



Corrosion can be defined as the deterioration of material by reaction to its environment. Water intrusion is the principal cause of corrosion problems encountered in the field use of equipment. At normal atmospheric temperatures the moisture in the air is enough to start corrosive action. Oxygen is essential for corrosion to occur in water at ambient temperatures. Other factors that affect the tendency of a metal to corrode are:

- 1 - acidity or alkalinity of the conductive medium (pH factor)
- 2 - stability of the corrosion products
- 3 - biological organisms (particularly anaerobic bacteria)
- 4 - variation in composition of the corrosive medium
- 5 - temperature

TYPES OF CORROSION

Concentration Cell Corrosion

Concentration cell corrosion occurs when two or more areas of a metal surface are in contact with different concentrations of the same solution. There are three general types of concentration cell corrosion :

Metal Iron Concentration Cell Corrosion

In the presence of water, a high concentration of metal ions will exist under faying surfaces and a low concentration of metal ions will exist adjacent to the crevice created by the faying surfaces. An electrical potential will exist between the two points. The area of the metal in contact with the low concentration of metal ions will be cathodic and will be protected, and the area of metal in contact with the high metal ion concentration will be anodic and corroded.

This can be eliminated by sealing the faying surfaces in a manner to exclude moisture. Proper protective coating application with inorganic zinc primers is also effective in reducing faying surface corrosion.



Oxygen Concentration Cells

A water solution in contact with the metal surface will normally contain dissolved oxygen. An oxygen cell can develop at any point where the oxygen in the air is not allowed to diffuse uniformly into the solution, thereby creating a difference in oxygen concentration between two points. Corrosion will occur at the area of low-oxygen concentration (anode).

The severity of corrosion due to these conditions can be minimized by sealing, maintaining surfaces clean, and avoiding the use of material that permits wicking of moisture between faying surfaces.

Active-Passive Cells

Metals that depend on a tightly adhering passive film (usually an oxide) for corrosion protection; e.g., austenitic corrosion-resistant steel, can be corroded by active-passive cells. The corrosive action usually starts as an oxygen concentration cell; e.g., salt deposits on the metal surface in the presence of water containing oxygen can create the oxygen cell. If the passive film is broken beneath the salt deposit, the active metal beneath the film will be exposed to corrosive attack. An electrical potential will develop between the large area of the cathode (passive film) and the small area of the anode (active metal). Rapid pitting of the active metal will result. This type of corrosion can be avoided by frequent cleaning and by application of protective coatings.

Galvanic Corrosion

Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It occurs when dissimilar metals are in contact. It is recognizable by the presence of a build-up of corrosion at the joint between the dissimilar metals. Filiform corrosion is a unique type of galvanic corrosion occurring under painted surfaces or plated surfaces that do not exhibit good adhesion and under gaskets when moisture permeates the coating.

The following recommended practices should be observed to keep galvanic corrosion to a minimum:

- a. Avoid the use of widely dissimilar metals in direct contact.
- b. When dissimilar metals must come into contact, they should be separated by using nonconductive barrier materials, a paint coating, or by plating.
- c. The anode should be as large as feasible in relation to the cathode.
- d. Coat both the anode and the cathode with the same material.
- e. When possible, install fasteners that have been dipped in epoxy mastic coatings.
- f. Seal threaded inserts with epoxy mastic coatings prior to insertion into castings.
- g. Avoid the use of lock or toothed washers over plated or anodised surfaces.
- h. Use only dry-film lubricants that are graphite free.

Intergranular Corrosion

Intergranular corrosion is an attack on the grain boundaries of a metal or alloy. A highly magnified cross section of any commercial alloy will show its granular structure. This structure consists of quantities of individual grains, and each of these tiny grains has a clearly defined boundary that chemically differs from the metal within the grain center.

Frequently, the grain boundaries are anodic to the main body of the grain, and when the grain boundaries are in this condition and in contact with an electrolyte, a rapid selective corrosion of the grain boundaries occurs.

Exfoliation is a form of intergranular corrosion. It manifests itself by lifting up the surface grains of a metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface. It is visible evidence of intergranular corrosion and most often seen on extruded sections where grain thickness is less than in rolled forms.



Intergranular corrosion can be prevented by adopting one or more of the following methods:

- a. Select an alloy type that is resistant to intergranular corrosion.
- b. Avoid heat treatments or service exposure that makes a material susceptible. Normally this occurs with austenitic stainless steels when they are held for some time in the sensitising temperature range of 470 to 915 degrees Celsius (800 to 1600 F).
- c. Apply a protective coating.

