Corrosion & Its Control

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Corrosion and its control
(Syllabus)

- Mechanism of Dry (Chemical) and wet (electrochemical) corrosion
- Types of electrochemical corrosion (differential aeration corrosion, galvanic corrosion, pitting corrosion, waterline corrosion)
- Factors influencing corrosion,
- Protection from corrosion (Sacrificial protection, Cathodic protection, Organic coatings.

Introduction

Corrosion has been defined as a destructive chemical and electrochemical reaction of a metal with its environment (like O_2, moisture, CO_2 etc.) which disfigures metallic products leading to reduction in their thickness and also causes loss of useful properties such as malleability, ductility, electrical conductivity and optical refractivity.

Except few metals such as gold, platinum (called noble metal) are prone to corrosion.

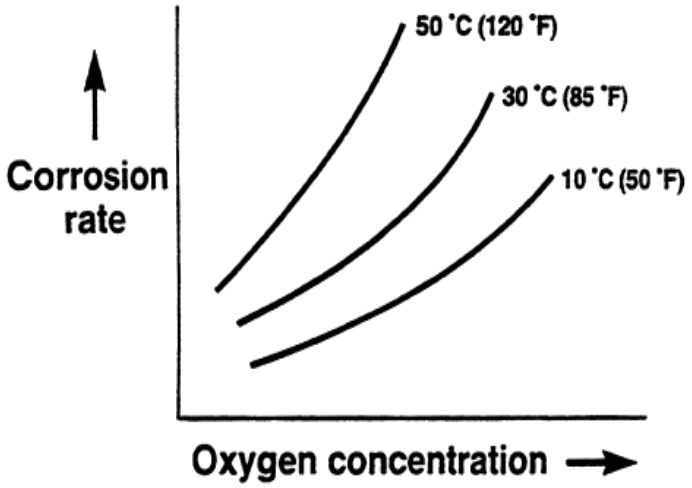
Typical examples of **corrosion**

1. Rusting of iron due to formation of hydrated ferric oxide.
2. Tarnishing of silver wares in H_2S laden air due to formation of silver sulphide.

Factors influencing corrosion

Corrosion is enhanced by the presence of

- impurities
- air and moisture
- electrolytes
- strains in metals like dent, scratches etc.



Mechanism or causes of corrosion

Metals are electropositive in nature. Except few metals like gold, platinum (noble metal) other metals are found in nature as their compounds (such as oxides, hydroxides, carbonates, chlorides, sulphides, phosphates, silicates etc.) which are called their ore.

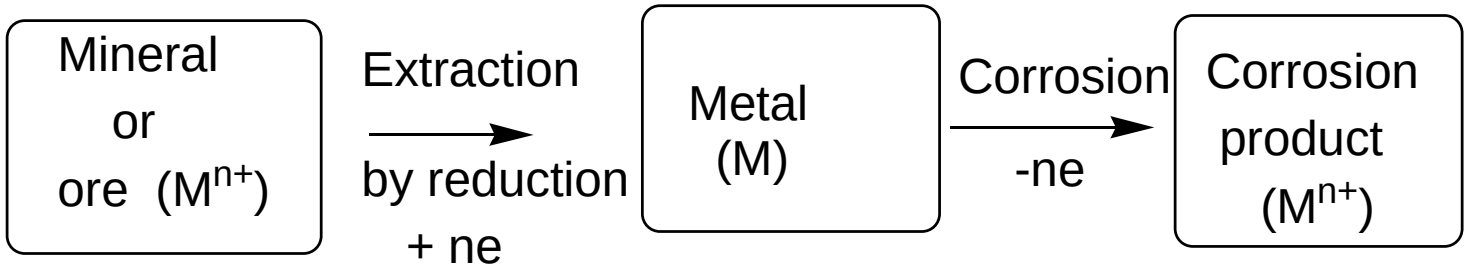
Metals are thus obtained by extraction from their ores by reduction process.

In nature, when metals exists as their compounds (or ore) they are stable and they are in the low energy states.

However, during extraction of metals from their ores, free metals are become less stable and are in the higher energy state than in the ionic state.

So, metals have a tendency to back to the ionic state and hence metal atoms are prone to get attacked by environment .

This is the main reason for corrosion of metals.



Types Of Corrosion

- Dry or Chemical Corrosion

- Wet or Electrochemical Corrosion

Types of corrosion

- **Chemical (or dry) corrosion:** It involves direct chemical attack of atmospheric gases like CO_2, O_2, H_2S, SO_2, halogen, moisture and inorganic acid vapours on metal..

Example, turnishing of silver ware in H_2S laden air.

