Corrosion Resistant Material

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What is Corrosion???

- Loss of useful properties of a material as a result of chemical or electro-chemical reaction with its environment.
- Humans have most likely been trying to understand and control corrosion for as long as they have been **using metal objects.**
- The most important periods of pre-recorded history are named for the metals that were used for tools and weapons like *Bronze age, Iron age* etc.

What is Corrosion???

- Most popularly known corrosion is “Rusting”, which is confined to corrosion of iron & steel
- Tarnishing of silver articles, fogging of nickel & dulling of brass are also example of corrosion as per the definition stated earlier
- Similarly, deterioration of paint, rubber and plastic components by sunlight or chemicals can also be termed as corrosion

Why do the metals corrode???

- Corrosion of metals is considered as extractive metallurgy in reverse
- Metals are usually extracted from ores through the application of a considerable amount of energy.
- The pure metals possess a large amount of Free energy

Why do the metals corrode???

- The release of free energy takes the metal back to its ore stage, which is the lower energy stage.
- In fact the reverse journey of the pure metal back to its ore state is called corrosion.
- This is a spontaneous process.
- The most important corrosion is “Rusting”

Damage due to corrosion

- Over-design to allow for corrosion.
- The cost of repair or replacement of the corroded component or equipment.
- Safety, e.g., sudden failure of equipment may cause fire, explosion or accident
- Rapidly diminishing metal resources will have far more profound effect on the civilization

Advantages of Corrosion

- Corrosion is, however, desirable and beneficial in some cases
- Metallographic examination of metallic structures will not be practicable unless corroding action of the etchants is used to reveal the grain boundaries, etc
- Electrochemical machining is widely used to machine the hard and difficult-to-machine parts economically.
- Anodizing of aluminium is another beneficial corrosion process used for obtaining better appearance and corrosion resistance.

Classification of corrosion

Dry Corrosion:

- At room temperature, most metals carry a thin oxide layer as a result of the reaction of metals with oxygen in the atmosphere.
- Zinc and zinc coatings carry a fairly protective zinc hydroxide or carbonate layer (zinc patina) which increases in thickness very slowly.
- Aluminium carries a thin, highly protective oxide layer.

Classification of corrosion

Wet Corrosion:

- Wet corrosion takes place in environments where the relative humidity exceeds 60 %.
- The corrosion may be uniform destruction of the metal surface or localised destruction (pitting, stress corrosion cracking).
- The corrosion can be concentrated adjacent to a more noble metal or at points where the oxygen supply is limited.

High temperature & Low temperature Corrosion

- High temperature corrosion is a form of corrosion that does not require the presence of a liquid electrolyte. Sometimes, this type of damage is called "dry corrosion" or "scaling"
- Low temperature corrosion refers to corrosion attack to a structural material in the presence of a liquid material

Electro-chemical corrosion & Chemical corrosion

Electro-chemical corrosion

- Corrosion in metals, whether in the atmosphere, under water, or underground, is caused by a flow of electricity from one metal to another metal or a recipient of some kind or from one part of the surface of one piece of metal to another part of the same metal or other metal when conditions permit the flow of electricity.

Electro-chemical corrosion & Chemical corrosion

Chemical corrosion

- Direct chemical reaction of a metal with its environment.
- There is no transport of electric charge and the metal remains film free.
- This would include corrosion in gaseous environments when the reaction product is volatile, corrosion in liquid metals, fused halides and organic liquids

Rusting

- “Rusting” is confined to the corrosion of iron and steel
- Ordinarily, iron and steel corrode in the presence of both oxygen and water, and corrosion usually does not take place in the absence of either of these.
- Water, therefore, especially salt water, is an excellent electrolyte.
- A corrosion cell consisting of an anode, cathode & electrolyte is formed

Corrosion cell for Rusting

- Which parts of the metal serve as anodes and cathodes can depend on many factors, as can be seen from the irregular corrosion patterns that are commonly observed.
- Atoms in regions that have undergone stress, as might be produced by forming or machining, often tend to have higher free energies, and thus tend to become anodic.

Corrosion cell for Rusting

- If one part of a metallic object is protected from the atmosphere so that there is insufficient O2 to build or maintain the oxide film, this "protected" region will often be the site at which corrosion is most active.
- The fact that such sites are usually hidden from view accounts for much of the difficulty in detecting and controlling corrosion.

