Corrosion control by material selection

Corrosion may be minimized by employing an appropriate design as discussed, on the other hand the selection of appropriate materials in a given environment is a key for corrosion control strategy. The following table shows the contribution of corrosion resistance to be the process of material selection.

Factors Affecting the performance of material

1. Expected performance and functions of the products, for example if a sea water storage tank is to be fabricated, fiberglass would be an ideal material because of its advantage of density and resistance to corrosion, while for industrial water supply discharge of used water and irrigation water, PVC (polyvinyl chloride) would be ideal because of the advantage of increased durability, non corrosivity, ease of maintenance and quality-to-price ratio, they offer, and for aerospace application Aluminum alloys (Al-Mg-Si-Cu alloy) is very promising and finding increased application because of its combination of mechanical properties, corrosion resistance, weld ability and high strength-to-weight.

2. Physical characteristics such as electrical conductivity, thermal coefficient of expansion, and thermal conductivity are important for selection material for instance copper-nickel (90-10 Ni-Cu) are excellent material for heat exchanger.
tubes in thermal desalination plants employing raw sea water, because of their excellent conductivity and corrosion resistance.

3. Strength & mechanical characteristics, factors such as yield strength, tensile strength, fatigue strength and creep strength are crucial to design as they dictate the ability of a product or component to withstand different types of stress imposed upon them while in service. Mechanical properties also affected by environment. for instance the yield strength of steels may be significantly reduced by saline water over period of time.

4. Corrosion and wear characteristics improper selection of materials without consideration of their corrosion behavior in aggressive service environment can lead to failure of components and plant shutdown, to avoid failures caused by corrosion:

   1. Material should be compatible with environment. they must possess sufficient resistance to corrosion for the designed life

   2. Appropriate preventive maintenance practice must be adopted.

The selection of material must be based on an extensive knowledge of service environment. It is to be realized that the behavior of a material may dramatically change when exposed to a corrosive environment.

The behavior of material largely depends upon the following:

![Diagram of Corrosive Medium parameters]

- Physical state (solids, liquids, gases)
- Chemical composition
- External factors
- Dissolved gases (O₂, H₂S, CO₂, etc.)
- Organic matter and bacteria
- Temperature, pH, conductivity
1. Corrosive medium parameter

(a) Composition of the corrosive medium. For instance, if a metal is exposed in seawater, a quantitative analysis of all constituents must be made to determine the composition.

(b) Physical and external factors affecting the medium, such as pH, conductivity, temperature and velocity affect the magnitude of corrosion induced by the medium.

(c) Presence of dissolved gases, such as oxygen, carbon dioxide, hydrogen sulfide in fluids promotes the corrosivity of the medium.

(d) Presence of organic matter and bacteria promote the corrosivity of the environment. For instance, sulfide reducing bacteria, desulfovibrio and Clostridium, induce corrosion by producing hydrogen sulfide, a serious corrodant for steel. Algae, yeasts and molds also contribute to corrosion.

(e) Physical state of the corrosive medium has a pronounced effect on the corrosivity of the medium. For instance, a dry soil would be less aggressive to corrosion than a wet soil in which salts are dissolved. Similarly, a frozen soil with a very high resistivity exceeding 10000 ohm-cm would not corrode a pipe, whereas, a wet soil with a low resistivity, such as 500 ohm-cm would cause severe corrosion to structure buried in the soil. Liquids in intimate contact with metals, such as seawater, acids alkides and alkalies, are serious corroders for a large variety of metals and alloys. The presence of gases leads to adsorption on the surface and the formation of an oxide, sulfide, and chlorides. Dry oxidation refers to an electron producing reaction in a dry gaseous environment. It is also known as 'hot corrosion' if sulfur is involved. Accelerated oxidation (catastrophic oxidation) occurs at high temperatures and leads to accelerated failure of metals.

**Design Parameters**

Design parameters which affect the rate of corrosion include the following:

(1) Stresses acting on the materials in service.

(2) Relative velocity of the medium and obstacles to flow.

(3) Bimetallic contacts.

(4) Crevices.

(5) Riveted joints.

(6) Spacing for maintenance.

(7) Drainage and directional orientation of loop.
(8) Joints to avoid entrapment.
(9) Sharp corners.
(10) Non-homogeneous surface.

**Materials Parameters**

The following are the material parameters which may affect corrosion resistance:

(1) Impurity segregation on grain boundaries leads to weakening of grain boundaries and accelerates corrosion attack. In 18-8 steels, the depletion of chromium due to the formation of chromium carbide promotes intergranular attack. The formation of Mg$_2$Si at the grain boundaries in Al-Mg alloys leads to weakening of grain boundaries and promotes corrosion of Al-Mg alloys.

(2) Microstructural constituents. A heterogeneous microstructure forms anodic and cathodic sites which promotes corrosion. The intermetallic precipitate serves as anodic and cathodic sites and they may be anodic or cathodic to the matrix. For instance, a C11Al2 precipitate is cathodic to the aluminum matrix and Mg2Si is anodic to the matrix. Microstructural variation plays a leading role in metal matrix composites. For instance, Al 6013-SiC composite corrodes at the Al matrix/SiC interface because of the preponderance of intermetallic secondary phases. Also a non-homogeneous distribution of SiC contributes to accelerated corrosion.

(3) Surface treatment, such as galvanizing, phosphating and painting increase the resistance of materials to corrosion. Galvanizing improves the resistance of steels to corrosion and is widely used in automobile industry. Galvanized pipes are widely used for transport of hot water in domestic plumbing systems. If the temperature, however, exceeds 65°C, reversal of polarity (steel becomes anodic) can cause corrosion of the galvanized pipes.

(4) Alloying elements and film formation. Alloying elements in steels, such as chromium, nickel or molybdenum contribute to the production of a protective oxide layer which makes steel passive. Addition of copper to aluminum alloy increases the strength but decreases the corrosion resistance. Scandium addition to Al-Mg-Si alloys significantly increases their strength without affecting a decrease in their corrosion resistance. Coatings of epoxy and polyurethanes provide a longer life to structures exposed to corrosive environments. Amorphous thermally sprayed coatings using physical vapor deposition (PVD), chemical vapor deposition (CVP), laser or electron surface remelting and thermal spraying techniques offer excellent resistance to corrosion. Recently electron beam physical vapor deposited coatings (EB-PVD) has been found to increase the component life significantly.
FABRICATION PARAMETERS

Following are the fabrication parameters required for analyzing material selection:

Weldability. Welding procedures, such as electric arc welding, friction welding, spot welding, need to be carefully selected to minimize the effect of corrosion. For instance, gaswelding in the sensitive temperature range may cause intergranular cracking.

(2) Machinability. Machining operations, such as drilling, milling, shearing, turning, may lead to enhancement of corrosion if they are not properly controlled. Drilling fluids are highly corrosive and need to be handled with care.

(3) Surface modification procedures, such as cladding, galvanizing and metallizing (metallic coatings) increase the resistance of the materials to corrosion. The success of the coating depends on the bonding between the coating and the substrate and surface preparation before the application of coatings according to the international standards. Surface preparation techniques include hand, power tool cleaning and abrasive blast cleaning according to the American Standards for Surface Cleaning.