- **Electrochemical (or wet)corrosion:** It occurs due to setting up of a large number of tiny galvanic cells in metals in presence of an impurity as well as in presence of moisture. Generally impurity (more active metal) act as anode and original metal act as cathode so anode is the area where corrosion occurs.

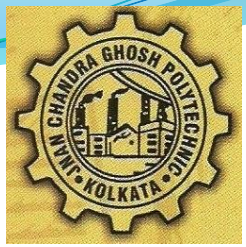
Example, rusting of iron in moist atmosphere.

Dry or Chemical Corrosion

- Occurs
  - Due to direct chemical reaction of atmospheric gases
  - Due to molten metal in contact with metal surface

- Types
  - Oxidation corrosion
  - Corrosion by gases
  - Liquid Metal Corrosion

Types of dry corrosion



Oxidation corrosion

Occurs

- **due to direct chemical reaction of atm. O2 with metal surface forming metal oxide**
- **Absence of moisture**
- **Increases with increase in temp.**

Mechanism

- on exposure to atm., metal gets oxidized to form metal ions

(i) $M\ (S) \longrightarrow M^{+n} + ne^-$

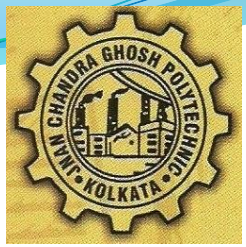
- Electrons lost by metal are taken up by oxygen to forms oxide ions

(ii) $1/2O_2\ (g) + 2e^- \longrightarrow O^{2}$

$$2M + n/2O_2 \longrightarrow 2M^{+n} + nO^{2-} \longrightarrow M_2On$$

Metal Oxide

Nature of metal oxide layer



- Types of Layers

- Stable Layer: - Al, Pb, Cu, Sn
- Unstable Layer :- Ag, Au, Pt
- Volatile Layer:- Mo
- Porous Layer:- Alkali metals &alkaline earth metals

- Pilling – Bed Worth Rule

A protective and Non-Porous metal oxide layer has volume equal to or greater than the volume of metal from which it is formed.

A Non-Protective and Porous metal oxide layer has volume lesser than the volume of metal from which it is formed.

$$\textbf{Specific Volume Ratio} = \frac{\textbf{Volume of oxide formed}}{\textbf{Volume of metal}}$$

Types of dry corrosion

Corrosion by Other Gases

- $2AgCl + Cl_2 \rightarrow AgCl$
- (Non-Porous layer)
- $Fe + H_2S \rightarrow FeS + H_2$
- (Porous Layer)
- $Sn + 2Cl_2 \rightarrow SnCl_4$
- (Volatile Layer)

Liquid Metal Corrosion

- Occurs due to the action of flowing liquid metal at high temp on solid metals or alloys.
- Observed in nuclear reaction where Na metal used as a coolant leads to corrosion of Cd.

Wet or Electrochemical or Immersed Corrosion

Occurs

- When a metal is contact with moist air or any liquid medium
- When two diff. metals are partially immersed in a soln.
- Chemically non- uniform surfaces of metals behave like electochemical cells in the presence of water containing dissolved O_2 & CO_2
- Always occurs at anodic areas