Corrosion cell for Rusting

- When two electrochemically dissimilar metals are metallically connected and exposed to a corrosive environment, the less noble metal (anode) suffers accelerated attack and the more noble metal (cathode) is cathodically protected by the galvanic current.
- The tendency of a metal to corrode in a galvanic cell is determined by its position in the “galvanic series” of metals and alloys
- In low carbon steel & cast iron combination,, Low carbon steel will be anode

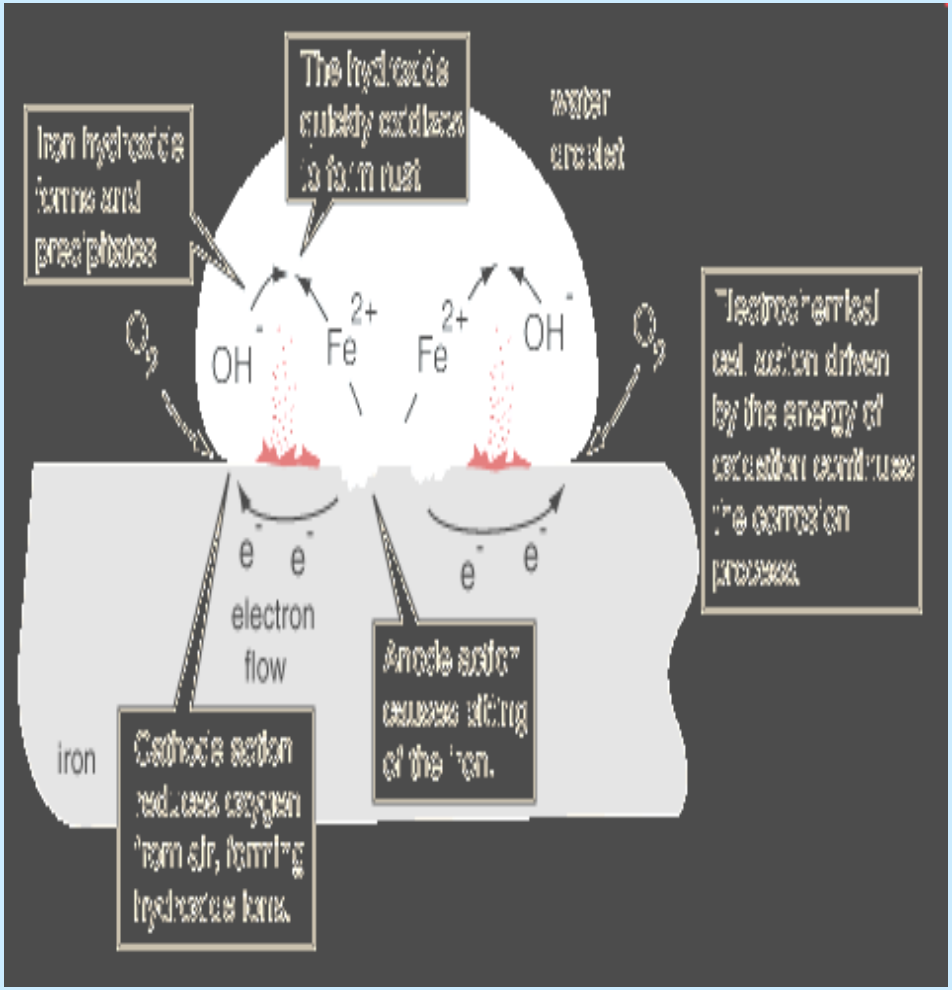
Reaction of Rusting

- If iron (Fe) was exposed to an aerated, corrosive water, the anodic reaction would be

$$2Fe = 2Fe^{++} + 4e$$

- At the cathode, reduction of oxygen would occur

$$O_2 + 4H_2O + 4e = 4(OH)^-$$



$$2Fe(OH)_2 + O_2 = 2Fe_2O_3, H_2O + 2H_2O$$

How to prevent corrosion???

- Material selection and design considerations
- Coatings
- Cathodic protection (galvanizing, sacrificial anodes, etc.)
- Anodic protection (passivation)
- Inhibitors

Material selection

- Strength/weight ratio, elastic modulus, electrical or thermal conductivity or other considerations may determine the nature of the metal or alloy to be used in a particular application
- Likely corrosion problems may only be considered as part of the design after these primary requirements have been met

Material selection

- The modes and rates of corrosion are not constant for a given material, but rather they are dependent upon the environment to which it is exposed.
- The use of a stainless steel instead of a mild steel will not always diminish corrosion problems
- The table in next slide refer to the corrosion rates, expressed in terms of depth of metal removed in unit time, for mild steel and various stainless steels in different acids

Material selection

Steel	70% HNO_3 60ºC	20% HCl 20ºC	80% H_2SO_4 20ºC
Mild Steel	Very High	38	0.4
13%Cr	0.15	120	4.5
12%Cr 12% Ni	0.05	5	0.5
17% Cr	0.1	35	0.7
18% Cr 8% Ni	Nil	25	1.5

