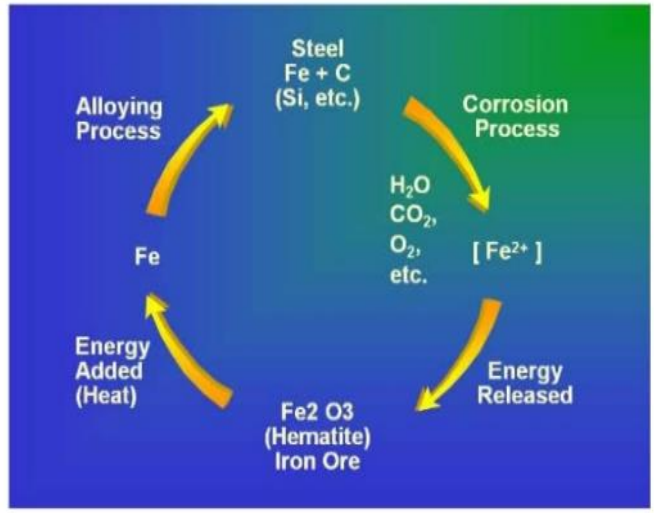
Topic: Corrosion: Methods to prevent Corrosion

Introduction

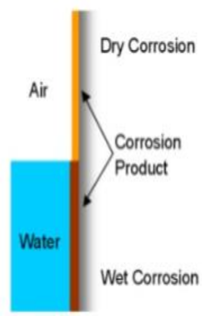
- Corrosion is natural phenomenon which attacks metal by chemical, electrochemical action converts metal into metallic compound , such as an oxide , hydroxide or sulphate.
- Destruction or deterioration and consequent loss of solid metallic materials , starting at its surface due to chemical or electro chemical attack, by their environment.
- Corrosion is major problem worldwide in all industrial sectors.
- It impacts on safety , health and environmental issues .



Corrosion cycle

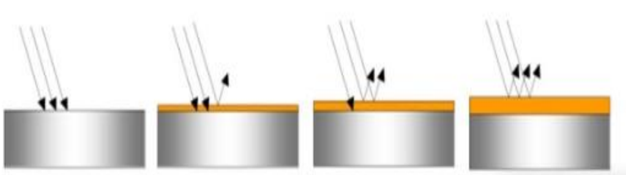
Classification of Corrosion

- **on the basis of working temperature**
  - i) Low temperature Corrosion
  - ii) High temperature Corrosion
- **on the basis of working environments**
  - i) Dry or Chemical Corrosion
  - ii) Wet or Electrochemical Corrosion

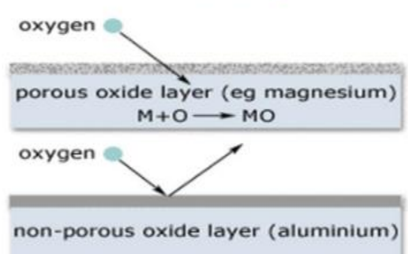


i) Dry or Chemical Corrosion

- It occurs when oxygen in air reacts with metal , without presence of liquid.
- It is very sensitive to temperature
- Rate of dry corrosion varies from metal to metal , as a result of mechanisms involved.
- Oxide layer on steel & iron is known as rust.



- In aluminum , copper oxide layer formed due to reaction with atmospheric oxygen ,stops further corrosion.
- As oxide layer formed , prevents further contact of oxygen as film is non porous.
- This stopping is known as Passivations.
- Active Corrosion- steel, CI , Mg.



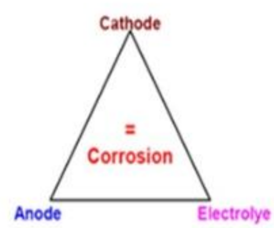
ii) Wet or Electrochemical Corrosion

- It is electrochemical phenomenon , which occurs in galvanic cell.
- Particularly when two metals are in contact with a liquid , liquid containing salt and electric potential is formed between the metals.
- in some cases in single metal , when comes in contact with liquid or electrolyte , a anode and cathode areas are created.
- When anode area starts corroding with respect to cathode areas , is termed as wet corrosion.

DRY CORROSION	WET CORROSION
• Corrosion occurs in the absence of moisture.	• Corrosion occurs in presence of conducting medium.
• It involves direct attack of chemicals on the metal surface.	• It involves formation of electrochemical cells.
• The process is slow.	• It is a rapid process.
• Corrosion products are produced at the site of corrosion.	• Corrosion occurs at anode but rust is deposited at cathode.
• The process of corrosion is uniform.	• It depends on the size of the anodic part of metal.

