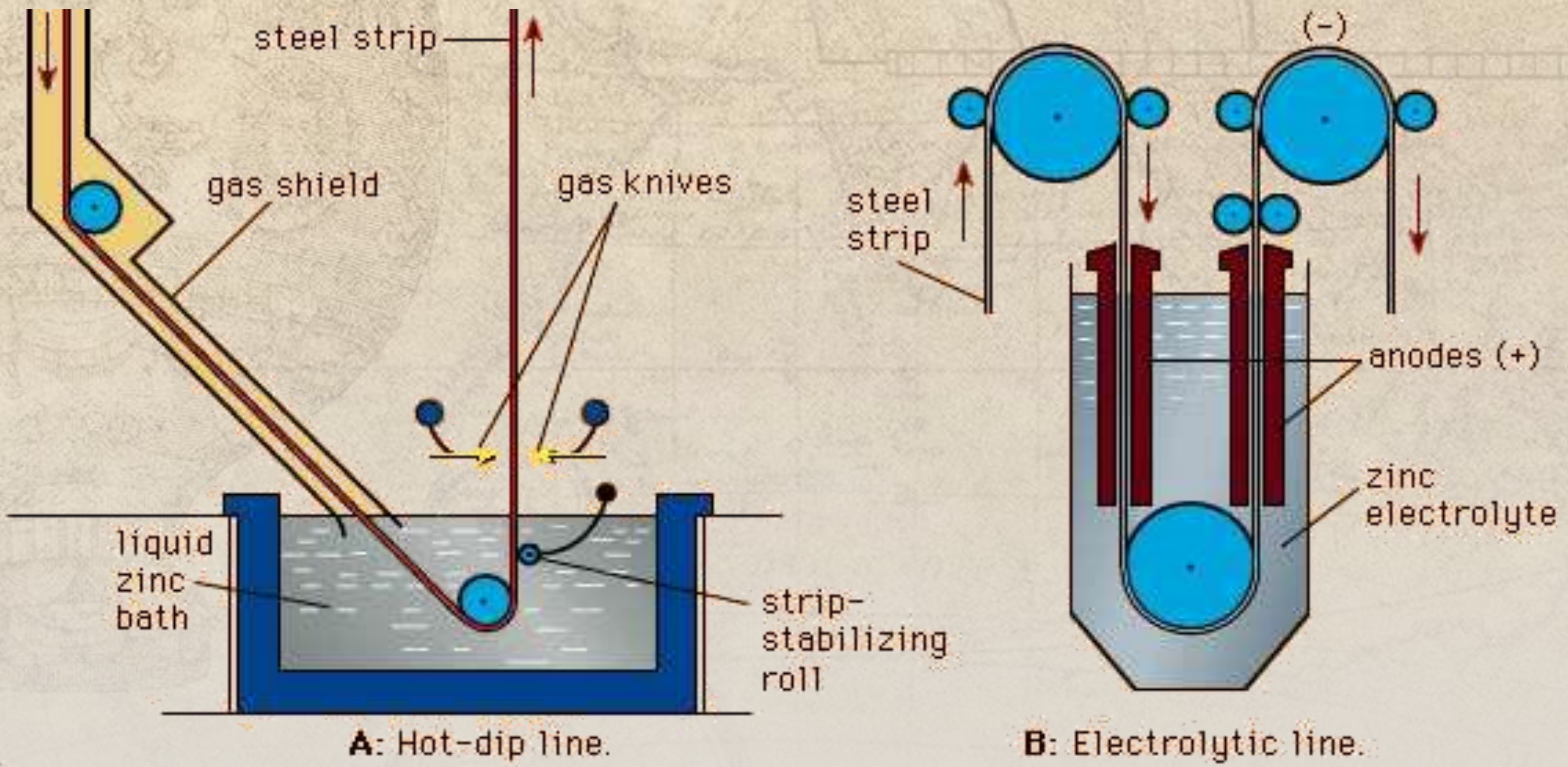
CLEANING

- The removal of organic substances and other residues from the surface of steel, in particular after cold forming with lubricants, is carried out either in special cleaning lines or in the cleaning sections of another processing line. Hot solutions of caustic soda, phosphates, or alkaline silicates are used. The strip is often moved through several sets of electrodes, which, submerged in the cleaning liquid, electrolytically generate hydrogen gas at the steel surface for lifting residues off the strip.

SURFACE COATING

- Approximately one-third of the steel shipped by the industry is coated on its surface by a metallic, inorganic, or organic coating. By far the largest installations are operated for coating cold-rolled strip. In this group the most widely used are those which coat the steel with zinc, zinc alloys, or aluminum.

HOT-DIP GALVANIZING & ELECTROLYTIC GALVANIZING



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