Pitting Corrosion

The most common effect of corrosion on aluminum and magnesium alloys is called pitting. It is noticeable first as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is cleaned away, tiny pits or holes can be seen in the surface.

Pitting may be a serious type of corrosion because it tends to penetrate rapidly into the metal section. Pits begin by a breakdown of passivity at nuclei on the metal surface. The breakdown is followed by formation of an electrolytic cell, the anode of which is a minute area of active metal and the cathode of which is a considerable area of passive metal. The large potential difference characteristic of this "passive-active cell" (0.5 to 0.6 volt for 18-8 stainless steel) accounts for a considerable flow of current with attendant rapid corrosion at the small anode.

The corrosion-resistant passive metal surrounding the anode and the activating (passivity-destroying) property of the corrosion products within the pit account for the tendency of corrosion to penetrate the metal rather than spread along the surface. Pitting is most likely to occur in the presence of chloride ions, combined with such depolarizers as oxygen or oxidizing salts.

Methods that can be used to control pitting include maintaining surfaces clean, application of a protective coating, and use of inhibitors or cathodic protection for immersion service.

Uniform Etch Corrosion

The surface effect produced by most direct chemical attacks (e.g., as by an acid) is a uniform etching of the metal. On a polished surface, this type of corrosion is first seen as a general dulling of the surface and, if allowed to continue, the surface becomes rough and possibly frosted in appearance. The use of chemical-resistant protective coatings or more resistant materials will control these problems.

Stress Corrosion Cracking

Stress corrosion cracking (SCC) is caused by the simultaneous effects of tensile stress and corrosion. Stress may be internally or externally applied. Internal stresses are produced by non-uniform deformation during cold working, by unequal cooling from high temperatures, and by internal structural rearrangement involving volume changes. Stresses induced when a piece is deformed, those induced by press and shrink fits, and those in rivets and bolts are internal stresses.

A few guides in avoiding the problem are:

- a. Use metal alloys at no greater than 75 percent of their yield strength and use exotic materials only where they are actually required.
- b. Avoid assemblies where high-tensile loads are concentrated in a small area.
- c. Place surfaces under compressive stresses where feasible, by shotpeening, sandblasting, etc.
- d. Remove stress risers from counter bores, grooves, etc.
- e. Metals shall be selected from alloys that are highly resistant to SCC.

Fatigue Corrosion

Fatigue corrosion is a special case of stress corrosion caused by the combined effects of cyclic stress and corrosion. No metal is immune from some reduction of its resistance to cyclic stressing if the metal is in a corrosive environment.

Fatigue corrosion failure occurs in two stages. During the first stage, the combined action of corrosion and cyclic stresses damages the metal by pitting and crack formation to such a degree that fracture by cyclic stressing will ultimately occur, even if the corrosive environment is completely removed.

The second stage is essentially a fatigue stage in which failure proceeds by propagation of the crack and is controlled primarily by stress concentration effects and the physical properties of the metal.

Protection of all parts subject to alternating stress is particularly important wherever practical, even in environments that are only mildly corrosive.

Fretting Corrosion

The rapid corrosion that occurs at the interface between contacting, highly loaded metal surfaces when subjected to slight vibratory motions is known as fretting corrosion. This type of corrosion is most common in bearing surfaces in machinery, such as connecting rods, splined shafts, and bearing supports, and often causes a fatigue failure. It can occur in structural members such as trusses where highly loaded bolts are used and some relative motion occurs between the bolted members.

Fretting corrosion is greatly retarded when the contacting surfaces can be well lubricated as in machinery-bearing surfaces so as to exclude direct contact with air.

Crevice Corrosion

Crevice or contact corrosion is the corrosion produced at the region of contact of metals with metals or metals with nonmetals. It may occur at washers, under barnacles, at sand grains, under applied protective films, and at pockets formed by threaded joints. Whether or not stainless steels are free of pit nuclei, they are always susceptible to this kind of corrosion because a nucleus is not necessary. Crevice corrosion may begin through the action of an oxygen concentration cell and continue to form pitting.

Contact or crevice corrosion occurs when surfaces of metals are used in contact with each other or with other materials and the surfaces are wetted by the corrosive medium or when a crack or crevice is permitted to exist in a stainless-steel part exposed to corrosive media.

Cleanliness, the proper use of sealants, and protective coatings are effective means of controlling this problem.