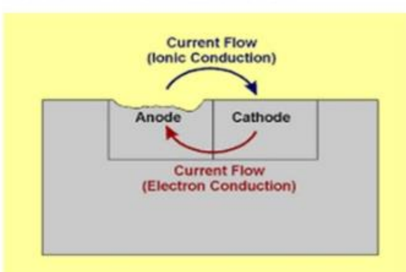
Causes of Corrosion

- Pure or noble metals such as gold, silver, platinum, aluminum , copper do not corrode since they are chemically uncombined in their natural state.
- Following conditions must exist before corrosion.
  i) Presence of metal that will corrode (anode)
  ii) Presence of cathode
  iii) Presence of conductive liquid (electrolyte)
  iv)Electrical contact between anode and cathode
- Elimination of any one of these condition will reduce or stop corrosion.



Mechanism of Corrosion

- Electrochemical reaction – transfer of electrons
- Electrochemical corrosion cell- Electrical circuit and its associated chemical reaction are called electrochemical corrosion cell.



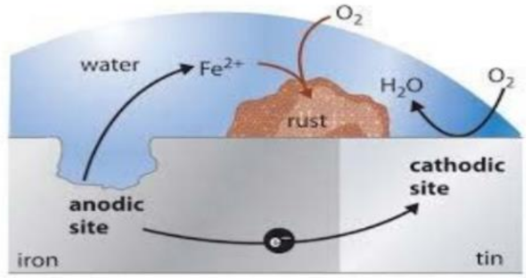
i) Anode- Oxidation occurs, metal dissolution takes place & production of electrons

ii) Cathode – electrons are consumed & reduction reactions occurs

iii) Metal Path – movement of electron from anode to cathode

iv) Electrolyte- ionic current flows

Anodic & cathodic reactions in corrosion cell



At Anode-Oxidation

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

At Cathode -reduction

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

Why Corrosion needs to be controlled?

- Economic Aspects: It can be referred to as cost of corrosion under Direct Loss and Indirect Loss.
- Health Aspects: Surgical instruments, implants, pacemakers, etc. are all prone to corrosion.
- Cultural Aspects: Antiques and Monuments may get extinct due to corrosion.
- Safety Aspects: Machine parts in factories and home appliances can cause harm if corroded.

Methods of combating corrosion (protection of metals against corrosion)

The following methods are used to protect metals against corrosion:

I. Selection of the right material of construction

II. Surface coating.

III. Inhibitors

V. Electrical protection

I. Selection of the right material of construction

The right material of construction should have the following properties:

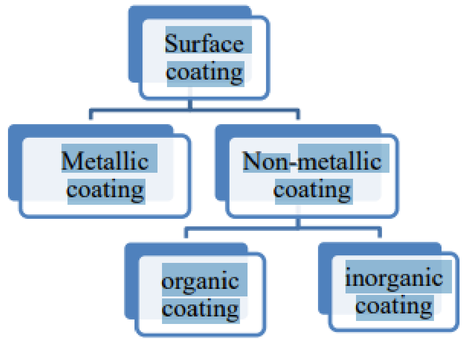
(1) high mechanical strength (2) high corrosion resistance (3) low cost

The material selection is carried out through the following steps

1. Preliminary selection Based on experience, availability and safety aspects
2. Laboratory testing Reevaluation of apparently suitable materials under process conditions
3. Interpretation of laboratory results and other data Effect of possible impurities, excess temperature, excess pressure, agitation, and presence of air in equipment
4. Economic comparison of apparently suitable materials Material and maintenance cost, probable life, cost of product degradation, and liability to special hazards
5. Final selection

Surface coating:

There are two types of surface coating



A. **Metallic coating**: The structure is coated with a layer of other metal which may be more noble than the structure or less noble than it e.g. steel structures can be coated with copper which is more noble than steel or zinc which is less noble. In case of coating the structure with a more noble metal care should be taken that the coat is free from pores or cracks to avoid the formation of dissimilar metal corrosion cells which would lead to corrosion of the structure.

Factors that must be considered in selection of a coating metal:

1. The coating should be able to resist direct attack of the environment.

2. The coating should be nonporous and continuous (no cracks) to a void acceleration of corrosion especially in case of a more noble metal (ex: coating of Fe by Cu).