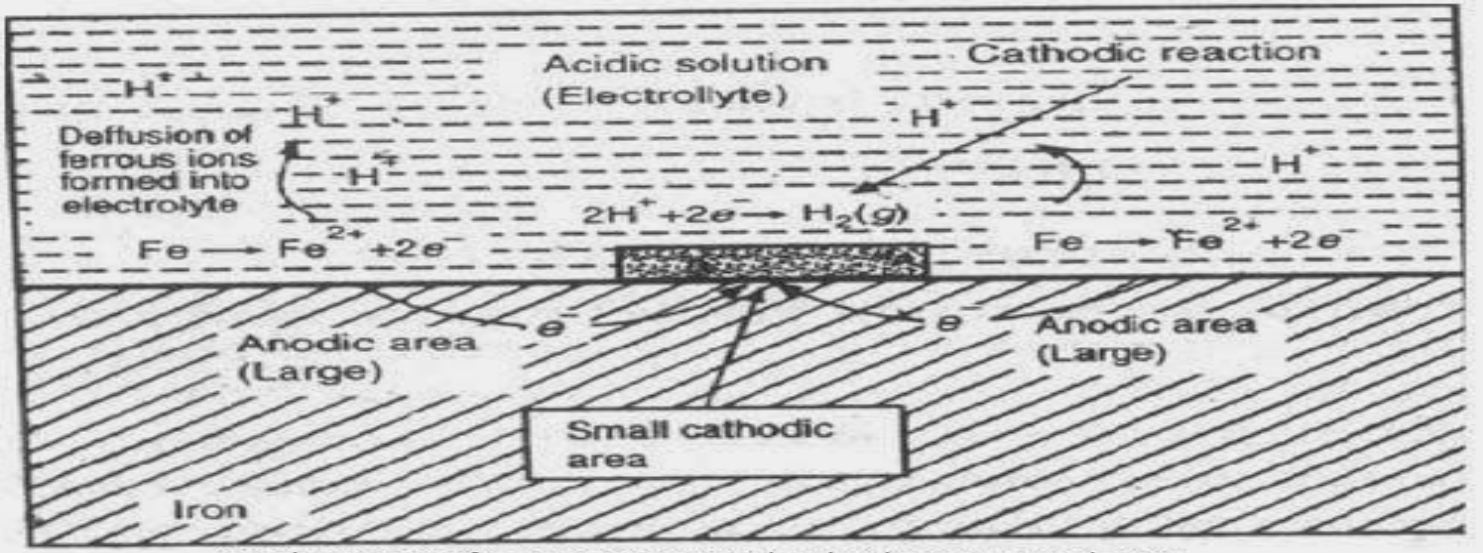
Mechanism

- Involves oxidation- reduction process
- depending on the nature of corroding enviornment, electrons released at anode are consumed at the cathodic area by two ways :

❖ Evolution of H_2

❖ Absorbtion of O_2

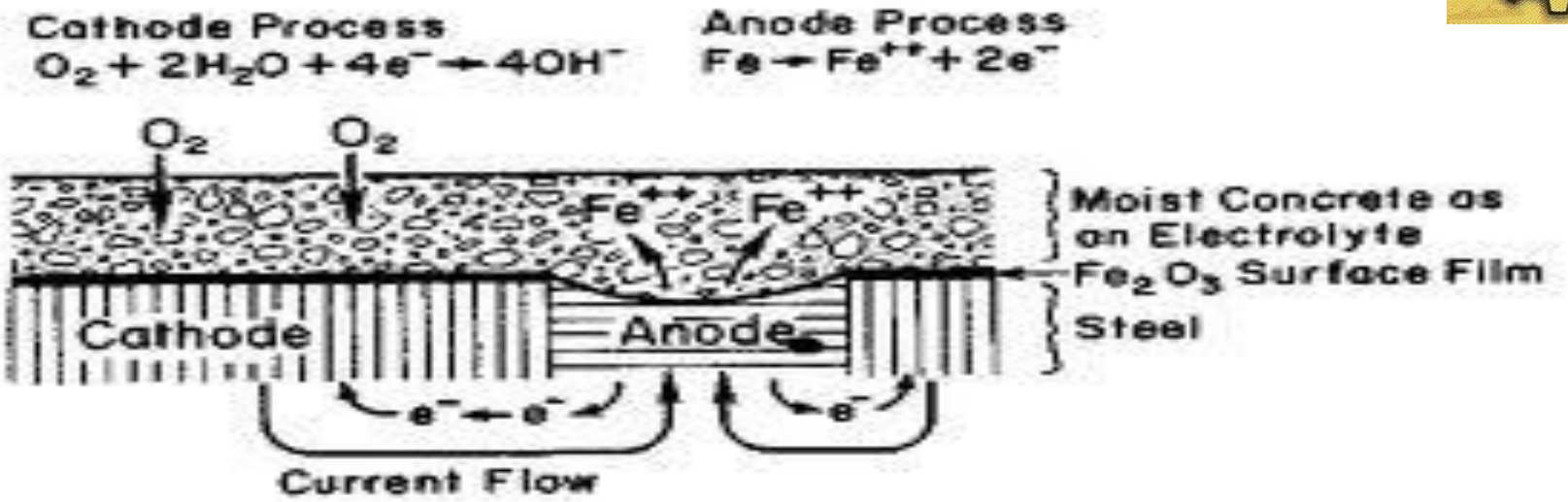
Mechanisms Of Corrosion by H2 Evolution



Mechanism of wet corrosion by hydrogen evolution

- Anode :
- M (S) $\longrightarrow$ M^{+n} + ne^- (Oxidation)
- **Cathode :**
- $2H^+ + 2e^-$ $\longrightarrow$ H_2 (g) (Reduction)
- **Over All Rxn :**
- $2M\ (S) + 2n\ H^+ \longrightarrow 2M^{+n} + nH_2\ (g)$

