Lecture # 9

Corrosion and Degradation of Materials

Learning objectives

- To learn about the effect of environmental conditions on the mechanical and physical properties of materials.

- To describe the conditions that cause the physical, chemical and biological degradation of materials.

- To know how materials degrade in certain conditions and how materials are altered by degradation.

Definition

- **Corrosion** is the deterioration of a material as a result of a reaction with its environment, especially with oxygen (oxidation).

Although the term is usually applied to metals, all materials, including wood, ceramics (in extreme conditions) and plastics, deteriorate at the surface to varying degrees when they are exposed to certain combinations of sunshine (UV light), liquids, gases or contact with other solids.

Materials degradation

Wood

Furniture Beetle

The environmental factors that affect degradation in wood are;

- Biological organisms – fungi and insects
- Risk of wetting or permanent contact with water
- Wood is susceptible to attack when the moisture content exceeds 20%

Dry Rot

Degradation of Materials

- **Physical and Mechanical effects of degradation in wood**
- Change in cross-sectional dimensions, swelling and shrinkage
- Strength and stiffness decrease as moisture content increases
- Durability is affected
- Coatings can be compromised

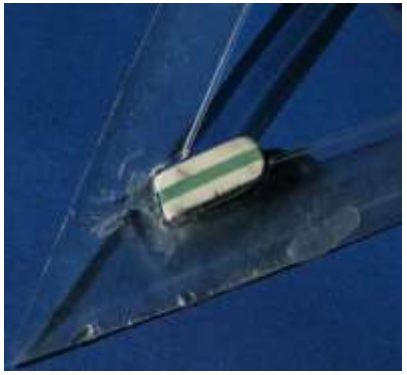
Degradation of Materials

Plastics

- It is widely accepted that plastics do not corrode however micro organisms which can decompose low density polyethylene do exist.
- Elastomers can cause other plastics to corrode or melt due to prolonged contact e.g. rubber left on a setsquare.
- UV light will weaken certain plastics and produce a chalky faded appearance on the exposed surface.
- Heat will weaken or melt certain plastics even at relatively low temperatures.

Cold can cause some plastics to become brittle and fracture under pressure.

- Bio-degradation – the chemical breakdown in the body of synthetic solid phase polymers.



Metals

- Most metals corrode because they react with oxygen in the atmosphere, particularly under moist conditions – this is called oxidation.
- Ferrous metals such as steel are particularly susceptible to oxidation and require ongoing maintenance or they will suffer inevitable structural failure.