3. The coating should be hard. In case of coating the structure with a less noble metal the presence of pores and cracks in the coat is not dangerous because in this case the less noble metal will corrode by the formation of dissimilar metal cells while the structure will remain protected.

In practice metallic coating is carried out by different methods such:

(1) Electroplating, (2) Hot dipping of the work piece in molten metal covered with a flux, (3) Spraying of the molten metal on the work piece. Surface coating Metallic coating Non-metallic coating organic coating inorganic coating 5

(1) Electroplating: Electroplating is the method of coating one metal with another. It is most commonly used for¬ decorative purposes, appearance and protection. Electroplated items include chrome bumpers, jewelry, electronics, circuit boards and airplane¬ parts.

Electroplating procedure

1. Preparation of the workpiece. Solutions such as alkaline cleaners, solvent degreasers or acidic pickling mixtures are used to remove dirt, greases, oxidation and contaminants from the piece.

2. The piece to be plated is connected to the negative pole (cathode) of the d. c. power supply while the plating (coating) metal anode is connected to the positive pole (anode). Multi-range ammeter (in series) and voltmeter (in parallel) are connected to the cell to measure the cell current and voltage.

3. The piece is then immersed in the plating solution until coated and rinsed and then buffed or polished, if necessary.

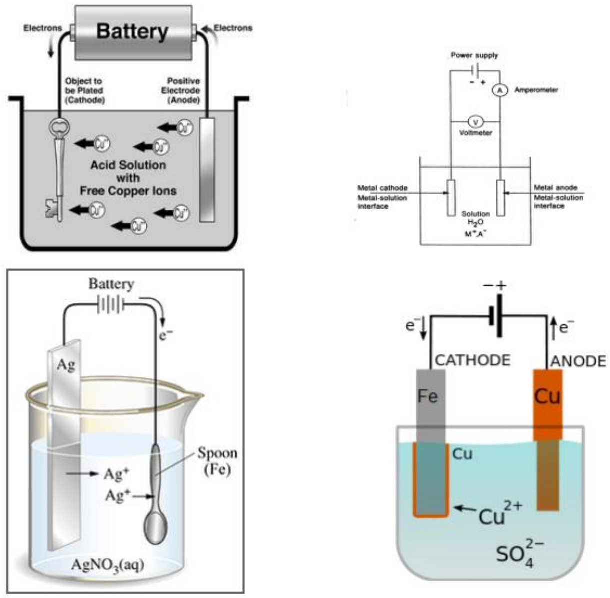


Fig. 1, Some examples for electroplating process

Hot dipping of the work piece in molten metal covered with a flux:

There are two common processes of hot dipping:

1. Hot dipping galvanizing: It is a hot coating process whereby the cleaned steel is immersed in molten zinc usually at a¬ temperature of between 445 °C and 450 °C. When the cleaned steel is immersed into the molten zinc, a chemical reaction results, which¬ we refer to as following "metallurgical laws". As a result of this process the coating consists of a series of zinc iron alloy layers (intermetallic layer) and usually a top pure zinc layer. The adhesion of the coating to the steel is¬ therefore determined by means of a chemical bond, or a "metallurgical bond". Such bonding is considered to be far superior to that of a mechanical bond. A hot dipped galvanized coating will provide greater corrosion protection to steel when¬ compared to that of an electroplated product.