Mechanisms Of Corrosion by O_2 Absorbtion



- **Anode :**
- M (S) $\longrightarrow$ $M^{+n} + ne^-$ (Oxidation)
- **Cathode :**
- $O_2 + 4e^- + 2H_2O \longrightarrow 4OH^-$ (Reduction)
- **Over All Rxn :**
- $4M (S) + 2nH_2O \longrightarrow 4M^{+n} + 4OH^-$

Rusting of Iron

$$Fe \rightarrow Fe^{2+} + 2e^-$$

$$O_2 + 4e^- + 2H_2O \rightarrow 4OH$$

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$$

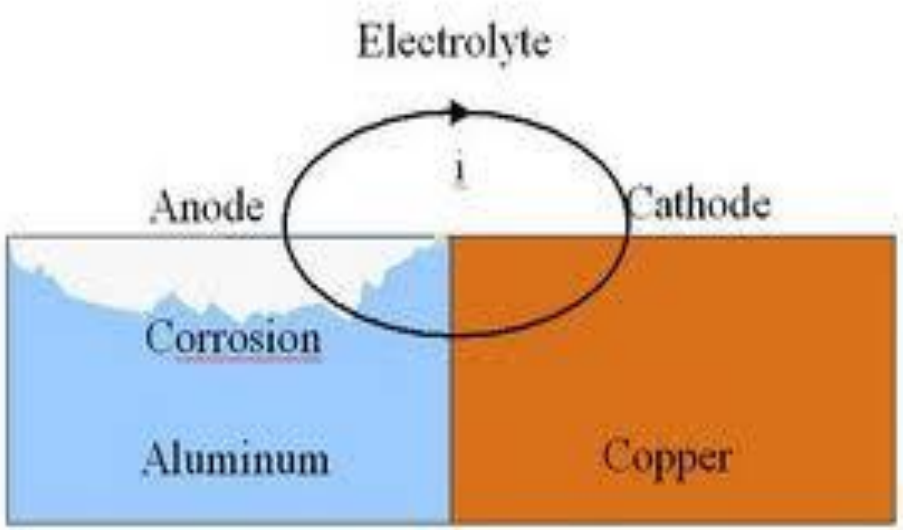
$$4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 + 4H_2O$$

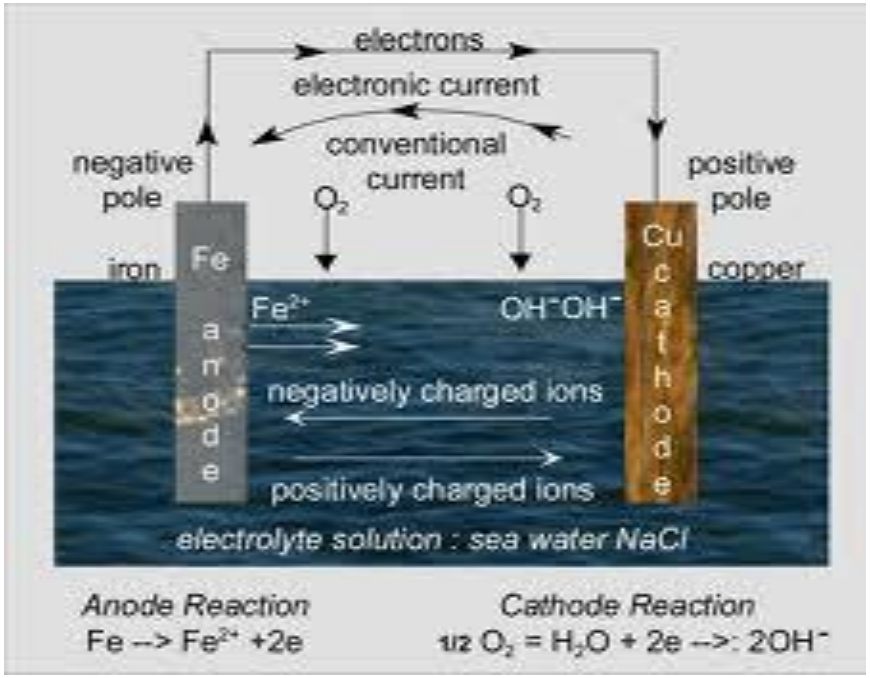
Difference between Dry & Wet Corrosion

Dry Corrosion	Wet Corrosion
Occurs in the absence of moisture	Occurs in the presence of conducting medium
Involves direct attack of chemicals on the metal surface	Involves formation of electrochemical cells
Slow Process	Rapid Preocess
Corrosion products are produced at the site of corrosion	Corrosion occurs at anode but rust is deposited at cathode
Process of corrosion is uniform	Depends on the size of the anodic part of the metal

Types of electrochemical corrosion

- **Galvanic Corrosion:-** When two different metals are present in contact with each other in conducting medium





