

## Some typical electrochemical/wet corrosion

In general, wet corrosion is more common than the dry corrosion. Rusting of iron in a neutral/alkaline/acidic environment belongs to this class of corrosion. Some of the typical wet corrosions are: (1) *Galvanic corrosion*, (2) *Waterline corrosion*; (3) *Pit corrosion*; (4) *Soil corrosion*, etc.

### Galvanic Corrosion/Differential Metal Corrosion/Bimetallic Corrosion

Galvanic corrosion occurs when two different metals or alloys are in contact and are immersed in a conducting medium. Here, the metal with higher standard oxidation potential acts as anode and undergoes dissolution/corrosion. When two different metals are joined together, they form a Galvanic couple. Some examples of Galvanic couples are: Zn and Cu; Fe and Cu, Zn and Ag, etc. This corrosion is otherwise known as *differential/bimetallic corrosion* as two different metals are used.

In Zn and Cu Galvanic couple, Zn with higher standard oxidation potential (+ 0.76 V) than Cu (-0.34 V) acts as anode and here Cu acts as cathode.

In order to discuss the mechanism of corrosion, let us consider that a Zn-Cu couple is exposed to a neutral humid environment.

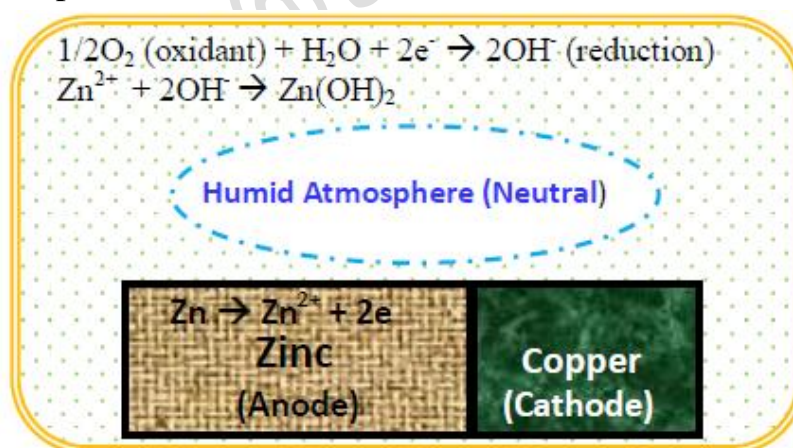
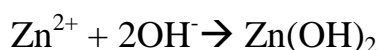


Fig. 4. Mechanism of Galvanic Corrosion.

### Mechanism:

- (i) Zn undergoes oxidation:  $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^{-}$
- (ii) Oxidant (O<sub>2</sub>) in the atmosphere accepts these electrons to form anions  
 $\frac{1}{2}\text{O}_2 \text{ (oxidant)} + \text{H}_2\text{O} + 2\text{e}^{-} \rightarrow 2\text{OH}^{-} \text{ (reduction)}$
- (iii) Corrosion product forms by combination of cations and anions



### *Factors affecting Galvanic Corrosion:*

The various factors are enlisted as below:

1. **Position of metals in the EMF series:** The more apart the metals are from each other in the series, the greater is the corrosion.
2. **Distance effect:** Corrosion is highest at the junction and rate decreases progressively with distance from the interface.
3. **Area effect:** If anodic area will be much smaller than cathodic area then rapid corrosion will be occur.
4. **% Moisture:** Higher is the % moisture; greater is the rate of corrosion.
5. **Conductivity of the medium:** Higher is the conductivity; greater is the rate of corrosion.

*Control of Galvanic corrosion:* It can be minimized by:

- a. By avoiding direct contact
- b. By choosing two metals close to one other in the Galvanic series
- c. By proper designing (By keeping anodic area much larger than cathode)
- d. By putting an insulating layer between two metals

### ✓ **Some examples of Galvanic corrosion**

1. Steel screws in Brass marine hardware (steel-anode)
2. Lead-tin solder around copper wire (tin-anode)
3. A steel propeller shaft in Bronze bearings (steel-anode)
4. Steel or iron pipe connected to copper plumbing (steel-anode)

**Q. Iron corrodes faster than Aluminium even though Fe is placed below Al in the EMF series. Give reason**

**Ans.** It is because Al forms a protective oxide of  $\text{Al}_2\text{O}_3$  on its where as Fe forms a porous  $\text{Fe}_2\text{O}_3$  layer.