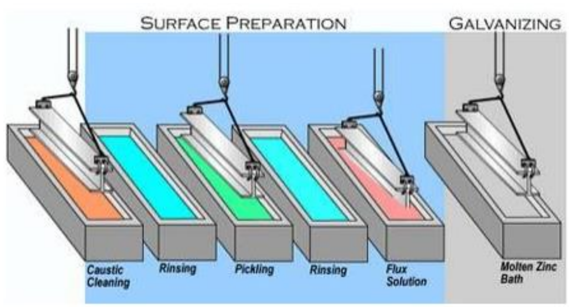


Fig. 2, Hot dipping galvanizing of steel

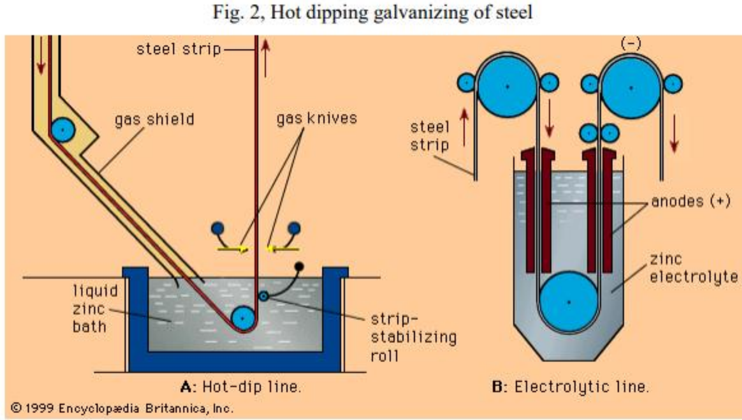


Fig. 3, Galvanization of steel by hot dipping and electroplating

2. Hot-dipped tin plating: Tinning is the process of thinly coating sheets of iron or steel with tin, and the resulting product is known as tinplate. It is most often used to prevent rust Tinplate made via hot-dipped tin plating is made by cold rolling steel or iron, pickling or remove any scale, annealing to remove any strain hardening, and then coating it with a thin layer of tin. The attached figure shows the tinning process steps. Fig. 4, Basic concept of hot dipped tin plating process Advantage of hot dipping process No waste from production process.¬ No hazardous substance (such as cyanogens, lead, etc.) is used at all in production process.¬ The coating metal and the base metal are strongly bonded as inter-metallic layer formed.¬ Provide greater corrosion protection to steel when compared to that of an electroplated¬ product.

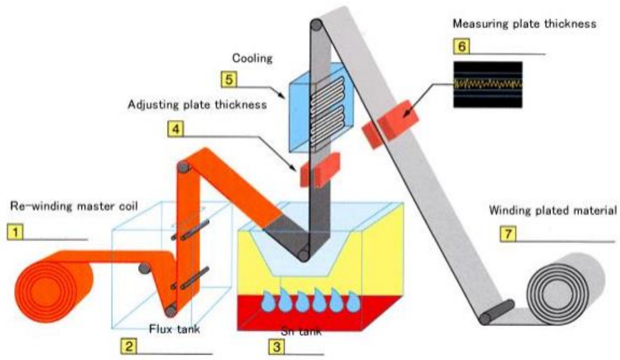


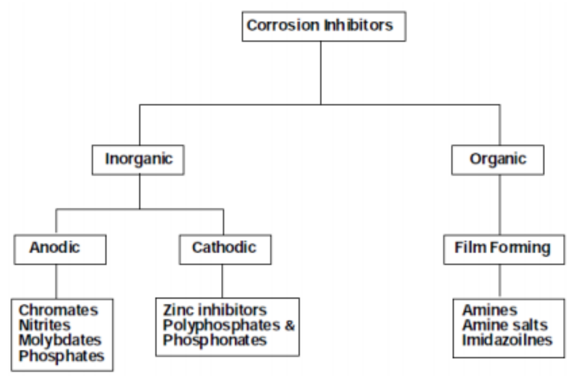
Fig. 4, Basic concept of hot dipped tin plating process

(3) Spraying of the molten metal on the work piece. Thermal spraying refers to a process by which a metal wire or powder is melted and¬ sprayed onto a surface to form a coating. A thermal spray gun is used to apply the coatings.¬ The thermal spray gun heats the metallic wire or powder to a molten state and compressed¬ air or other gas propels it onto the surface to form a coating. The compressed gas also aids in division and atomization of the molten coating. The two metals most commonly applied by thermal spray are zinc and aluminum. These¬ metals and their alloys provide excellent protection in a variety of marine and industrial corrosive environments.

III. Corrosion Inhibitors Required: Corrosion inhibitors are substances that are added in small amount (e.g 0.1%) to the corrosive medium stop or slow down electrochemical corrosion reactions on a metal surface. Mechanism:¬ Corrosion inhibitors work by one or more of the following mechanisms.

- They adsorb on metal surfaces to form protective films.
- They combine with corrosion product films to protect metal surfaces.
- They form precipitates, which visibly coat and protect metal surfaces.

Types of inhibitors: Inhibitors can be divided into two main categories—inorganic and organic.
Inorganic inhibitors are used mainly in boilers, cooling towers, and fractionation units.
Organic inhibitors are used mainly in oil field systems.¬ As shown in the figure, inorganic inhibitors are further divided into anodic and cathodic classifications.
These classifications describe the part of the electrochemical process that is interrupted by the inhibitor. Organic film-forming inhibitors interrupt both the anodic and cathodic processes.