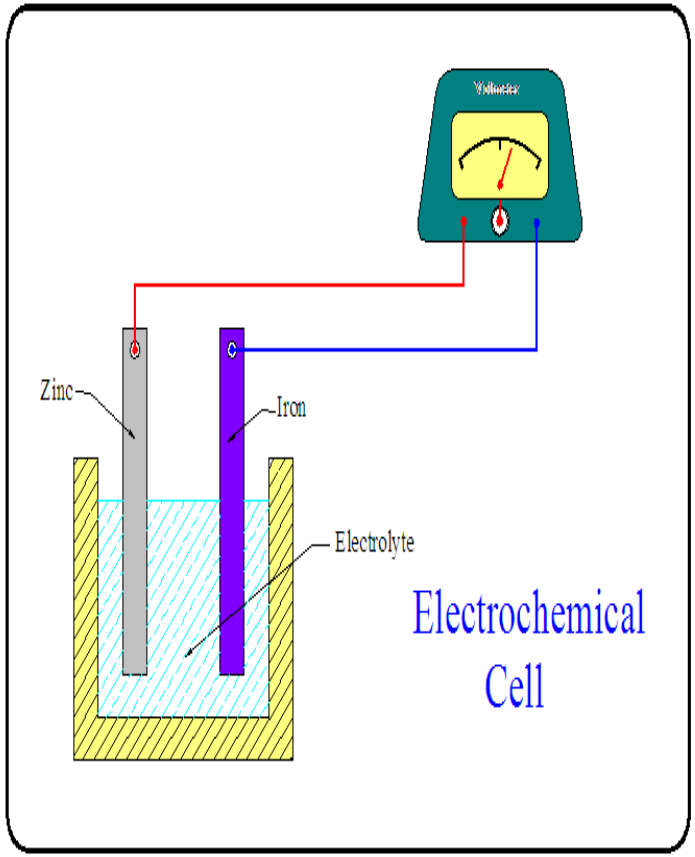
Metals

- Some non-ferrous metals are particularly resistant to corrosion, e.g. Copper and Zinc.
- They form strong oxides on their surfaces (as do aluminium and lead) and these protect the metal from further oxidation. Shown as **cladding** on the buildings above.

Metals

- Most corrosion of ferrous metals occur by **electro-chemical reaction**. This is also known as **wet corrosion**

- **Electro-chemical corrosion can occur when;**
- Two different metals are involved.
- There is an electrolyte present.
- Metals are separated on the Galvanic Table (potential difference exists)
- The metals are in contact.
- When two **dissimilar** metals are placed in a jar of electrolyte (sea water), an electric current is produced



Metals

- In actual two metal situations, **designers must be aware of the Galvanic Series**. The potential difference between the two metals determines which metal will corrode

- In the environment, rainwater will also act as an electrolyte. One of the metals will be eaten away (**the anode**) if it is higher up on the Galvanic Table

Galvanic Table

Magnesium

Zinc

Cadmium

Aluminium

Lead

Steel

Chromium

Tungsten

Brass

Bronze

Copper

Silver

For any combination of dissimilar metals the metal which is higher on the table will act as an anode and corrode preferentially

Metals

Protection and Finishing

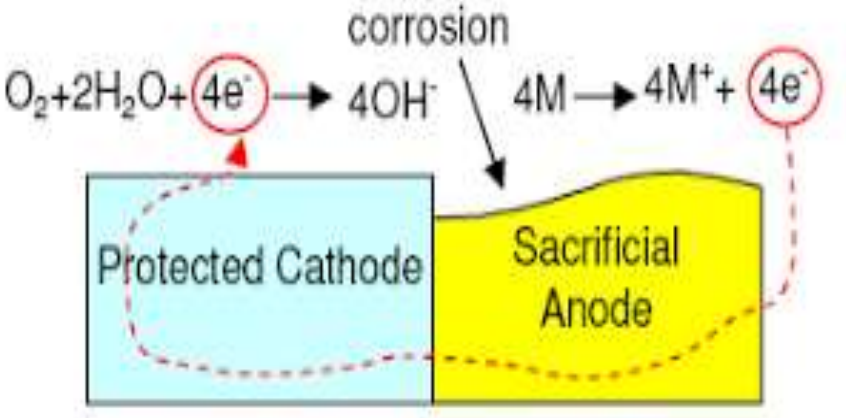
- There are various protection and finishing treatments applied to metals, they include;

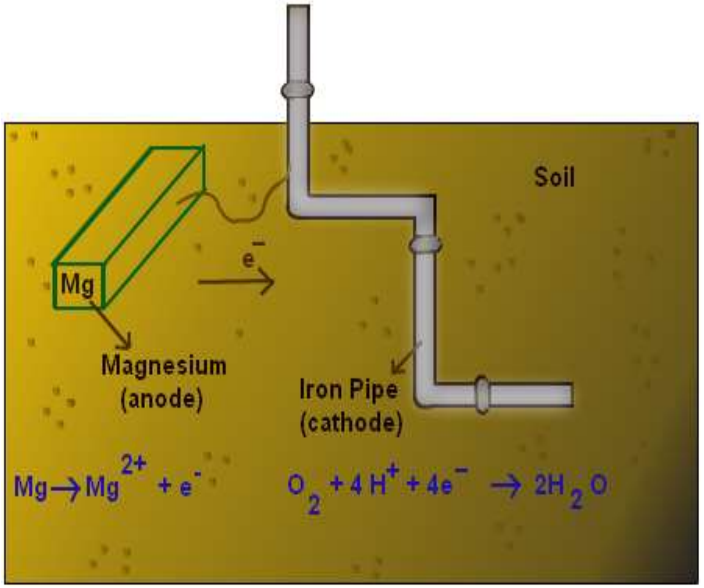
- Sacrificial protection
- Design features
- Anodising of aluminium
- Protective coating e.g. paint, plastic, metal
- Electro plating.