**Q. What is Galvanic corrosion? How to control it?**

**Ans.** Galvanic corrosion occurs when two different metals or alloys are in contact are immersed in a conducting medium. Here, the metal with higher standard oxidation potential acts as anode and undergoes dissolution/corrosion.

*Control of Galvanic corrosion:* It can be minimized by:

- By avoiding direct contact
- By choosing two metals close to one other in the Galvanic series
- By proper designing (By keeping anodic area much larger than cathode)
- By putting an insulating layer between two metals

**Q. Mention factors affecting the rate of Galvanic corrosion.**

Ans. The various factors are enlisted as below:

- Position of metals in the Galvanic series: The more apart the metals are from each other in the series, the greater is the corrosion.
- Distance effect: Corrosion is highest at the junction and rate decreases progressively with distance from the interface.
- Area effect: If anodic area will be much smaller than cathodic area then rapid corrosion will be occur.

**Long type**

**Q. Discuss the mechanism of Galvanic corrosion with a specific example. Mention the factors affecting its rate. Suggest some control methods.**

Ans. Refer above

**Q. Nut and bolt made of the same metal is preferred in practice. Give reason.**

Ans. This is done to avoid Galvanic corrosion.

**Q. Impure metal corrodes faster than pure metal under identical conditions. Give reason.**

Ans. Impurities in metal result in heterogeneity. Hence, it causes formation of a large number of small electrochemical cells and corrosion occurs at anodic part.

**Q. A steel or iron screw in a brass marine hardware corrodes. Give reason.**

Ans. This is due to Galvanic corrosion. Here, steel or iron screw acts as anode due to their higher standard oxidation potential.

**Q. Where the wet corrosion takes place?**

Ans. It always takes place at anode. At, anode loss of electron takes place.

**Q. A piece of impure and pure zinc are placed in a salt solution. Which will corrode faster?**

Ans. Impure one. As impurities leads to formation of Galvanic cells.

**Q. Small anodic area results in intense corrosion. Give reason.**

Ans. This is due to area effect. If anodic area will be very small than cathodic area then the huge demand of electrons by cathode can only be fulfill by small anode via rapid dissolution. Rapid dissolution means rapid corrosion.

Here (Cathodic area/Anodic area)  $\gg 1$ .

**Q. A copper equipment should not possess a small steel bolt. Give reason.**

Ans. Here bolt will act as anode and (Cathodic area/Anodic area)  $\gg 1$ . So, rapid dissolution or rapid corrosion of bolt (anode) will occur.

**Q. Why does a steel pipe in a large copper tank undergoes rapid corrosion?**

Ans. Steel is anodic to copper, i.e., steel pipe will act as anode. Again the steel pipe is much smaller than the tank. That is here (Cathodic area/Anodic area)  $\gg 1$ . So, rapid corrosion will occur in steel pipe.

**Q. In a structure, two dissimilar metals should not allow to come in contact with each other. Give reason.**

Ans. If they will contact, Galvanic corrosion will occur at metal with higher standard oxidation potential.

**Q. Rusting of iron is quicker in saline water than in ordinary water. Give reason.**

Ans. The presence of NaCl in saline water leads to increased conductivity of water layer in contact with the iron surface, thereby corrosion current increases and rusting is speeded up.

### ***Differential $O_2$ -concentration cell corrosion or Differential aeration corrosion***

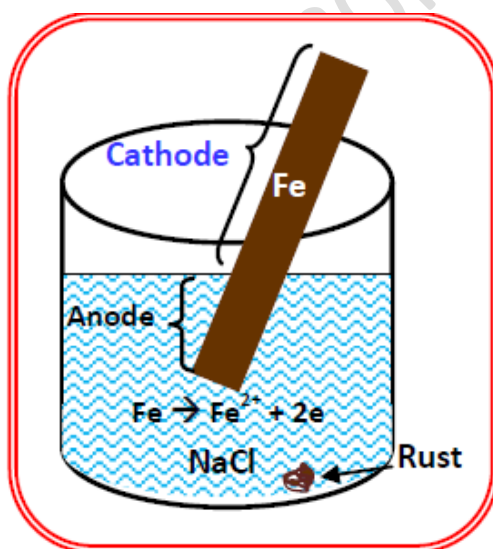
It is an electrochemical corrosion which occurs when a portion of metal is exposed to different air or oxygen concentration than the rest part. This

difference in air or  $O_2$  concentration causes a difference in standard oxidation potential between the two areas. Here, the poorly aerated/oxygenated part acts as anode and undergoes corrosion.

