Module -2.

CORROSION SCIENCE

Syllabus:

Definition and scope of corrosion, Dry and wet corrosion; Direct chemical corrosion, Electrochemical corrosion and its mechanisms; Types of electrochemical corrosion, (differential aeration, galvanic, concentration cell); Typical Electrochemical corrosion like Pitting, Inter-granular, Soil, Waterline; Factors affecting corrosion, Protection of corrosion.

Course Outcome: Utilize the knowledge of electrochemistry and corrosion science in preventing engineering equipments from corrosion.

Objectives:

- **To know about the basic nature of corrosion and its processes**
- **To identify types of corrosion**
- **To recognize the various factors affecting corrosion**
- **To understand about the various protective measures against corrosion**

1.0 Introduction

Whenever a design engineer choose a metal for any application, he/she consider the various properties of materials like mechanical, physical, chemical, etc. But, it is also true that a construction engineer gives importance to mechanical and physical properties of a metal and completely ignores the chemical properties, i.e., *effect of interaction of a metal with its environment.* For example, in construction we usually concentrate on the mechanical strength of metallic rods and normally ignore its chemical reactivity towards the environment. However, the interaction of metals & alloys with its environment plays an important role in selection and hence the performance of materials for any purposes. So, effective use of any constructional materials depends on mechanical, physical and chemical properties of materials.

For example, lead (Pb) pipes are not used for plumbo-solvent water(soft water) as concentration of Pb beyond 0.05 ppm is highly toxic and galvanized iron containers are not used for storing food stuff as zinc salts obtained via chemical interaction are toxic to human beings.

This lesson largely confined to interaction of metal with its environment, factors affecting such interaction and various way to control their interaction.

1.1 What is Corrosion?

Corrosion is "A process of loss of metallic materials from its surface through an undesirable chemical or electrochemical attack by its environment". It is a naturally occurring process, i.e., a thermodynamically feasible process for which $\Delta G < 0$.

N.B.: Corrosion always starts from its surface because surface is active due to presence of unsatisfied valency forces known as *active sites*.

Examples of corrosion: (1) R*usting of iron:*

Fe (substrate) + O_2 (environment) + H_2O (electrolyte) → Fe_2O_3. xH_2O (rust)

Fig. 1. Rusting of iron pipe

(2) *Tarnishing of silver:*

$2Ag + H_2S \rightarrow Ag_2S$ (black layer on the Ag-surface) + H_2

Fig. Tarnished silver articles

(3) *Greenish layer on copper articles:*

$2Cu + CO_2 + H_2O + O_2 \rightarrow \underbrace{CuCO_3 + Cu(OH)_2}$

(Green layer; basic copper carbonate)

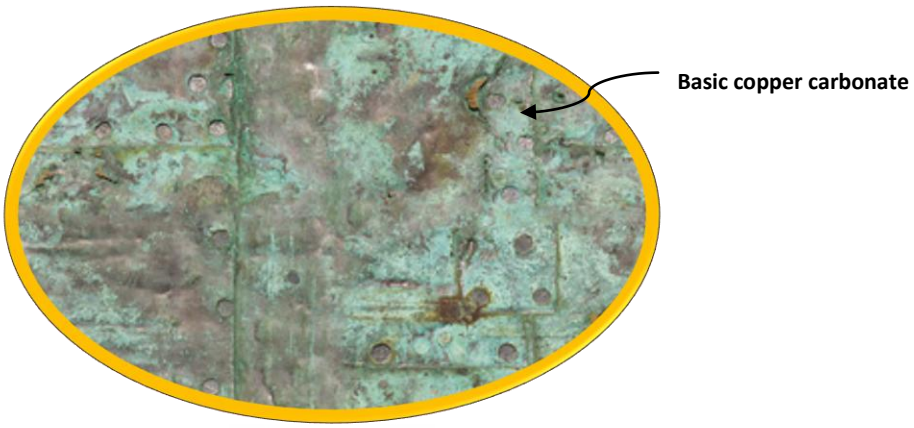

Fig. Green layer on the surface of a copper strip

1.2 Why corrosion occurs in metal?

We know that metals are extracted from their ores (i.e., combined form of metals) by the expense of huge amount of energy. It means that ores are energetically stable than pure metal. In other words, isolated pure metals are lies in excited state (a higher energy state) than their corresponding ores. For example, as pure Ca metal has a higher energy than its combined state, it prefers to lies in a lower energy & higher stability state, i.e., $CaCO_3$. So, when metals (possessing higher energy) are exposed to various environments (such as gases, moisture, liquids, etc.) during their uses, they interact with environment chemically or electrochemically cause loss of metal from its surface in the combined form (lower energy state). So in conclusion, the stability matter. We term such interaction as corrosion.

