NOTE 01 · MARCH 2024

Galvanic corrosion in mixed-metal assemblies

Nordoxa — Materials & Corrosion Engineering, Rotterdam

Galvanic corrosion needs three things at the same time: two metals with different electrochemical potentials, an electrolyte bridging them, and an electrical connection between them. Remove any one and the mechanism stops. That is the whole of it, and it is worth remembering because most practical mitigations are simply a decision about which of the three to remove.

The area ratio decides the severity

The separation between two metals on the galvanic series sets the driving force. What sets the rate at the anode is the ratio of cathode area to anode area. All the current collected over the cathode surface has to leave through the anode surface, so a large cathode feeding a small anode concentrates the attack.

- A stainless steel bolt in an aluminium bracket: small cathode, large anode. The aluminium corrodes, but the current is spread over a wide area and the loss per unit area is modest.
- An aluminium rivet in a stainless steel plate: large cathode, small anode. The same potential difference, the same electrolyte, and the rivet is consumed.

> *If you have to mix metals, put the noble metal in the small part. A noble fastener in a base-metal structure is usually tolerable. A base-metal fastener in a noble structure is not.*

Coat the cathode, not the anode

The instinct is to paint the metal that is corroding. It is the wrong move. A coating on the anode will always have some defects, and each holiday becomes a very small anode still connected to the full, uncoated cathode. The area ratio becomes worse than it was before painting, and perforation at the defects is faster than the general attack would have been.

Coating the cathode reduces the area collecting current, which reduces the total current the anode has to supply. If you can only coat one side of a galvanic couple, coat the noble one.

Electrolyte conductivity and distance

Galvanic effects are strongly localised in low-conductivity electrolytes such as rainwater or condensate: attack concentrates within a few millimetres of the joint and falls away quickly. In seawater the current spreads over a much greater distance, so the whole of a connected structure can participate.

Two cases that are frequently missed

Graphite and carbon-filled materials are cathodes. Graphite gaskets, carbon fibre composites and carbon-loaded seals sit at the noble end of the series and will drive attack on steel and aluminium in contact with them. They are often specified as non-metallic on the assumption that they are electrochemically inert. They are not.

Copper ions do not need contact. Water that has run over copper or brass upstream carries dissolved copper, which plates out on aluminium or galvanised surfaces downstream and creates a galvanic couple where none was

designed.

Standards and further reading

1. ISO 21857:2021 — Prevention of corrosion on pipeline systems influenced by stray currents.
2. ASTM G82 — Development and use of a galvanic series for predicting galvanic corrosion performance.
3. ASTM G71 — Conducting and evaluating galvanic corrosion tests in electrolytes.