UNIT-4

CORROSION AND ITS CONTROL

4.1INTRODUCTION:

Corrosion is defined as the slow and continuous destruction of metals or alloys by the chemical or electrochemical reaction with its environment.

Corrosion is an undesirable process. Due to corrosion, there is limitation of progress in many areas. The cost of replacement of materials and equipment lost through corrosion is unlimited.

Metals and alloys are used as fabrication or construction materials in engineering. If the metals or alloy structures are not properly maintained, they deteriorate slowly by the action of atmospheric gases, moisture, and other chemicals. This phenomenon of destruction of metals and alloys is known as corrosion. Corrosion of metals is defined as the s spontaneous destruction of metals due to chemical, electrochemical or biochemical interactions with the environment. Thus, it is exactly the reverse of extraction of metals from ores.

Example: Rusting of iron. A layer of reddish scale and powder of oxide (Fe_3O_4) is formed on the surface of iron metal.

CAUSES OF CORROSION:

In nature, metals occur in two different forms.

1) Native State (2) Combined State

Native State: The metals exist as such in the earth crust then the metals are present in a native state. Native state means free or uncombined state. These metals are non-reactive in nature. They are noble metals which have very good corrosion resistance. Example: Au, Pt, Ag, etc.,

Combined State: Except noble metals, all other metals are highly reactive in nature which undergoes reaction with their environment to form stable compounds called ores and minerals. This is the combined state of metals. Example: Fe_2O_3, ZnO, PbS, $CaCO_3$, etc.,

Metallic Corrosion: The metals are extracted from their metallic compounds (ores). During the extraction, ores are reduced to their metallic states by applying energy in the form of various processes. In the pure metallic state, the metals are unstable as they are considered in excited state (higher energy state). Therefore, as soon as the metals are extracted from their ores, the reverse process begins and form metallic compounds, which are thermodynamically stable(lower energy state).
Hence, when metals are used in various forms, they are exposed to environment, the exposed metal surface begin to decay (conversion to more stable compound). This is the basic reason for metallic corrosion.

Although corroded metal is thermodynamically more stable than pure metal but due to corrosion, useful properties of a metal like malleability, ductility, hardness, luster, and electrical conductivity are lost.

Corrosion factors

Environmental Conditions:

- **Moisture:** Water or high humidity can accelerate corrosion by providing a medium for electrochemical reactions.
- **Temperature:** Higher temperatures generally increase the rate of corrosion by speeding up chemical reactions.

- **Presence of Salts:** Salts, especially chlorides like sodium chloride (common table salt), can accelerate corrosion, often seen in coastal environments where sea spray contains salt.

Material Properties:

- **Metal Composition:** Different metals have different susceptibilities to corrosion. For instance, iron corrodes easily, while stainless steel resists corrosion better due to its chromium content.
- **Protective Coatings:** Metals with protective coatings, such as paint or galvanization, are less likely to corrode because these coatings act as barriers to environmental elements.

Electrical Factors:

- **Galvanic Corrosion:** This occurs when two different metals are in contact in the presence of an electrolyte (like water), leading to one metal corroding faster than the other.

Mechanical Factors:

- **Stress and Strain:** Physical stress on a material can make it more susceptible to corrosion, especially if it leads to the formation of cracks or other defects.

Pollutants:

- **Industrial Pollution:** Gases such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) can contribute to acid rain, which accelerates the corrosion of metals.

TYPES OF CORROSION:

Chemical Corrosion(or) Dry Corrosion

Definition

Direct attack of metals with atmospheric gases such as O_2 , H_2S ,SO_2, N_2 etc in the absence of moisture.

Types of Chemical Corrosion

i) Corrosion due to O_2 (oxidation Corrosion)
ii) Corrosion due to H_2.
iii) Liquid Metal corrosion.

i) Corrosion due to O_2

Direct attack of Metal with oxygen in the atmosphere in the absence of moisture.

