Dr. Fastener- Questions about Galvanic Corrosion

This edition's Dr. Fastener will address the subject of Galvanic Corrosion. Although this has always been a concern for fastener engineers having to connect components made of a different material than the fastener, in recent years this topic has garnered special attention because of the interest in lightweighting. In fact, one of the frequent strategies of designers today is to utilize hybrid material structures where the fastener material is not the same as the clamped components. Thus, designing for the probability of galvanic corrosion may be a much higher priority than in the past. In response, fastener manufacturers, suppliers, and engineers must be familiar with this failure mechanism and strategies to defeat it.

Q What is galvanic corrosion?

A Galvanic Corrosion is an electrochemical corrosion mechanism that results when two materials with different electrical potentials are put into contact with one another in the presence of a conducting electrolyte. When the conditions are right and two contacting materials have an electrical potential difference, an electrical circuit is created which strips electrons from the less noble (anodic) material and conducts them towards the more noble (cathodic) material. Stated in simpler terms, the more cathodic material will cause the corrosion of the more anodic material.

Q How does the galvanic corrosion mechanism work?

A When two dissimilar materials are in contact with one another and the electrical potentials are noticeably different, the material with the lower potential will become the anode and the one with the higher potential the cathode. In the presence of an electrolyte the charge goes from the cathode to the anode by electron conduction and from the anode to the cathode by ion conduction. As the charge leaves the anode a metal ion is dissociated resulting in the corrosion of the anode material.

Q Can you give a couple of examples of this phenomenon?

A Absolutely. One of the most common examples of this phenomenon is seen in older homes where plumbing pipes and systems have been added to and changed over the years. Seventy-five years ago, the common material for pipes carrying water was galvanized iron. This changed about thirty or forty years ago when pipe material transitioned to copper. Many homes that have been revised or remodeled in recent years often contain pipe connections between galvanized iron and copper. Anyone who has such a home is likely to experience reduced water pressure and sediment in the lines. An inspection of these connections would show that the copper pipe seems to be intact but the iron pipe is badly rusted and corroded. Eventually, these connections will completely fail with the iron pipe failing or filling up with so much corrosion by-product that they will no longer allow water to flow. Another common example is the protection mechanism afforded by zinc electroplating on steel. When the zinc plated steel component is exposed to an electrolyte (such as rainwater), the zinc plating acts as the anode and sacrifices itself (erodes) to protect the more cathodic steel underneath. When the zinc is completely corroded away, the base steel will begin to rust.

Q What conditions must be present to trigger a galvanic cell and start galvanic corrosion?

A Three things must be present for galvanic corrosion to occur. First two dissimilar materials must be in contact with one another. Secondly, those two materials must have a significantly different electrical potential so that when in contact with one another they will trigger an electric cell with the more noble material being the cathode and the less noble material the anode. Thirdly, an electrolyte must be present to allow charge conduction from the cathode to the anode.

Q Explain the galvanic table

A The Galvanic Table (See **Figure 1**) lists the electrical potential of different metals. The top of the table represents materials that are less noble, thus will behave as the anode. The bottom of the table represents materials that are more noble and thus will behave as the cathode. Designers can use this chart to understand the effect of dissimilar pairing. The further apart the two dissimilar materials are from one another, the stronger the circuit that is created between the two. For example, a pairing of platinum, a very strong cathodic material with magnesium, a strong anodic material will result in a very strong galvanic circuit. In the presence of an average electrolyte, one might expect that this pairing would result in immediate and heavy corrosion of the magnesium material. The other thing to recognize about this table are the colored bands. Each colored band represents metals that possess similar electrical potentials. Pairing these metals together results in an extremely weak pairing and generally would not be considered a problem. Thus, as an example, pairing magnesium and zinc together would not be expected to be a problem.