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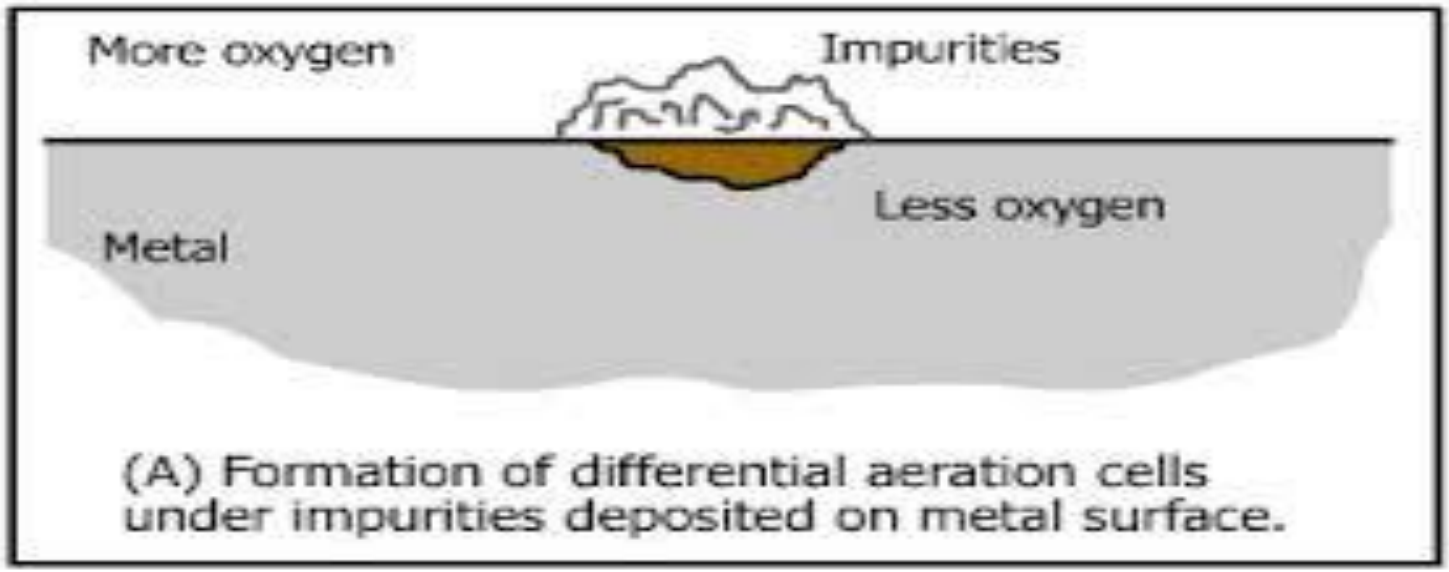
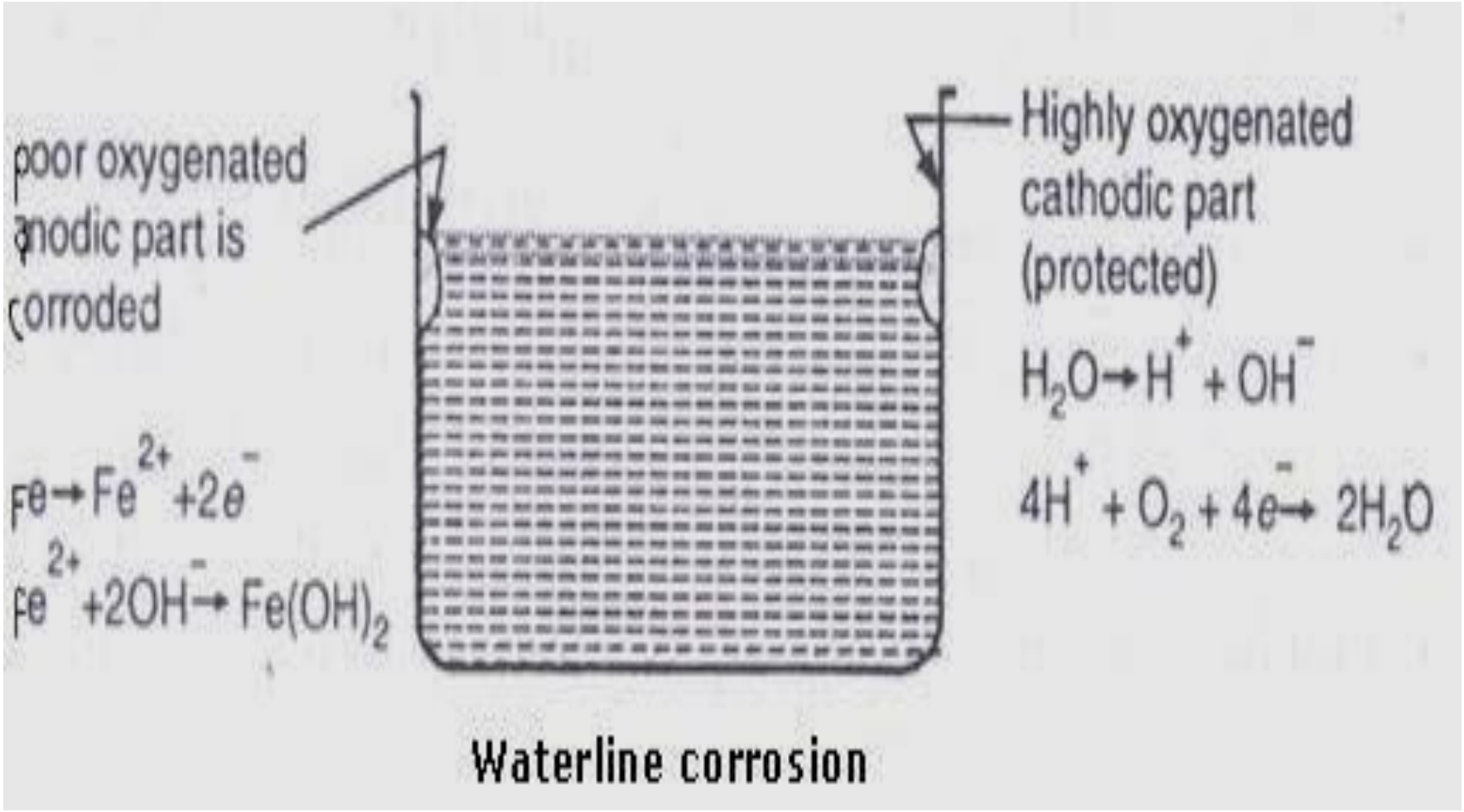
Conc. Cell or Differential Aeration Corrosion

