TOPIC:Material of Pharmaceutical Plant Construction , Corrosion and its Prevention

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Corrosion is a process of formation of the compound of pure metal by the chemical reaction between metallic surface and its environment.

It is an oxidation process. It causes loss of metal.

Hence, disintegration of a metal by its surrounding chemicals through a chemical reaction on the surface of the metal is called corrosion.

Example: Formation of rust on the surface of iron, formation of green film on the surface of copper.

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DIFFERENTTHEORIES OF CORROSION

- Acid theory
- Dry or chemical corrosion
- Galvanic or electrochemical

This theory suggests that corrosion of a metal (iron) is due to the presence of acids surrounding it.

According to this theory, iron is corroded by atmospheric carbon di-oxide, moisture and oxygen. The corrosion products are the mixture of $Fe(HCO_3)_2$, $Fe(OH)CO_3$ and $Fe(OH)_3$.

CHEMICAL THEORY

- According to this theory, corrosion on the surface of a metal is due to direct reaction of atmospheric gases like oxygen, halogens, oxides of sulphur, oxides of nitrogen, hydrogen sulphide and fumes of chemicals with metal.
- The extent of corrosion of a particular metal depends on the chemical affinity of the metal towards reactive gas.
- Oxygen is mainly responsible for the corrosion of most metallic substances when compared to other gases and chemicals

Wet or electrochemical theory of corrosion

- It is a common type of corrosion of metal in aqueous corrosive environment. This type of corrosion occurs when the metal comes in contact with a conducting liquid or when two dissimilar metals are immersed or dipped partly in a solution.
- According to this theory, there is the formation of a galvanic cell on the surface of metals. Some parts of the metal surface act as anode and rest act as cathode.
- The chemical in the environment and humidity acts as an electrolyte.
- Oxidation of anodic part takes place and it results in corrosion at anode, while reduction takes place at cathode.
- The corrosion product is formed on the surface of the metal between anode and cathode.
- The chemical in the environment and humidity acts as an electrolyte.
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Factors Influencing Corrosion

The nature and extent of corrosion depend on the metal and the environment. The important factors which may influence the corrosion process are

(i) Nature of the metal

(ii) Environment

(iii) Concentration of electrolyte

(iv) Temperature

(v) Electrode potential and

(vi) Hydrogen over voltage

TYEPS OFCORROSION

I. Uniform corrosion

II. Pitting corrosion

III. Transgranular and Intergranular (Intercrystalline) corrosion

IV. Exfoliation corrosion

V. Stress corrosion

VI. Crevice corrosion

VII. Galvanic corrosion

VIII. Erosion

UNIFORM CORROSION

This type of corrosion develops as pits of very small diameter, in the order of a micrometer, and results in a uniform and continuous decrease in thickness over the entire surface area of the metal.

The rate of uniform corrosion can be easily determined by measuring the mass loss, or the quantity of released hydrogen.

PITTING CORROSION

This localized form of corrosion is characterized by the formation of irregularly shaped cavities on the surface of the metal. Their diameter and depth depend on several parameters related to the metal, the medium and service conditions.

Unlike uniform corrosion, the intensity and rate of pitting corrosion can be assessed neither by determining the mass loss nor by measuring released hydrogen.

III.Transgranular and Intergranular (Intercrystalline) corrosion

It spreads in all directions, corrosion indifferently affects all the metallurgical constituents; there is no selective corrosion.

Exfoliation Corrosion

Exfoliation corrosion is a type of selective corrosion that propagates along a large number of planes running parallel to the direction of rolling or extrusion.

Between these planes are very thin sheets of sound metal that are not attacked, but gradually pushed away by the swelling of corrosion products, peeling off like pages in a book; hence the term exfoliation corrosion.

The metal will swell, which results in the spectacular aspect of this form of corrosion.

Stress corrosion

This type of corrosion results from the combine action of a mechanical stress (bending, tension) and a corrosive environment.

Each of these parameters alone would not have such a significant effect on the resistance of the metal or would have no effect at all.

Crevice corrosion

Crevice corrosion is a localized corrosion in recesses :

overlapping zones for riveting, bolting or welding, zones under joints and under various deposits. These zones also called crevices, are very tiny and difficult to access for the aqueous liquid that is covering the rest of the readily accessible surfaces.

This type of corrosion is also known as deposit attack.

Galvaniccorrosion

When two dissimilar metals are in direct contact in a conducting liquid, experience shows that one of the two may corrode. This is called galvanic corrosion. The other metal will not corrode; it may even be protected in this way.

This corrosion is different in its kind and intensity from the one that would occur if they were placed separately in the same liquid.

Unlike other types of structural corrosion, galvanic corrosion does not depend on the metal's texture, temper, etc.

Galvanic corrosion may occur with any metal, as soon as two are in contact in a conductive liquid. It works like a battery.