Metals

Sacrificial (cathodic) Protection

Is a technique used to control the corrosion of a metal surface by making it the **cathode** of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded "sacrificial metal" to act as the anode. The sacrificial metal then corrodes instead of the protected metal.





What need protection = Cathode

Metals

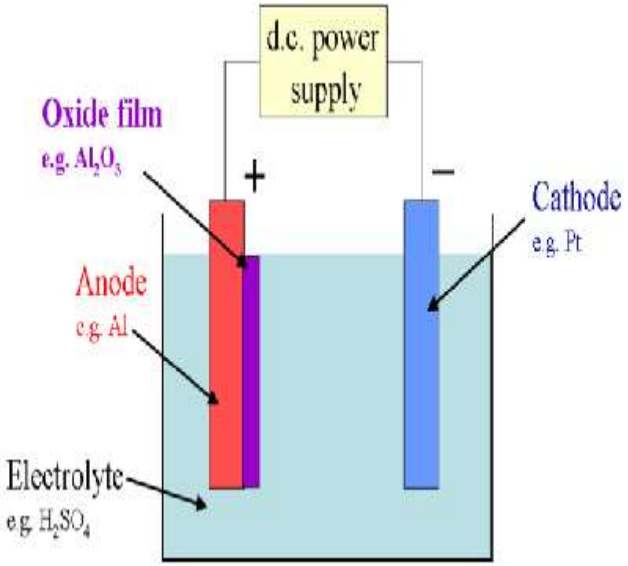
Anodising of Aluminium

Is an electrochemical process that converts the metal surface into a decorative, durable, corrosion-resistant, anodic oxide finish.

Aluminum is ideally suited to **anodizing**, although other nonferrous metals, such as magnesium and titanium, also can be anodized.

This is produced by applying direct current through a suitable electrolyte (dilute sulphuric acid) in which the aluminium is the anode and a suitable material e.g. (lead) is the cathode.

Organic acid electrolytes will produce harder films and can incorporate dyes to give the coating an attractive colour.



- **Metals**
- **Protective Coating - Paint**
- Paint is widely used particularly to protect steel. It is not effective over time and under certain conditions and must be renewed regularly – often at considerable expense.
- The more effective paints contain lead, zinc or aluminium in suspension.
- Part of the protection they provide is sacrificial

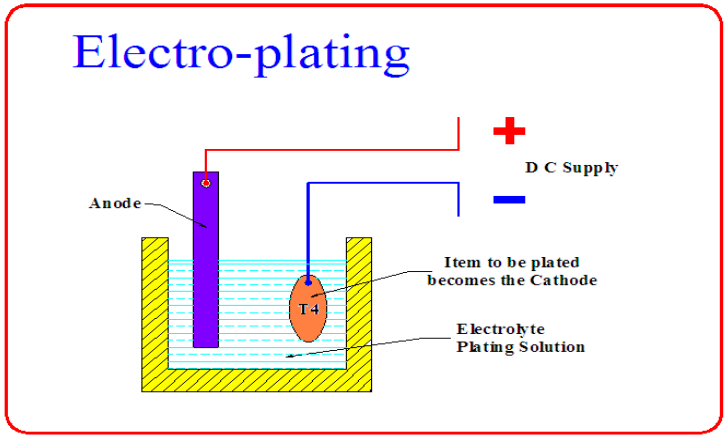
- **Metals**
- **Protective Coating - Plastic**
- A variety of **plastic** coatings exist, they include;

