



Corrosion and Types of corrosion Materials

Corrosion is the slow but continuous eating away of metallic components by chemical or electrochemical attack. That this is costly and destructive will be vouched for by any motorist.

Three factors govern corrosion.

- The metal from which the component is made.
- The protective treatment the component surface receives.
- The environment in which the component is kept.

All metals corrode to a greater or lesser degree; even precious metals like gold and silver tarnish in time, and this is a form of corrosion. Prevention processes are unable to prevent the inevitable failure of the component by corrosion; they only slow down the process to a point where the component will have worn out or been discarded for other reasons before failing due to corrosion. Let's now look at the three ways in which metals corrode.

Dry corrosion This is the direct oxidation of metals which occurs when a freshly cut surface reacts with the oxygen of the atmosphere. Most of the corrosion-resistant metals such as lead, zinc and aluminum form a dry oxide film which protects the metal from further atmospheric attack.

Wet corrosion: This occurs in two ways:

- a) The oxidation of metals in the presence of air and moisture, as in the rusting of ferrous metals.
- b) The corrosion of metals by reaction with the dilute acids in rain due to the burning of fossil fuels (acid rain) - for example, the formation of the carbonate 'patina' on copper. This is the characteristic green film seen on the copper clad roofs of some public buildings.

Galvanic corrosion: This occurs when two dissimilar metals, such as iron and tin or iron and zinc, are in intimate contact. They form a simple electrical cell in which rain, polluted with dilute atmospheric acids, acts as an electrolyte as generated and circulates within the system. Corrosion occurs with (depending upon its position in the electrochemical series) being eaten away.

Other metals, in addition to iron and steel, corrode when exposed to the atmosphere. The green corrosion-product which covers a copper roof, or the white, powdery film formed on some unprotected aluminum alloys is clear evidence of this.

Fortunately the reactivity of a metal and the rate at which it corrode is not related. For example, although aluminum is chemically more reactive than iron, as soon as it is exposed to the atmosphere it forms an oxide film which seals the surface and prevents further corrosion from taking place. On the other hand, iron is less reactive and forms its oxide film more slowly. Unfortunately, the iron hydroxide film (rust) is porous and the process continues unabated until the metal is destroyed.

Types of corrosion

1. Atmospheric corrosion

Any metal exposed to normal atmospheric conditions become covered with an invisible, thin film of moisture. This moisture film is invariably contaminated with dissolved solids and gases which increase the rate of corrosion. The most common example of corrosion due to dissolved oxygen from the atmosphere is the rapid surface formation of 'red rust' on unprotected ferrous metals. This 'red rust' is a hydroxide of iron and should not be confused with the blue-black oxide of iron called 'mill-scale' which is formed by heating iron in dry air.



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Once 'rusting' commences the action is self-generating - that is, it will continue even after the initial supply of moisture and air is removed. This is why all traces of rust must be removed or neutralized before painting, otherwise rusting will continue under the paint, causing it to blister and flake off.

2. Galvanic corrosion

It has already been stated that when two dissimilar metals come into intimate association in the presence of an electrolyte that a simple electrical cell is formed resulting in the eating away of one or other of the metals. Metals can be arranged in a special order called the electrochemical series. This series is listed in Table 1 and it should be noted that, in this context, hydrogen gas behaves like a metal.

Metal	Electrode
Sodium	-2.71 Corroded (anodic)
Magnesium	-2.40
Aluminium	-1.70
Zinc	-0.76
Chromium	-0.56
Iron	-0.44
Cadmium	-0.40
Nickel	-0.23
Tin	-0.14
Lead	-0.12
Hydrogen (reference potential)	0.00
Copper	+0.35
Silver	+0.80
Platinum	+ 1.20
Gold	+ 1.50 Protected (cathodic)

If any two metals come into contact in the presence of a dilute acid, the more negative metal will corrode more rapidly and will be eaten away.

3. Corrosion accelerated by mechanical stresses

We have seen that failure of a component may take place due to corrosion arising from electrolytic action between two different phases in a microstructure, or between two different materials in a fabricated structure. Failure of a component may also occur as a result of the complementary effects of chemical corrosion and mechanical stress. The methods of stress application may vary and this will affect the extent of corrosion which occurs. Forms of corrosion in which stress plays a part can be classified as follows:

3.1 Stress Corrosion

In a cold-worked metal the pile-up of dislocations at crystal boundaries and other points increases the energy in those regions so that they become anodic to the rest of the structure. Consequently, corrosion takes place in these regions of high energy and the locked-up stresses give rise to the formation of cracks which grow progressively with the continuance of corrosion. A similar process may take place in components in which unequal heating or cooling has given rise to the presence of locked-up stresses, as, for example, near to welded joints.



