

GALVANIC CORROSION

When different metals come into contact with each other, one is likely to corrode faster if they get wet, but there are ways to minimise or even prevent corrosion.

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Galvanic corrosion, sometimes referred to as bimetallic corrosion or dissimilar metal corrosion, can be defined as quick deterioration due to contact between dissimilar metals. This type of corrosion is commonly seen when two metals are in electrical contact while moisture (or any conducting corrosive electrolyte) is present. The result is enhanced and aggressive corrosion of one metal at the joint area together with partial or complete protection of the other metal (see Figure 1).

Rusting corrugated roofing steel is a prime example. When the galvanised zinc coating is partially damaged, both zinc and the underlying steel are exposed to the aggressive environment. The zinc is attacked while the underlying steel is protected. Only when zinc is consumed will the steel rust in earnest. Another example is aluminium alloys. When they are joined to steel or copper and exposed to a marine environment, aluminium alloys corrode faster than they do when exposed alone.

Why one material will corrode faster than another

Different materials have different electrical potentials. This difference is the main driving force for galvanic corrosion. In the presence of an electrolyte, such as a wet industrial atmosphere, an electrochemical cell can be established between two metals if the difference in potential between them is enough to drive an electric current flow from one material to another.

For galvanic corrosion to occur, certain basic requirements are necessary such as electrolytes, noble and less noble metals and electron conductors. By eliminating any one of these factors, corrosion can be prevented.

Other conditions necessary for galvanic corrosion include:

- electrical connection: in a structure, this

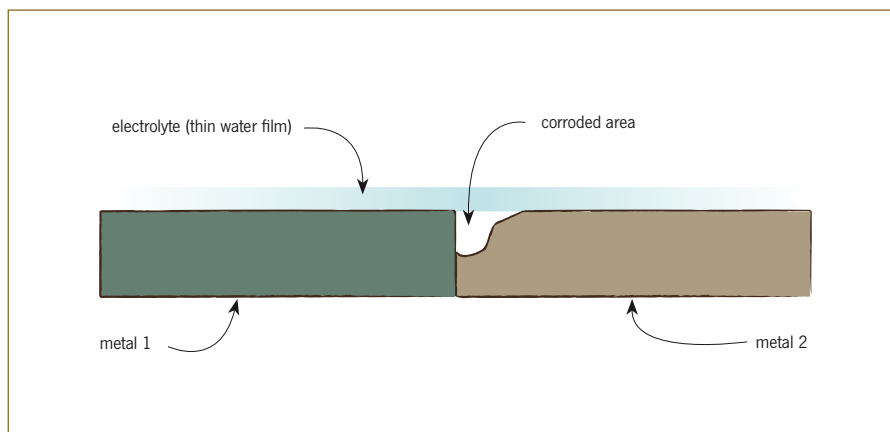


Figure 1: Schematic showing galvanic corrosion.

usually involves a direct metal-to-metal contact, e.g. rivets, bolts, spot welds

- sustained cathodic reaction: in most practical situations, this is the consumption of dissolved oxygen on the more noble (less active) of the two metals.

The corrosion process

Various factors are important for enhancing the corrosion rate of one metal when it is in direct electronic contact with another.

CORROSION POTENTIALS UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

The 'corrosion potentials' of any two metals in the environment will determine the direction of the transfer of electrons. Electrons will transfer from the metal with a negative potential (less noble) to the metal with a more positive potential (noble). The standard electrode potentials, as given in the electromotive force (EMF) series of metals, are often irrelevant in predicting the galvanic effect of coupling two metals in service.

The galvanic series in which metals are listed according to their corrosion potentials in sea water is more helpful (see Figure 2). The farther apart the metals are in the series, the greater

the corrosion effect could be. The less noble metal is the anode, or the one that will corrode. For example, if aluminium is in contact with AISI 304 stainless steel, the potential difference would be around 450 mV and the aluminium will corrode.

A criterion setting a maximum value of 250 mV difference in corrosion potential in sea water has sometimes been used as the safe limit for elimination of galvanic corrosion. However, the magnitude of the potential difference alone is not sufficient and sometimes has little or no technical significance. Metals with a potential difference of only 50 mV have shown galvanic corrosion problems, whereas other metals with a potential difference of 800 mV have been successfully coupled together.

However, the galvanic series can be misleading when other environments are involved. It is more realistic to determine the galvanic corrosion risk by measuring the actual corrosion potentials of the metals under whatever environmental conditions prevail.

THE RATIO OF METAL AREAS IN ELECTRICAL CONTACT

The intensity of galvanic corrosion is related to the ratio of areas of the metals in electrical →

**Noble
(least
active)**

Graphite	(0.2 → 0.29V)
Platinum (Pt)	(0.22 → 0.25V)
AISI 316 (Passive)	(-0.1 → 0V)
AISI 304 (Passive)	(-0.1 → -0.05V)
Lead (Pb)	(-0.25 → -0.19V)
AISI 430 (Passive)	(-0.28 → -0.2V)
AISI 410 (Passive)	(-0.35 → -0.26V)
Silicon bronze	(-0.29 → -0.26V)
Copper	(-0.37 → -0.3V)
Brass	(-0.4 → -0.3V)
Mild steel	(-0.63 → -0.57V)
Aluminium (Al)	(-1.0 → -0.76V)
Zinc (Zn)	(-1.03 → -0.98V)
Magnesium (Mg)	(-1.63 → -1.6V)

Figure 2: Galvanic series of common metals and alloys in sea water – V versus SCE (saturated calomel electrode).