- Occurs due to diff. in potential between differently aerated areas
- Part of metal exposed to air is more oxygenated part & acts as CATHODE
- Part of metal immersed in electrolyte is poorly oxygenated & acts as ANODE



(A) Formation of differential aeration cells under impurities deposited on metal surface.

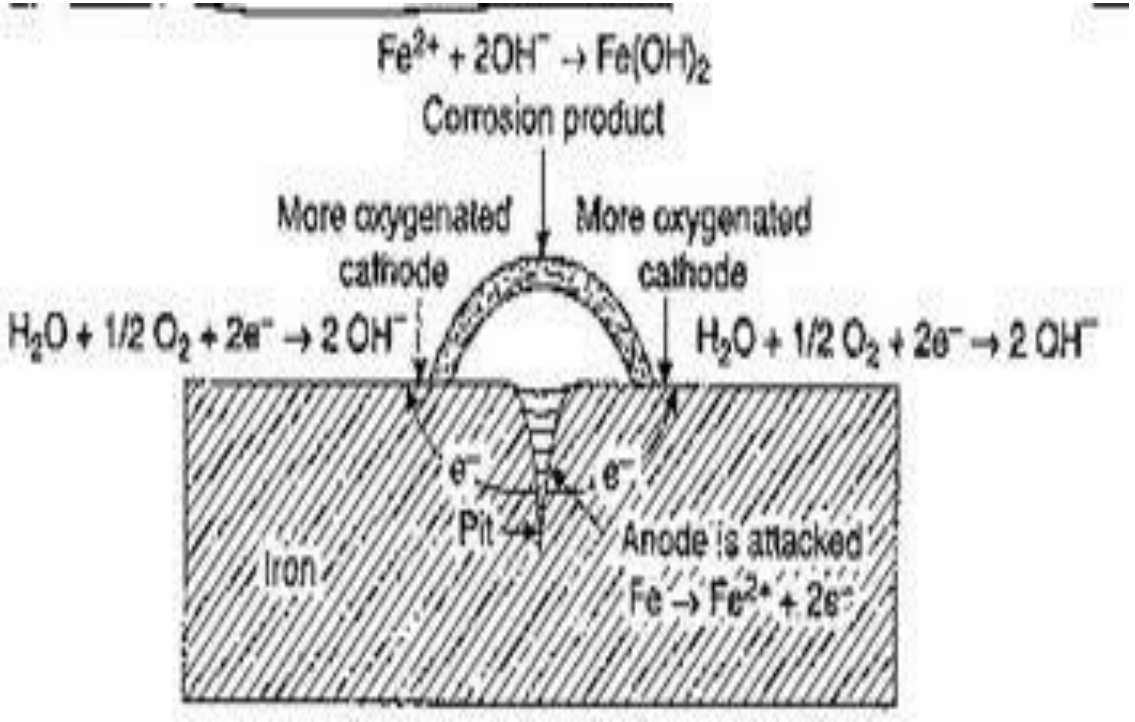
Water Line Corrosion



Waterline corrosion

Pitting Corrosion

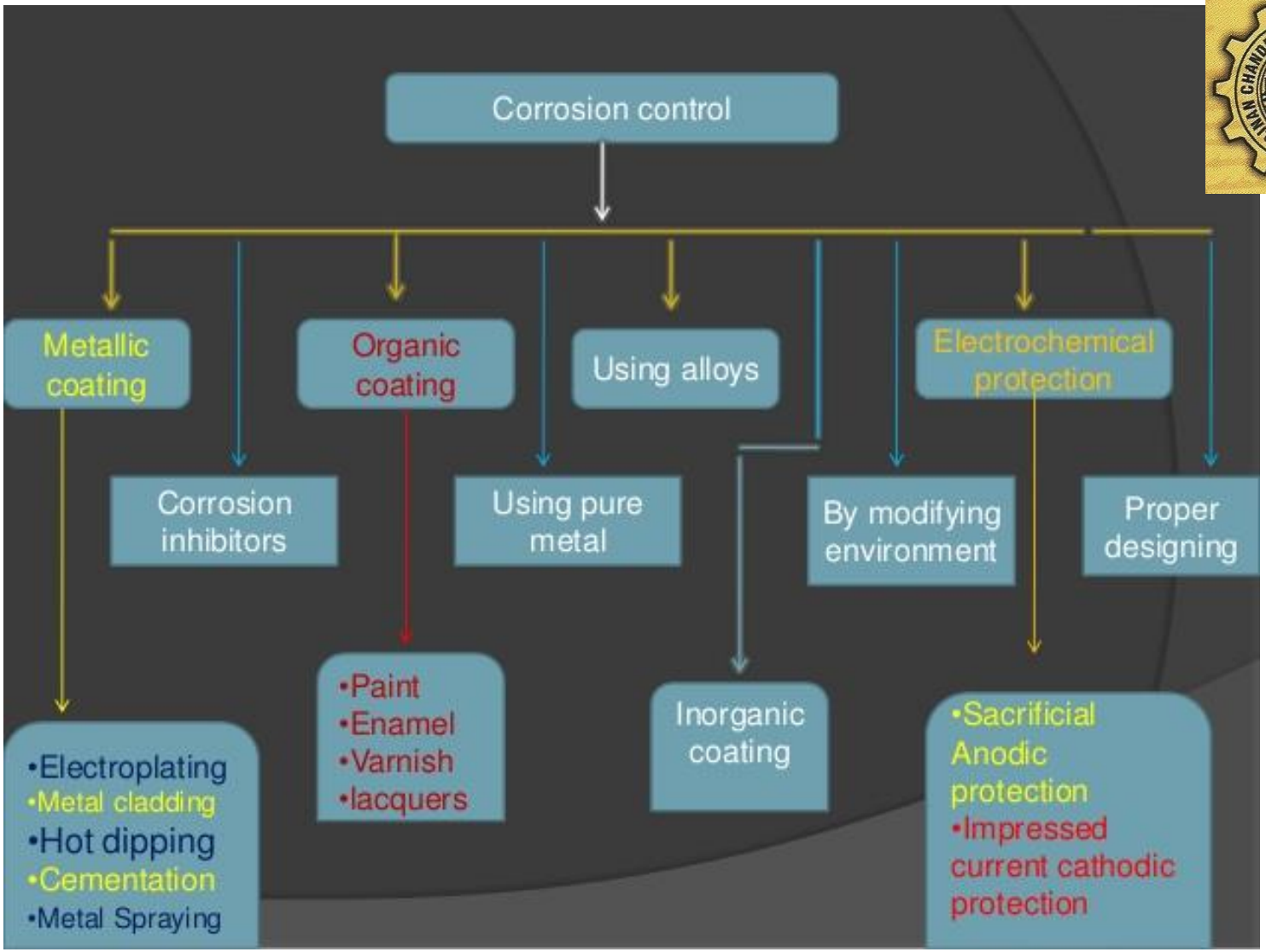
- Formed as a result of pit and cavities
- Localized attack and formed by cracking protective coating