3.2 Corrosion Fatigue.

As might be expected, any component which is subjected to alternating stresses and is working in conditions which promote corrosion may fail at a stress well below the normal fatigue limit (3.72). The action of the corrosive medium will tend to be concentrated at any surface flaw and behave as a focal point for the initiation of a fatigue crack. Once a crack has been formed it will spread more rapidly as a result of the corrosive action combined with alternating stress.

3.3 Fretting Corrosion

Is allied to corrosion fatigue and occurs particularly where closely fitting machine parts are subjected to vibrational stresses. In steel this form of corrosion appears as patches of finely divided ferric oxide (Fe₂O₃).

3.4 Impingement Corrosion

Refers to the combined effects of mechanical abrasion and chemical corrosion on a metallic surface. Mechanical wear can be caused by the impingement of entrained air bubbles or abrasive particles suspended in the liquid. The impingement of such media may lead to the perforation of any protective film existing on the surface. This film may be an oxide, which is cathodic to the exposed metal beneath. This type of corrosion is encountered in pump mechanism turbine and tuber carrying sea-water.

Factors affecting corrosions

1. Structural design

The following factors should be observed during the design stage of a component or assembly to reduce corrosion to a minimum.

- The design should avoid crevices and corners where moisture may become trapped, and adequate ventilation and drainage should be provided.
- The design should allow for easy washing down and cleaning.
- Joints which are not continuously welded should be sealed, for example, by the use of mastic compounds or impregnated tapes.
- Where dissimilar metals have to be joined, high-strength epoxy adhesives should be considered since they insulate the metals from each other and prevent galvanic corrosion.
- Materials which are inherently corrosion resistant should be chosen or, if this is not possible, an anti-corrosive treatment should be specified.

2. Environment

The environment in which the component or assembly is to spend its service life must be carefully studied so that the materials chosen, or the anticorrosion treatment specified, will provide an adequate service life at a reasonable cost. It would be unnecessary and uneconomical to provide a piece of office equipment which will be used indoors with a protective finish suitable for heavy-duty contractors plant which is going to work on construction sites in all kinds of weather conditions.

3. Applied or internal stresses

Chemical and electrochemical corrosion is intensified when a metal is under stress. This applies equally to externally applied and internal stresses, although more common in the latter case. Internal stresses are usually caused by cold working and, if not removed by stress-relief heat treatment, results in corrosive attack along the crystal boundaries. This weakens the metal considerably more than simple



surface corrosion. An example of inter-crystalline corrosion is the 'season cracking' of a brass after severe cold working.

Inter-crystalline corrosion occurs at the grain boundaries of crystals not only when impurities are present but also when stress concentrations are present. Grain boundaries are regions of high energy levels, even in very pure metals, so corrosion tends to occur more quickly at the grain boundaries.

Severely cold-worked α brasses are prone to 'season cracking'. Here, inter-crystalline corrosion follows the grain boundaries until the component is no longer able to sustain the internal stresses due to cold working. The component then cracks. This can be prevented by a low temperature stress relief annealing process. This low temperature does not cause recrystallization but is sufficient to remove the locked up stresses by allowing the atoms to move small distances nearer to their equilibrium positions.

4. Composition and structure

The presence of impurities in non-ferrous metals reduces their corrosion resistance. Hence the high level of corrosion resistance exhibited by high purity copper, aluminum and zinc. The importance of grain structure has also been mentioned above, and a fine-grain structure is generally less susceptible to corrosion than a coarse-grain structure. The inclusion of certain alloying elements such as nickel and chromium can also improve corrosion resistance - for example, the stainless steels and cupro-nickel alloys.

5. Temperature

For all chemical reactions there is a critical temperature below which they will not take place. Since corrosion is the result of chemical or electrochemical reactions, corrosion is retarded or stopped altogether at low temperatures. On the other hand, corrosion is at its worst in the hot, humid atmosphere of the tropical rain forests, and equipment for use in such environments has to be 'tropicalised' if it is to have a reasonable service life. High temperatures alone do not increase the rate of corrosion, and corrosion is virtually nonexistent in arid desert areas of the world. Failure of mechanical devices in desert environments is due generally to the abrasive effect of the all-pervasive sand.

Metals which resist corrosion

It has already been made clear that metals combine with atmospheric oxygen and or atmospheric pollutants to a greater or lesser extent. The following metals, which resist corrosion, react to form impervious, homogeneous coatings on their surfaces which prevent further corrosion from taking place, providing these coatings remain undisturbed. Such as copper, zinc, aluminum, lead, stainless steel, nickel and chromium.