Mechanism

- Metals undergo oxidation resulting in the formation of Metal ion.

$$M \longrightarrow M^{2+} + 2e^-$$

- Oxygen in the atmosphere absorbs the electron released by Metal ion to form oxide ion

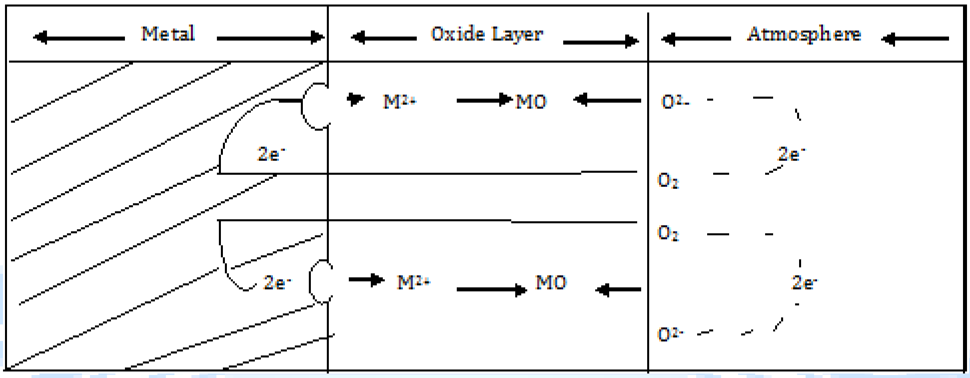
$$\tfrac{1}{2} O_2 + 2e^- \longrightarrow O^{2-}$$

- Metal ion reacts with oxide ion to form Metal –oxide film

$$M^{2+} + O^{2-} \longrightarrow MO$$

- For further corrosion metal ion diffuses outward through Metal oxide layer or the oxide ion diffuse inward through Metal oxide layer.

- Both processes are possible that depends on nature of layer formed above the metal surface.



Types of layer formed during chemical corrosion are

i) Stable layer
ii) Unstable layer
iii) Volatile layer
iv) Protective and Non protective layer

Pilling Bed worth rule

The ratio of volume of oxide layer formed to the volume of metal consumed is Pilling Bed worth rule.

According to this rule,

a) If volume of oxide layer formed is less than volume of metal, the oxide layer is porous and non- protective.

$V_{MO} < V_M$; porous & Non –protective (eg) Oxides of Na, ca, Mg

b) If volume of oxide layer formed is greater than volume of Metal, the oxide layer is Non –porous and protective

$V_{Mo} > V_M$; Non- porous & protective

(eg) Oxides of Pb & Sn

ii) Corrosion due to H_2

The direct attack of Metals with hydrogen present in the atmosphere in the absence of moisture.

Types

a) Hydrogen Embrittlement (Hydrogen Blistering)

b) Decarburization

a) Hydrogen Embrittlement

When a metal is exposed to atmosphere containing H_2S at ordinary temperature , atomic hydrogen is formed.

$$Fe + H_2S \longrightarrow FeS + 2H$$

Atomic hydrogen diffuses readily into voids and form molecular hydrogen

$$H + H \longrightarrow H_2 \uparrow$$

Collection of these gases in voids develop pressure that causes cracks and blisters.

This process is Hydrogen blistering or hydrogen Embrittlement.

b) Decarburization

Removal of carbon from steel is called decarburization.

At high temperature atomic hydrogen is formed by thermal dissociation of molecular hydrogen.

$$H_2 \xrightarrow{heat} 2H$$

When steel is exposed to this environment , atomic hydrogen combines with carbon in steel and forms CH_4 gas.