The appearance of galvanic corrosion is very characteristic. It is not dispersed like pitting corrosion, but highly localized in contact zone with the other metal.

The zone affected by galvanic corrosion often has a shinier aspect than the rest of the surface.

Erosion

Corrosion by erosion occurs in moving media. This type of corrosion is related to the flow speed of the fluid.

It leads to local thinning of the metal, which results in scratches, gullies, and undulations, which are always oriented in the same direction, namely the flow direction.

CORROSION AND ITS PREVENTION

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 pharmaceuticals. 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 spontaneous destruction of metals in the course of their 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. A green film of basic carbonate [$CuCO_3$ + Cu $(OH)_2$] is formed on the surface of copper, when it is exposed to moist-air containing carbon dioxide

EFFECTS OR CONSEQUENCES OF CORROSION:

The economic and social consequences of corrosion include:

Due to formation of corrosion product over the machinery, the efficiency of the machine gets failure leads to plant shut down.

The products contamination or loss of products due to corrosion.

The corroded equipment must be replaced.

Preventive maintenance like metallic coating or organic coating is required.

Corrosion releases the toxic products.

Health (e.g., from pollution due to a corrosion product or due to the escaping chemical from a corroded equipment).

CAUSES OF CORROSION:

In nature, metals occur in two different forms.

- *Native State*
- *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.

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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.

Corrosion-Oxidation

Metal----------Metallic Compound + Energy

Metallurgy-Reduction

Although corroded metal is thermodynamic-ally 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 BY OTHER GASES (BY HYDROGEN):

1) **Hydrogen Embrittlement:**Loss in ductility of a material in the presence of hydrogen is known as hydrogen embrittlement .

Mechanism:

This type of corrosion occurs when a metal is exposed to hydrogen environment. Iron liberates atomic hydrogen with hydrogen sulphide in the following way.

$Fe + H2S \rightarrow FeS + 2H$

Hydrogen diffuses into the metal matrix in this atomic form and gets collected in the voids present inside the metal. Further, diffusion of atomic hydrogen makes them combine with each other and forms hydrogen gas.

$H + H \rightarrow H2\uparrow$

Collection of these gases in the voids develops very high pressure, causing cracking or blistering of metal.

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2) Decarburization:

The presence of carbon in steel gives sufficient strength to it. But when steel is exposed to hydrogen environment at high temperature, atomic hydrogen is formed.

H2 ----------> 2H

Atomic hydrogen reacts with the carbon of the steel and produces methane gas.

C + 4H → CH4

Hence, the carbon content in steel is decreases. The process of decrease in carbon content in steel is known as decarburization.

Collection of methane gas in the voids of steel develops high pressure, which causes cracking. Thus, steel loses its strength.

School of medical and Allied Sciences

Course Code : BPHT3004 **Course Name: Pharmaceutical Engineering**

Name of the Faculty: Dr. Shikha Yadav **Program Name:Pharmacy**

3) Liquid metal corrosion:

This is due to chemical action of flowing liquid metal at high temperatures on solid metal or alloy. Such corrosion occurs in devices used for nuclear power. The corrosion reaction involves either: (i) dissolution of a solid metal by a liquid metal or (ii) internal penetration of the liquid metal into the solid metal. Both these modes of corrosion cause weakening of the solid metal.

TYPES OF ELECTROCHEMICAL CORROSION:

The electrochemical corrosion is classified into the following two types:

(i) Galvanic (or Bimetallic) Corrosion

(ii) Differential aeration or concentration cell corrosion.

Galvanic Corrosion:

When two dissimilar metals (eg. zinc and copper) are electrically connected and exposed to an electrolyte, the metal higher in electrochemical series undergoes corrosion. In this process, the more active metal (with more negative electrode potential) acts as a anode while the less active metal (with less negative electrode potential) acts as cathode.

In the above example, zinc (higher in electrochemical series) forms the anode and is attacked and gets dissolved; whereas copper (lower in electrochemical series or nobler) acts as cathode.

Explanation: If a metal is partially immersed in a conducting solution the metal part above the solution is more aerated and becomes cathodic. The metal part inside the solution is less aerated and thus becomes anodic and suffers corrosion.

At anode: Corrosion occurs (less aerated) $M \rightarrow M^{2+} + 2e^-$

At cathode: OH^- ions are produced (more aerated) $\frac{1}{2} O_2 + H_2O + 2e^- \rightarrow 2OH$

Factors affecting selection of an engineeringmaterial

- Physical
- Chemical
- Economy

PHYSICAL

- Strength
- Mass
- Wear and tear
- Thermal conductivity
- Thermal Expansion
- Cleansing
- Sterilization
- Transparency

CHEMICAL

- Contamination
- Reactivity with chemicals

Classification ofmaterial

- **Metal**

  Ferrous

  - Cast Iron
  - Steel Carbon
  - Stainless steel
  - Nickel
  - Lead

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