Factors Affecting Corrosion

- **Nature of Metal**
  - Purity of metal
  - Physical state of metal
  - Position of metal in Galvanic series
  - Nature of oxide fim
  - Nature of products of corrosion
  - Relative areas of Cathode & anode
- **Nature of Corroding Environment**
  - Temp. & Humidity
  - Effect of pH
  - Presence of impurities in atm.
  - Nature of electrolyte
  - Solubility of products of corrosion

Protective Measures Against Corrosion



Prevention of corrosion

There are many methods of protecting metals against corrosion

- Barrier protection
- Sacrificial protection
- Cathodic protection
- Alloy formation

Barrier protection :

Here, a thin barrier is developed between the surface of iron and atmosphere by one of the following methods:

a) Painting of the surface

b) Coating the surface with a thin film of some non –corrosive metal like nickel, chromium copper etc.

Prevention of corrosion(contd)…

Coating the metal : In order to prevent corrosion, resistant coating is made between metal and environment. Different types of metallic coatings are

- Galvanizing (thin coating of Zn on iron)
- Electroplating (coating of Cu, Ni or Cr on iron with aid of direct current.
- Tin plating (coating of tin on iron)
- Sheradizing (it consists of dusting of Zn powder on iron surface followed by heating)
- Cladding

Prevention of corrosion(contd)…

Alloying the metal

Metal has better resistance to corrosion after forming alloy with other metal , e.g. stainless steel, in which ordinary steel is alloyed with chromium and nickel.

There are two kinds of alloys:

Homogeneous alloys are solid solutions in which the components are components are completely soluble in one another, e.g stainless steel

Heterogeneous alloys are the mixtures of two or more separate phases. The components of such alloy are not soluble and exist as separate phase.

Solid solution alloys are more corrosion resistant.

•Chromium is used as alloying metals for iron and steel.

• Silicon is also used in making Si-Fe alloy

Prevention of corrosion(contd).

Sacrificial protection:

In this case, the surface of iron is covered with a more electropositive metal like zinc or aluminum. Since this metal loses electrons more readily than iron, rusting is prevented. As long as metal is present, iron does not get rusted. This type of protection is called 'sacrificial production'.

Cathodic protection (Electrical protection):

It is protection of the parent metal from corrosion by connecting with a more active metal like Mg, Al, Zn etc. The more electropositive (active) metal acts like anode (supplies electrons) and parent metal acts like cathode (receives electrons). Thus, connected metal undergoes corrosion thereby protecting the parent metal from corrosion by turning it as a cathode. Hence, the method is called 'cathodic protection'.

Weblink: http://nptel.ac.in/courses/113104061/21

http://nptel.ac.in/courses/113108051/16

Protective Measures Against Corrosion

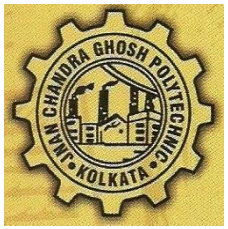
- Metallic Coating :

- Electroplating : A coating metal is deposited on the base metal by passing direct current through an electrolytic soln.
- Metal Cladding : The base metal to be protected and coating metal are sandwiched by presssing through rollers under the action of heat & pressure.
- Hot Dipping : The base metal to be coated is immersed in a bathof the molten coating metal.
- Cementation : A uniform surface coating is obtained by heating the base metal in a power of coating metal.
- Metal spraying : The coating metal in molten state is sprayed on base metal by means of spraying gun.

Protective Measures Against Corrosion

- Organic Coating :
  - Apply on metallic surface for protection from corrosion & also to impart decorative value. Such as paints, enamel, Varnishes & lacquers
- Corrosion Inhibitors :
  - Substances which when added in a small amount in an environment reduces the rate of corrosion of a metal exposed to that enviornment. These are of two types Cathodic & anodic
- Inorganic Coatings : are produced by chemical or electrochemical reactions at a metal surface to protect base metal from corrosion eg. : phophates, oxides etc.
- Using Pure Metal :
- Using Alloys :

Protective Measures Against Corrosion



- By Modifying Environment :
- By lowering the temp.
- By reducing the moisture
- By reducing the acidic corrosion environment
- Proper Designing :
- Proper designing of the equipment
- Avoid the direct contact of dissimilar metals
- Electrochemical Protection or Cathodic Protection :
- Sacrifical Anodic Protection : Metal to be protected is connected to more anodic metal to avoid corrosion
- Impressed Current Cathodic Protection : This process consists of connecting the material to be protected to –ve terminal of DC source& +ve terminal of DC source is connected toa insoluble anode . The current supplied is in opposite direction to the corrosion current.Thus the metal to be protected act as cathode & get protected.

Text books for reference

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