Figure 1: Galvanic Table

- (+) Corroded End (Anodic)
- Magnesium
- Magnesium Alloys
- Zinc
- Aluminum (1100 Series)
- Cadmium
- Aluminum (2024-T4)
- Steel and Iron
- Cast Iron
- Chromium-iron (active)
- Ni-Resist cast iron
- Type 304 Stainless (active)
- Type 316 Stainless (active)
- Lead tin solders
- Lead
- Tin
- Nickel (active)
- Iconel® nickel-chromium alloy (active)
- Hastelloy® Alloy C (active)
- Brasses
- Copper
- Bronzes
- Copper-nickel alloys
- Monel® nickel-copper alloy
- Silver solder
- Nickel (passive)
- Inconel® nickel-chromium alloy (passive)
- Chromium-iron (passive)
- Type 304 Stainless (passive)
- Type 316 Stainless (passive)
- Hastelloy® Alloy C (passive)
- Silver
- Titanium
- Graphite
- Gold
- Platinum
- (-) Protected End (Cathodic)

Q What is an electrolyte?

A Any substance that will allow ion conduction. Electrolytes are normally liquids like water but can be substances like dirt or sand.

Q Explain the difference between a weak and strong electrolyte?

A Not all electrolytes are the same. In fact, electrolytes with more minerals and ions in them are stronger than those without. For example, sea water is a strong electrolyte while distilled or deionized water is a very weak one. The strength of the electrolyte is very important to how quickly a galvanic cell reacts. In the presence of a weak electrolyte even a strong dissimilar pairing will react very slowly or not at all, while even an average strength dissimilar pairing in salt water may quickly trigger galvanic corrosion. This is one reason why cars exposed to road salt in the winter corrode much more quickly than those in warm and dry climates.

Q Explain how size of the joint components makes a difference

A Consider a single M8 fastener in contact with a sheet of metal 5m by 5m. Imagine for a moment that the fastener is made of aluminum and the sheet is made of 300 series passivated stainless steel. Consulting the Galvanic Table, it is obvious that the potential difference between these two materials is significant. This means that there will be a strong galvanic circuit created between these two materials. In this case the aluminum fastener is the anode (and is quite small) and the stainless steel sheet is the cathode (and quite large). In the presence of an average strength electrolyte, one might expect very fast corrosion of the aluminum fastener because the contribution of the cathode so greatly outweighs the anode. Now flip this scenario around. The large sheet is aluminum and becomes the anode and the fastener is stainless steel and the cathode. There will still be a galvanic coupling produced here but since the cathode is so small compared to the size of the anode, the corrosion effects are minimal. In this case, likely a small amount of corrosion or pitting will occur on the sheet around the edge surfaces of the fastener. Thus, size difference between the anode and cathode can make a big impact on the degree of corrosion the joint will experience.

Q What can be done to protect fasteners or the joint from galvanic corrosion?

A The most effective way to protect the joint or fastener from galvanic corrosion is to decouple one of the triggering factors required for galvanic corrosion to occur. This means isolating the dissimilar materials from contacting one another, using materials of similar potential on the galvanic table chart, and eliminating or protecting the joint from contact with an electrolyte. To address these issues, a couple of common actions emerge:

1. Isolate contact of the dissimilar materials. An insulator used to isolate contact of materials with electrical potential differentials is known as a di-electric. On fasteners these might be items like plastic washers placed underneath the bearing surface, plastic sleeves or grommets that isolate not only the bearing surface but the entire joint grip, and isolation material that can be sprayed onto the fastener in areas where it contacts other joint components.

2. Eliminate contact with an electrolyte. Protecting the joint from contact with and sustained presence of an electrolyte should slow down or completely eliminate galvanic corrosion. This can be accomplished through careful design placement, painting or sealing, or protective coverings.

3. Make the fastener the cathode. Since the fastener will usually be smaller than the joint materials it is connecting, taking advantage of the impact of size differential can be a smart move. Therefore choosing a material or surface finish that will make the fastener the cathode is a sound strategy.

Q Can galvanic corrosion be used to our advantage?

A Yes, and it commonly is. Sacrificial galvanic couplings are commonly made to protect underground steel tanks and pipe lines. By coupling steel tanks and pipes with sacrificial zinc or magnesium blocks, they can be preserved for longer periods. Another example of galvanic protection is employed by sub-sea oil operations where their equipment is cathodically charged to protect it from the rigors of immersion in salt water. ■

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