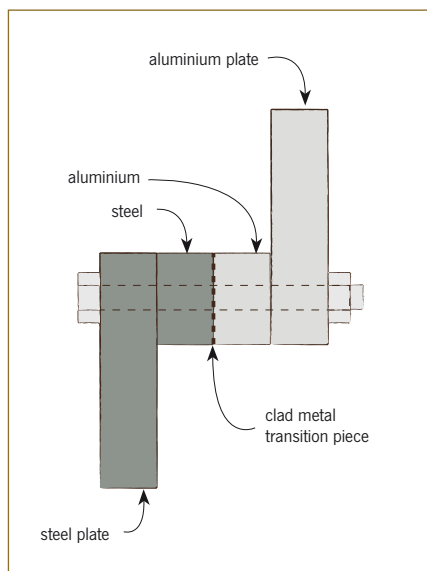


Figure 3: Transition piece inserted between dissimilar metal plates.

contact. When a noble metal with a large area is coupled to a less noble metal with a small area, galvanic action will cause much more severe corrosion of the less noble metal. Carbon steel or aluminium bolts in stainless steel members should be avoided because the ratio of the area of the stainless steel to the carbon steel is large and the bolts will be subject to enhanced attack; similarly for aluminium or zinc-plated steel rivets used in copper sheet.

The reverse situation, where the noble metal has a small area, produces little galvanic current. Thus, stainless steel fasteners in aluminium plates or sheets are normally considered safe. In practice, the anode (less noble metal) should be designed to have a larger area than the cathode (noble metal) to decrease risk of corrosion, even under extreme conditions (e.g. no insulation between the metals).

Dissimilar metals that are in close physical proximity usually suffer greater galvanic effects than those farther apart, because a long distance increases the resistance of the current path in the electrolyte and the external circuit.

ELECTROLYTE

Increased electrical conductivity of the electrolyte often increases the severity of galvanic corrosion. In practice, high conductivity is caused by the presence of aggressive ions such as chloride, or by acid or alkali. So galvanic corrosion is seldom a problem in pure water.

The electrolyte in atmospheric galvanic corrosion contains soluble contaminants such as acidic fumes from industrial atmospheres and chloride ions from marine atmospheres. Because such an electrolyte has a high electric resistance parallel to the surface, it is rare for corrosion to extend much further than 12–25 mm from the bimetallic junction.

Preventing galvanic corrosion

In practice, it is possible to reduce or eliminate galvanic corrosion damage between widely used dissimilar metals in a particular environment by altering one or more of the key factors mentioned above.

MATERIALS SELECTION – THE FEWER THE BETTER

Contact between austenitic stainless steels and zinc or aluminium may result in some additional corrosion of the latter two metals. Lead is not

compatible with zinc or aluminium coated products. Copper is not compatible with mild steel, galvanised steel, zinc/aluminium coated steel or prepainted roofing steel. Even when two incompatible metals are not in direct contact, it is still possible for metals to be damaged by bimetallic cells set up indirectly. Therefore, water run-off from copper to aluminium or zinc should be avoided, as traces of dissolved copper would set up multiple small bimetallic cells on the aluminium or zinc surface.

We recommend that designers use only one material in a construction or choose metal combinations in which the constituents are as close as possible in the corresponding galvanic series. If there is contact between dissimilar metals, it is important to avoid large area ratios of noble metal to less noble metal.

To eliminate a dissimilar metal junction, a transition piece can be used. This consists of the same metals as in the galvanic couple bonded together in a laminar structure. The transition piece is inserted between the members of the couple so that the similar metals are in contact (see Figure 3). The dissimilar metal junction where electrolyte may present is then eliminated.

ELECTRICAL ISOLATION

The physical contact between the dissimilar metals can be isolated to break the conducting path. This can be easily achieved by using non-conductive plastic or rubber gaskets and nylon or Teflon washers and bushes and polymeric coatings at the joint area. This approach is popular in the building and construction industry for isolation between fasteners and roofing steel sheets.

Another example is insulating domestic galvanised steel hot water heaters and tanks from black iron or copper plumbing. The design and maintenance must ensure that the insulator is not bridged by accumulated debris, and water-run-off issues need to be kept in mind.

PAINTING

Painting the galvanic couple can reduce the corrosion risk and rate by excluding water from the detail. Always paint both the anodic (less noble) and cathodic (noble) members of the couple to keep the exposed cathodic to anodic area ratio as small as possible. If only one member of the couple can be painted, the noble metal should receive this treatment. ■