Material selection

Metal	Atmosphere		
	Industrial	Marine	Rural
Aluminum	0.81	0.71	0.0025
Copper	1.19	1.32	0.58
Zinc	5.13	1.60	0.86
Mild steel	13.72	6.35	5.08
Cor-ten steel	2.54	3.81	1.27

Penetration rates (mm × 10^{-3} per year after 10 year exposure) of various metals exposed to different atmospheric conditions

Weathering steel

- Weathering" means that due to their chemical compositions, these steels exhibit increased resistance to atmospheric corrosion compared to unalloyed steels.
- This is because the steel forms a protective layer on its surface under the influence of the weather.
- best-known under the trademark **COR-TEN** steel, is a group of steel alloys which were developed to obviate the need for painting, and form a stable rust-like appearance if exposed to the weather for several years
- It contains 0.4% Copper 1% Chromium 0.1% Phosphorus

Weathering steel

- Indian Railways use Corten steel on exterior surface of wagons & Carriages.
- Indian Railways has developed new weathering steel like NCC (Ni- Cu- Cr) for Rail. Trial is under progress.
- Indian Railways has also developed Mo based rail. Its result is encouraging but found to be less cost effective as cost of Mo has gone very high.

Stainless steel

- Indian Railways has started stainless steel (Ferritic) for coaches & wagons
- Advantages are Ferritic stainless steel are better weldable, resistant to stress corrosion and cheaper
- It does not require any rigid painting system

Cathodic protection

- **Cathodic protection** (**CP**) is a technique to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell.
- This is achieved by placing in contact with the metal to be protected another more easily corroded metal to act as the anode of the electrochemical cell.
- Cathodic protection systems are most commonly used to protect steel

Cathodic protection

- In cathodic protection technology the structure to be protected is made cathode.
- Metals e.g. zinc, magnesium etc. which are anodic to steel are used for galvanic coupling, as they corrodes preferentially.
- Here anode is called sacrificial anode since it is consumed during the protection of the steel structure.
- Most common example of cathodic protection is galvanized steel, here zinc acts as a sacrificial anode.

Cathodic protection

- SEVERECORROSION PRONE AREAS OF RAIL, -ZINC METALISING, 140-150 MICRONS DFT, ONLY ONCE IN SERVICE LIFE FOLLOWED BY PROTECTIVE COATS OF PAINTS
  I) ETCH PRIMER –1C
  II) ZINC CHROME PRIMER TO IS-104-1C
  III)ALUMINIUM PAINT TO IS- 2339-2C
  THESE RAILS MAY BE REPAINTED WITH ABOVE SYSTEM AS AND WHEN REQUIRED

Cathodic protection

- **THE OVER HEAD EQUIPMENT MASTS (OHE) ARE BEING HOT DIP GALVANIZED TO 610 GM./ SQ.M. IN NON CORROSIVE AREAS AND 1000 GM/ SQ.M. FOR COASTAL AND INDUSTRIAL AREAS.**
- **THE GALVANIZED MASTS ARE PROTECTED WITH ORGANIC SEALING TO ENHANCE THE DURABILITY.**

Paint

- Paint is defined as a “ pigmented liquid composition which is converted to an opaque solid film after application as a thin layer”.
- The two primary functions of paints are (i) decoration and (ii) protection, according to service requirement.
- The protective function includes, inter-alia, resistance to air, water, organic liquids and aggressive chemicals such as acids and alkalies.
- The decorative effect may be obtained through colour, gloss or texture or combination of these properties.

Types of Paint

- Primer
- Undercoat / Surfacer
- Top Coats

Types of Paint

- **PRIMERS**
- Primer is the first layer to be applied.
- The main purpose of the primer is to wet the surface of the substrate and provide adhesion and corrosion protection.
- The choice of a primer is determined by the condition of the surface and corrosion severity of environment

Types of Paint

- **UNDERCOATS/SURFACERS**
- Intermediate coating are sometimes applied to improve adhesion and impact strength between primer and topcoats.
- They should have good compatibility with finish coat and primers.
- The undercoat and finishing paint serve to protect the primer and enable it to retain its inhibiting effect on the metal.