Fe (higher energy unstable state) + O_2 + H_2O → Fe_2O_3. xH_2O (lower energy stable state) + energy; ΔG is negative

In the above reaction, the rust (Fe_2O_3. xH_2O) formed is thermodynamically more stable than the pure iron metal.

In general, corrosion leads to loss in many useful properties like mechanical strength, luster, ductility, conductivity, etc. of the pure metal.

1.3 Consequences of corrosion

Corrosion is a big problem. It is a costly process in terms of costly to repair, costly in terms of contaminated product, in terms of environmental damage, and costly in terms of human safety. The various effects of corrosion are as follows:

A. *Production related consequences are*:

(i) Loss in some important properties (like mechanical strength, ductility, etc.) of metals
(ii) Increase in maintenance cost (repair/replace) resulting in an increase in the overall production cost
(iii) Decrease in production rate

B. Health related consequences are:

(i) Contamination of foods
(ii) Leakage of toxic gases, liquids from the cylinder/pipes
(iii) Contamination of drinking water (water pollution)
(iv) Contamination of medicines
(v) Infection caused by rusted iron articles

C. Safety related consequences are:

(i) Sudden collapse of bridges, buildings results in loss of life/resources
(ii) Unpredicted failure of machineries/ machineries parts

So, by adopting suitable protection measures one can reduce this cost considerably. One can also check the rate of corrosion to a great extent by *regular inspection and maintenance of equipments*. For example, some equipment requires regular repainting and occasional inspection but equipment used in power plants, processing plants, aircraft, marine, etc. needed extensive maintenance schedules.

N.B.: Corrosion is not always unwanted. It is required in various processes like electroplating, surface finishing/smoothening, for sample preparation, etc.

Q.1 Mention some health related issues with corrosion.

Ans. Some of the health related issues due to corrosion are:

(i) Contamination of foods
(ii) Leakage of toxic gases, liquids from the cylinder/pipes
(iii) Contamination of drinking water (water pollution)
(iv) Contamination of medicines
(v) Infection caused by rusted iron articles

Q.2 **Mention some production related consequences with corrosion.**

Ans. *Production related consequences are*:

(i) Decrease in production rate
(ii) Increase in maintenance cost (repair/replace) resulting in an increase in the overall production cost
(iii) Loss in some important properties of metals

Q.3 **Mention some safety related outcomes with corrosion.**

Ans.

(i) Sudden collapse of bridges, buildings results in loss of life/resources
(ii) Unpredicted failure of machines/ machineries parts

1.4 Types of corrosion

Corrosion affects the metal in various ways that depends on the nature metal itself and the nature of the immediate environment. One can classify corrosion in various ways which are as follows:

Based on the nature of the environment, corrosion is classified as (i) ***dry corrosion*** *and (ii)****wet corrosion*****.**

(i) *Dry corrosion/Chemical corrosion:* This class of corrosion occurs mainly by direct chemical action of the environment (oxygen, hydrogen sulphide, sulphur oxide, chlorine, anhydrous inorganic liquids, etc.) on the surface of the metal. It occurs usually in absence of moisture and at high temperature. Example includes oxidation corrosion, chlorination, sulphidation, liquid metal corrosion, etc.

$2Fe + 3/2O_2 \rightarrow Fe_2O_3$(oxidation)

$Sn + 2Cl_2 \rightarrow SnCl_4$(chlorination)

$2Ag + H_2S \rightarrow Ag_2S + H_2$ (sulphidation)

(ii) *Wet/Electrochemical corrosion:* This class of corrosion occurs when a metal comes in contact with a conducting liquid or when two different metals or alloys are either immersed or dipped partially in a solution. It occurs via formation of electrochemical cells in presence of moisture. It is otherwise known as *aqueous corrosion*. Wet corrosion is more common than dry corrosion. Examples are rusting of iron in an aqueous medium, Galvanic corrosion, etc.

Q.4 Differentiate between chemical and electrochemical corrosion.

Chemical/ Dry Corrosion	**Electrochemical/Wet Corrosion**
It occurs in dry or non-aqueous medium (in absence of moisture)	It occurs in wet condition or in presence of moisture
It occurs via direct chemical attack	It occurs via formation of electrochemical cells
It is uniform in nature (non localized)	It is not uniform. Localized in nature
It is a slow process	It is a fast process
It occurs on both homogeneous and hetero generous surfaces	It occurs only on heterogeneous surfaces
Corrosion product accumulates at the place of corrosion	Corrosion occurs at anode but product accumulated near the cathode
Example: Oxidation	Example: rusting of iron in an aqueous medium