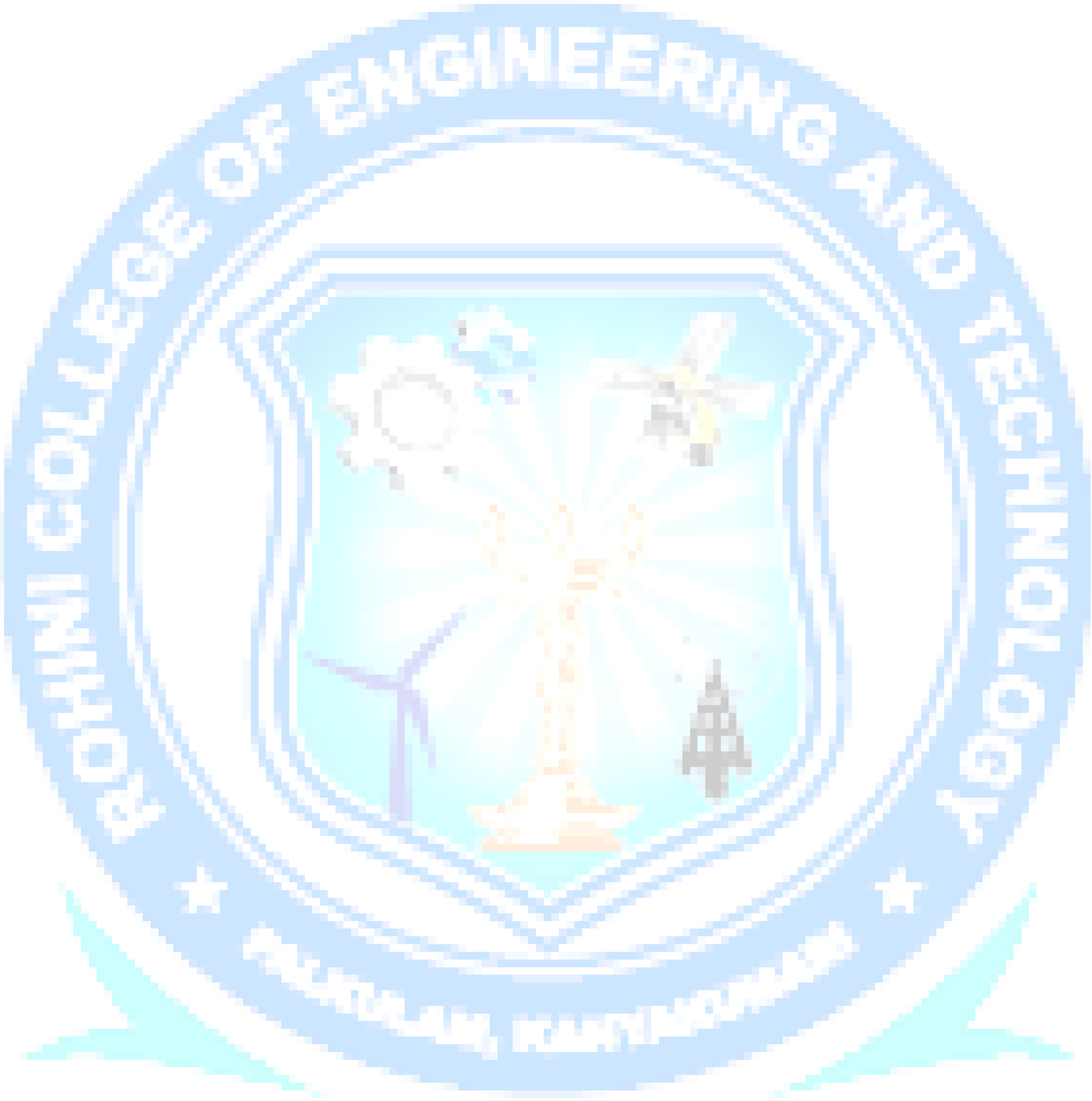
$$C + 4H \longrightarrow CH_4 \uparrow$$

Collection of these gasses in voids produce cracks.

iii) Liquid – Metal Corrosion.

In this type , corrosion occurs either by

a) Dissolution of solid metal by a liquid metal
b) Liquid metal may penetrate into solid metal.