Classification of corrosion inhibitors

Cathodic inhibitors: Cathodic inhibitors are chemical compounds which inhibit the cathodic reaction of the corrosion cell.

Anodic inhibitors: Are chemical compounds which inhibit the anodic reaction of the corrosive cells.

Electrical protection

A. Cathodic protection

Technique to reduce corrosion of a metal surface by making that surface the cathode of an electrochemical cell. Cathodic protection is a method to reduce corrosion by minimizing the difference in potential between anode and cathode. This is achieved by applying a current to the structure to be protected (such as a pipeline) from some outside source. When enough current is applied, the whole structure will be at one potential; thus, anode and cathode sites will not exist. Cathodic protection is commonly used on many types of structures, such as pipelines, underground storage tanks and ship hulls. Types of cathodic protection systems There are two main types of cathodic protection systems:

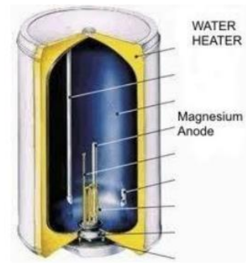


Fig. 12, Cathodic protection of water heater by sacrificial anode method

a) Galvanic system (sacrificial anode method)

b) Impressed current method

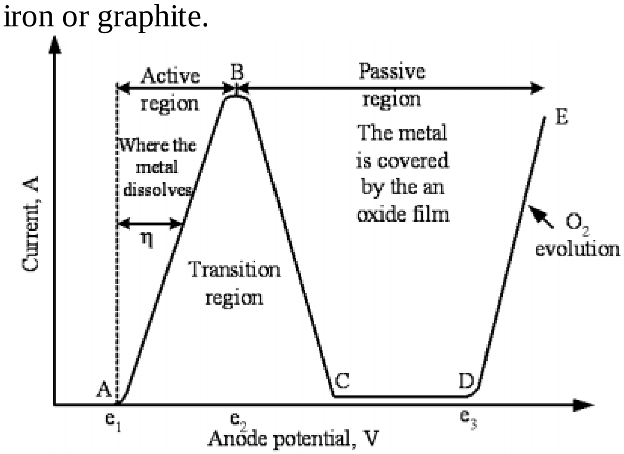
Galvanic system (sacrificial anode cathodic protection)

A galvanic cathodic protection system makes use of the corrosive potentials for different metals. Without cathodic protection, one area of the structure exists at a more negative potential than another, and corrosion results. If, however, a much less inert object (that is, with much more negative potential, such as a magnesium anode) is placed adjacent to the structure to be protected, such as a pipeline, and a metallic connection (insulated wire) is installed between the object and the structure, the object will become the anode and the entire structure will become the cathode. That is, the new object corrodes sacrificially to protect the structure. Thus, the galvanic cathode protection system is called a sacrificial anode cathodic protection system because the anode corrodes sacrificially to protect the structure. Galvanic anodes are usually made of either magnesium or zinc because of these metals' higher potential compared to steel structures.

Impressed current systems

Impressed current cathodic protection systems use the same elements as the galvanic protection system; only the structure is protected by applying a current to it from an anode. The anode and the structure are connected by an insulated wire, as for the galvanic system. Current flows from the anode through the electrolyte onto the structure, just as in the galvanic system. The main difference between galvanic and impressed current systems is that the galvanic system relies on the difference in potential between the anode and the structure, whereas the impressed current system uses an external power source to drive the current, as shown in Figure 1(b). The external power source is usually a rectifier that changes input AC power to the proper DC power level. The rectifier can be adjusted so that proper output can be maintained during the system's life. Impressed current cathodic protection system anodes typically are high-silicone cast iron or graphite.

B Anodic Protection: It is based on the phenomenon of passivity. To understand how the anodic protection is carried out the phenomenon of passivity should be explained first. Anodic protection is carried out by connecting the structure to be protected to the positive pole of an external d.c power supply, an auxiliary cathode made of corrosion resistant material is used to complete the circuit. The anode potential of the structure is adjusted to be in the passive region i.e the region represented by the area BCDE on the passivity curve. Under this condition the structure will be coated with a layer of oxide which protects it against corrosion.



Factors affecting the rate of corrosion

- Type of Metal
- Heat treatment & Grain direction
- Presence of dissimilar metal
- Anode & cathode surface area
- Temperature
- presence of electrolyte
- Availability of oxygen
- time of exposure to corrosive environment