Lecture 14

Prevention Strategies – Design and Coatings

Keywords: Corrosion Prevention, Designs, Protective Coatings.

There are a number of methods to control corrosion. The choice of any one control technique depends on economics, safety aspects and other technical considerations.

Design

Materials selection

Protective coatings

Inhibitors and environmental alterations

Corrosion allowances

Engineering design with a view to corrosion abatement is important. For example, a simple aspect such as providing drainage, as for an automobile side panel. Choice of appropriate materials keeping in mind the probability of corrosion in the existing environmental conditions is very critical. Among the materials available for selection; titanium, copper – alloys, stainless steels, carbon steels and aluminium and its alloys are often chosen.

Proper design of equipment

In the design of equipment, fittings such as baffles, valves and pumps to be considered

Elimination of crevices

Complete drainage of liquids

Easy to clean

Facilitate easy access to inspection and maintenance

Avoid bimetal contacts – Insulation of Joints.

General choice of metals and alloys for corrosive applications is given in Table 14.1.

Table 14.1 Choice of materials for corrosive environments

Material	Environment
Nickel and alloys	Caustic solutions
Monel	Hydrofluoric acid
Hastelloys	Hot hydrochloric acid
Stainless steels	Nitric acid
Lead	Dil. sulfuric acid
Tin	Water
Titanium	Hot strong oxidizing acids/liquids

Carbon steels are readily available cheaply and can easily be formed and worked into different shapes. Carbon steels can undergo different types of corrosion, such as rusting, hydrogen embrittlement and galvanic corrosion. Galvanization is commonly used to protect structural steels. Protective coatings, cathodic protection and inhibitor are extensively used to improve the structural life of carbon steels.

Stainless steels are generally immune to corrosion in mild environments. However, they may experience pitting, crevice and stress corrosion cracking in aggressive environments such as sea water, chemical processing etc. Ferritic and austenitic stainless steels are used in thin wall tubing in heat exchangers and also in many industrial and marine applications. Type 304 stainless steel is used in valve parts, pump shafts and fasteners. Duplex stainless steels (Cr – Mo alloys of iron) are used in chloride and high temperature environments. Martensitic stainless steels possess good mechanical strength.

Nickel and alloys are used in chemical process industries. Nickel – copper alloys as monel possess resistance to nonoxidizing acids. Nickel-chromium-iron alloys passivate in presence of oxidizers. Addition of molybdenum increases chloride resistance.

Copper and its alloys are quite resistant to non-oxidizing aqueous and many atmospheric environments. Brass undergoes dezincification. Aluminium and naval brasses are more resistant. Bronzes and aluminium bronzes are resistant to impingement. Copper-nickel alloys exhibit good resistance to impingement and stress corrosion.

Corrosion resistance of aluminium alloys vary widely depending on type of alloy addition and environments.

Titanium and alloys show stable, protective oxide film (passivation). Very good corrosion resistance in hot acids and many other corrosive environments.

Some general approaches for corrosion prevention are detailed in Tables – 14.2 and 14.3.

Table 14.2 Corrosion protection methods and processes

Approach	Process
Removal of oxidizers	Boiler water
Corrosion inhibition	Inhibitors & pH control
General corrosion prevention	Anodic and Cathodic protection
Coatings:	
Metallic	Electroplating, galvanizing, metal spray or immersion.
Organic	Claddings and paints.
Nonmetallic	Anodizing, Conversion coatings.
Metal modification	Alloying
Change in surface / environment conditions	Removal of corrosives (maintenance)
	Proper designs • Avoid crevices • Provide drainage • Avoid bimetallic joints

Since general corrosion is predictable, design considerations can include preventive measures whenever and wherever possible.

Some examples: Wall thickness control

Control of process stream composition (Elimination of chlorides)

Prevention of acid contacts - neutralization.

Minimization of vapor condensations and collection.

Prevention of leakage of corrosives.

For carbon steels: Cathodic protection combined with coatings.

Channel and angle sections positioned to collect and drain water, liquids and debris.

Table 14.3 Corrosion types with prevention strategies

Type of corrosion	Prevention Strategies
Stress corrosion cracking	More resistant alloys. Remove tensile stress, control of environment (elimination of chlorides)
Corrosion fatigue	Eliminate cyclic stress and corrosive environment. More rigid design to reduce stresses due to vibrations. Avoid stress concentration in design.
Hydrogen embrittlement	Choice of less – susceptible alloy / coatings. Avoid cathodic protection (steels in acid Environments)
Galvanic Corrosion	Selection of metals / alloys closer in galvanic series. Favorable cathode to anode ratio. Coating taking care not to create smaller anodes with larger cathodes, insulation of dissimilar joints.
Crevice corrosion	Proper design of junctions and joints to minimize crevices. Welded joints preferable to rivets and bolts. Pitting and crevice corrosion are enhanced in stagnant / slow flowing solution. Provide drainages.
Erosion corrosion and cavitation	Design to reduce velocity and turbulence, avoid abrupt changes in flow directions.

Coatings

- Barrier between corrosive environment and metal.
- Coatings may serve as sacrificial anodes (zinc on steels) or release substances that resist corrosion.
- Metal coatings - Noble coat - Silver, copper, nickel, chromium, tin, lead on steels (ensure pore - free, uniform, adherent coating; favorable anode / cathode ratio to minimise galvanic attacks).
  Sacrificial coatings – Zinc, aluminium, cadmium on steels. (steel is cathodic to plated metal).

Coatings can be applied through hot dipping, hot spraying, electroplating, electro-less plating, vapour deposition and metal cladding.

Aluminium, stainless steel, titanium, platinum etc can be cladded on various metallic substrate for enhanced corrosion protection (physical or chemical).

Other types of surface treatments.

Modification of substrates through ion implantation and laser processing.

Inorganic coatings: glass, cement, ceramic and chemical conversion coatings.

Chemical conversion: Anodizing, oxide, chromate, phosphatizing.

Organic coatings: Paints, lacquers, varnishes (Resin, solvent + pigment in the coating liquid). High performance organic coatings used in petroleum industries.

Development of corrosion – resistant synthetic resins.

Types of paint coatings

Good adhesion, flexibility, impact resistance and protection from chemicals, moisture, and atmospheric conditions.

- Lacquer – synthetic resins (vinyl chloride, acrylic, rubber).
- Latex (Acrylics and Vinyls)
- Oil-based and Epoxy coatings (good bending, hard and flexible)
- Coal – tar – epoxy.
- Poly – urethanes, polyester and vinyl ester (hard, brittle or elastomeric).
- Organic zinc rich coatings (organic barrier + galvanic Zn protection)
- Co-polymeric protective coatings.(thermoplastic – copolymer - aromatic coatings).

Anti - corrosion paints – various types additives to improve corrosion resistance, durability and impermeability.