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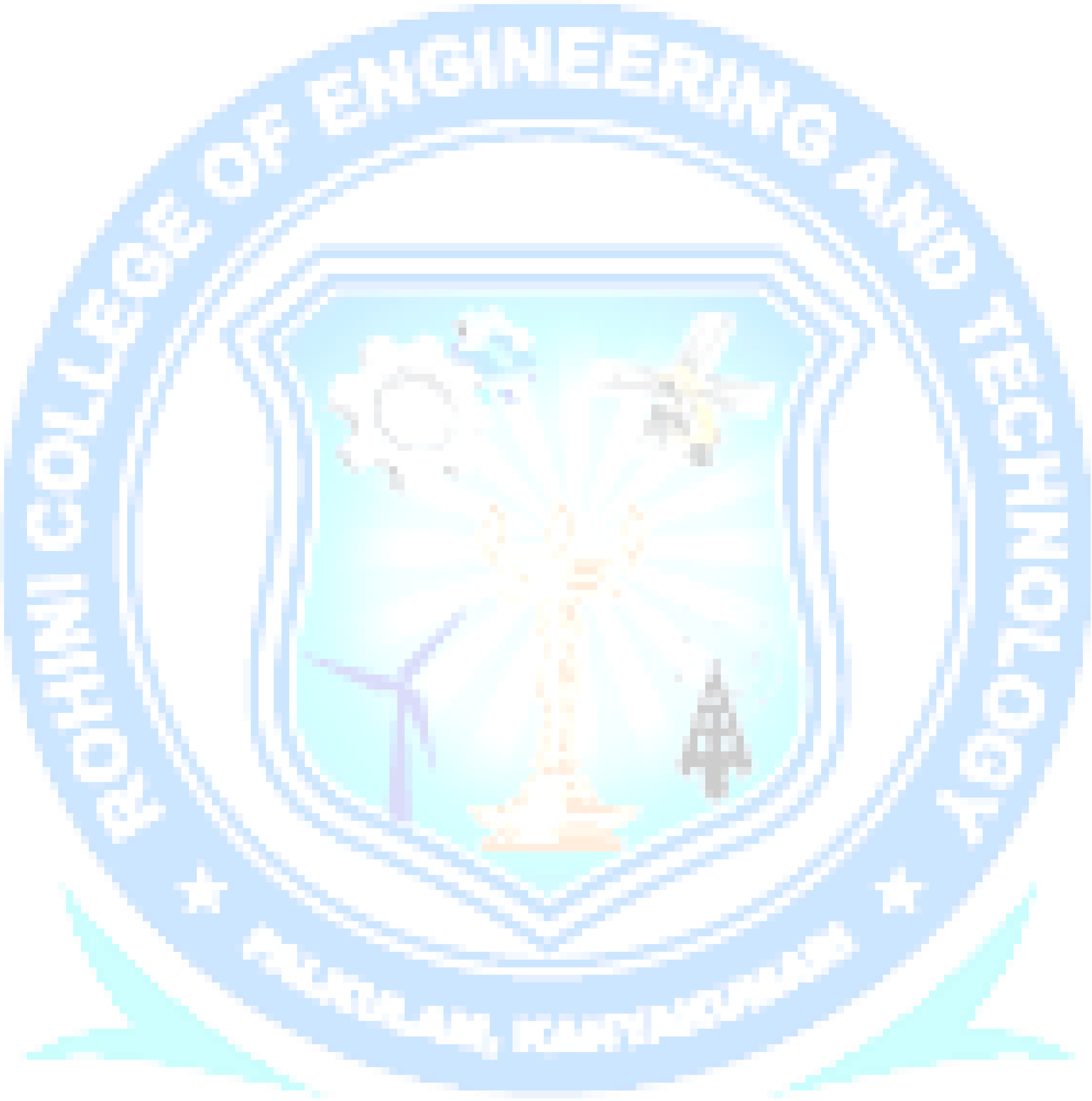
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