Types of Paint

- **TOP COATS**
- The final coating is described as the top or finish coat enamel.
- The top coat protects the metal against environmental attack like destructive ultraviolet light, ingress of air, moisture and attack from chemicals and corrosive fumes.
- The finish coat provides aesthetics of colour and gloss as well as hardness and abrasion resistance.
- It should be ensured that the finish coat is compatible with the undercoat**.**

Painting of wagons

- CONVENTIONAL PAINTS COMPRISING OF RED LEAD PRIMER TO IS : 102 FOLLOWED BY RED OXIDE PAINT TO IS : 123 ARE GENERALLY USED FOR GENERAL POOL WAGON PAINTING. NO PAINTING IS DONE ON THE INTERIOR OF WAGONS. WHILE IS : 102 HAS BEEN WITHDRAWN BY BIS, IS : 123 HAS BEEN MERGED WITH IS : 13607 IN WHICH 14 CONVENTIONAL PAINTS BASED ON OIL MEDIUM HAVE BEEN CONVERTED INTO OLEO RESINOUS BASED PAINTS**. NOW THESE WAGONS ARE BEING PAINTED WITH: ON EXTERIOR**
- **R O Zn Cr PRIMER TO IS:2074 -2C**
- **PAINT FINISHING,GP,SYNTHETIC TO IS:13607-2C OR**
- **RED OXIDE, BRUSHING, FINISH.GLOSSY TO RDSO SPECN NO. M&C/PCN/122/06 -2C**
- **UNDER GEAR PORTION: ALLTYPES OF WAGONS**
- **BITUMINOUS BLACK ,HEAT RESIS. TO IS:158-2C**

Coach painting

- **LIMITATIONS OF ALKYD BASE PAINTING SYSTEM**
- Low durability
- Poor gloss retention
- Frequent repainting

Coach painting

- **REASONS FOR SWITCH OVER TO PU SYSTEM**
- Better durability
- Better abrasion resistance
- Good gloss retention
- Better UV resistance
- Better chemical resistance

Coach painting

- **REASONS FOR SWITCH OVER TO EPOXY PU SYSTEM**
- Epoxy system is nontoxic
- Epoxy resin is abandently available in our country
- Epoxy primer has better adhesion property

Coach painting

- **LIMITATIONS OF EPOXY PU SYSTEM**
- **High initial cost**
- **Low pot life**
- **Being two component system, careful mixing ratio is to be maintained**
- **High consumption of costly thinners**
- **Precaution to be taken during application**
- **It may be noted that face masks, gloves, spray booth etc. are required for spraying any painting system.**

Bridge painting

- **BRIDGES SITUATED IN NON-COASTAL, NON-CORROSIVE AREAS:**
- **RED LEAD PRIMER (OR) ZINC CHROMATE PRIMER TO IS:104 OR ZNCR PRIMER TOIS:2074 -1COAT OF EACH**
- **FINISH : RED OXIDE FINISH TO IS:123 OR ALUMINIUM PAINT TO IS:2339, 2COATS**
- **BRIDGES SITUATED IN COASTAL & CORROSIVE AREAS:**
- **EPOXY ZN. PHOS. PRIMER (2 PACK)--2C**
- **EPOXY MIO (2 PACK)—1C**
- **PU ALUMINIUM (3 PACK)—2C**

Anodic protection

- Aluminium metal gets protected by the thin film of aluminium oxide when exposed to the atmosphere.
- Components made of aluminium are often anodised for having better corrosion protection

Inhibitors

- A **corrosion inhibitor** is a chemical compound that, when added to a fluid or gas, decreases the corrosion rate of a metal or an alloy.
- Some of the mechanisms of its effect are formation of a passivation layer (a thin film on the surface of the material that stops access of the corrosive substance to the metal),
- inhibiting either the oxidation or reduction part of the redox corrosion system (anodic and cathodic inhibitors), or
- scavenging the dissolved oxygen.

Inhibitors

- Inhibitors are used in coolant of cooling system of locomotives
- Recently RDSO has finalised a specification for concrete inhibitor admixure for inhibition of corrosion of reinforced bars and rods of concrete.

Conclusion

- **IT MAY BE SEEN FROM THE ABOVE THAT INDIAN RAILWAYS ARE DEALING WITH CORROSION PROBLEM ASSOCIATED WITH VARIOUS CONSTRUCTION MATERIALS AND THE ANTI CORROSIVE SYSTEMS RANGES FROM LUBRICANTS (GRAPHITED GREASE), CONVENTIONAL PAINTS, HIGH PERFORMANCE PAINTS BASED ON EPOXY AND POLYURETHANE AND ALSO METALLIC COATINGS VIZ GALVANIZING FOR OHE MASTS AND ALUMINIZING FOR BRIDGE GIRDERS.**

Conclusion

- **IN THE COMING DAYS, THE EMPHASIS MAY BE ON HIGH PERFORMANCE COATINGS AND MORE SO ON ECO-FRIENDLY PAINTING SYSTEM.**
- **THERE EXIST AN EXCELLENT POTENTIAL FOR INTRODUCTION OF THESE COATINGS WITH HIGH DURABILITY IN THE YEARS TO COME**

THANK YOU