In order to study the mechanism of corrosion, let us consider that a metal (say Iron) is partially immersed in a dilute solution of NaCl (electrolyte). The metallic part which is not immersed in the electrolyte is strongly aerated whereas the part inside the electrolyte is poorly aerated. So, a difference in potential thus developed causes the flow of electron from anode to cathode. The poorly aerated part will act as anode and suffers from metallic dissolution.

*Mechanism:*

- (i)  $Fe \rightarrow Fe^{2+} + 2e^-$  (oxidation)
- (ii)  $\frac{1}{2}O_2$  (oxidant) +  $H_2O + 2e^- \rightarrow 2OH^-$  (reduction)
- (iii)  $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2 \rightarrow \underbrace{Fe(OH)_3 \text{ or } Fe_2O_3 \cdot xH_2O}_{\text{(rust)}}$  (In pr. of excess  $O_2$ )



**Fig. 5. Mechanism of differential aeration corrosion.**

The two most common differential aeration corrosion is:

- A. *Water-line corrosion*
- B. *Pit Corrosion*

**Q. What is the chemical formula of rust?**

**Ans.**  $Fe(OH)_3$  or  $Fe_2O_3 \cdot xH_2O$

**Q. What is differential aeration corrosion? Give an example.**

Ans. It is an electrochemical corrosion which occurs when a portion of metal is exposed to different air or oxygen concentration than the rest part. Here, the poorly aerated/oxygenated part acts as anode and undergoes corrosion.

The two most common differential aeration corrosion is:

- A. *Water-line corrosion*
- B. *Pit Corrosion*

**Q. A pure metal rod half-immersed vertically in water starts corroding at the bottom. Give reason.**

**Ans.** This is due to differential aeration corrosion. The rod above the waterline is more strongly aerated and acts as cathode. On the other hand the lower part of the rod immersed in water is less-aerated and acts as anode and suffers from corrosion.

**Q. Why does part of an iron nail inside the wooden structure undergoes corrosion easily?**

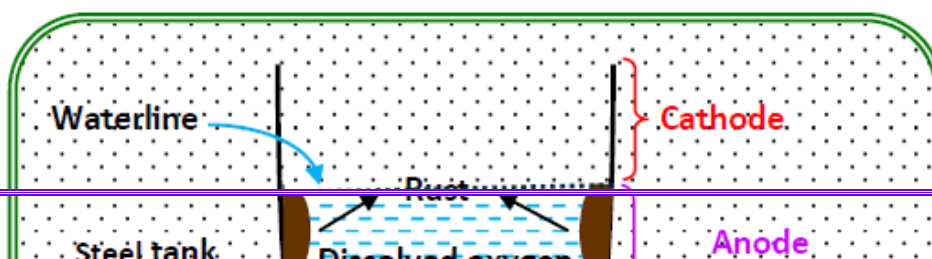
Ans. The part of the nail inside the wood is not exposed to the atmosphere. So, it is very poorly oxygenated part as compared to the remainder part. So, nail inside the wood acts as anode and suffers from corrosion. It is differential aeration corrosion.

### Water-line corrosion

It is a *differential aeration corrosion or oxygen concentration cell corrosion* wherein corrosion occurs just below the waterline when a steel tank is half-filled with water. Here, as the part just below the water-line is poorly aerated/oxygenated acts as anode and undergoes oxidation to form metallic ions. The part above the water-line has more access to air or oxygen acts as cathode.

*Mechanism:*

- (i)  $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$  (oxidation)
  - (ii)  $\frac{1}{2}\text{O}_2$  (oxidant) +  $\text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^-$  (reduction)
  - (iii)  $\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 \rightarrow \text{Fe}(\text{OH})_3$  or  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$  (In pr. of excess  $\text{O}_2$ )
- (rust)



**Fig. 6. Mechanism of water-line corrosion.**

N.B.: **Oxygen concentration cell corrosion:** It is an electrochemical corrosion occurs when the metal surface is exposed varying concentration of air or oxygen. Here, metallic part exposed to less oxygen acts as anode and undergoes dissolution.

**Control of waterline corrosion:** Some of the methods are as follows:

1. By removing dissolved oxygen upon addition of hydrazine
2. By metallic coating
3. By alloying
4. By decreasing the conductivity of electrolyte
5. By removing any alkali or acidic masses present in the water

**Q. Corrosion of water filled steel tanks occurs below water line. Give reason.**

**Ans.** This is due to differential aeration corrosion. Here, as the part just below the water-line is poorly aerated/oxygenated acts as anode and undergoes oxidation to form metallic ions. The part above the water-line has more access to air or oxygen acts as cathode.