- Brush on coating
- Electrostatic spraying
- Hot dipping in fluidised tank

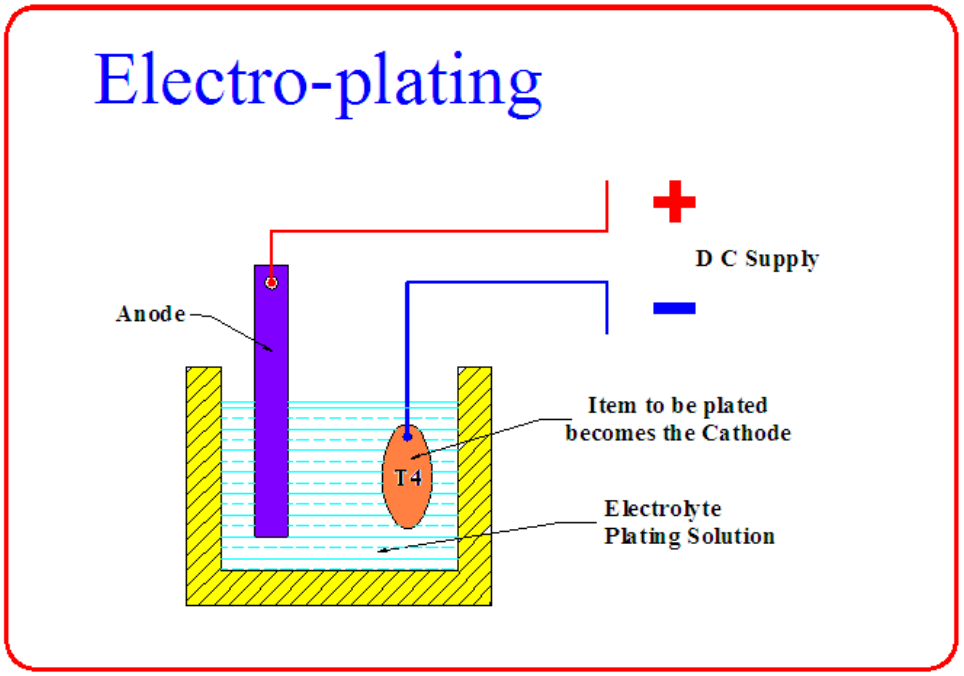
- **Metals**
- **Protective Coating - Metal**

- Metal coatings give the best protection – they include;

- Hot dipping
- Powder cementation
- Metal spraying
- Metal cladding
- Electro-plating



- **Metals**
- **Protective Coating – Electro-plating**
- Uses the chemical effect of an electric current to provide a decorative and/or protective metal coating to another metal object



- **Metals**
- **The Effect of Corrosion on Mechanical & Physical Properties**

- Reduction of metal thickness leading to loss of strength or complete structural failure
- Localised corrosion leading to “crack” like structure. Produces a disproportionate weakening in comparison to the amount of metal lost
- Fatalities and injuries from structural failure, e.g. bridges, buildings, or aircraft
- Damage to valves or pumps due to solid corrosion products

- **Metals**
- **Environmental Considerations**
- Contamination of fluids/foodstuffs in pipes and containers.
- Leakage of potentially harmful pollutants and toxins into the environment
- Increased production/design and ongoing maintenance **costs**.
- This results in greater use of scarce resources and the release of harmful CO^2 gasses into the environment.

Summary

- ✓ Corrosion is the deterioration of a material as a result of a reaction with its environment, especially with oxygen (oxidation).
- ✓ The environmental factors that affect degradation in materials, as general are**;** biological organisms (in wood), water, cold, being in contact with other materials.
- ✓ Corrosion and degradation decrease strength and stiffness of materials which leads to its break.
- ✓ In metals, when designers use more than one material , difference in potential (Galvanic table) should be taken into consideration.
- ✓ Coating with different materials is one of the solutions to protect all materials.
- ✓ Degradatiom could negatively impact the environment
- ✓ Maintenance and protection is costly.

Facade