

Chapter 1 : AC Corrosion - Corrosion and Corrosion Control

Corrosion can be defined as the degradation of a material due to a reaction with its environment. Degradation implies deterioration of physical properties of the material. This can be a weakening of the material due to a loss of cross-sectional area, it can be the shattering of a metal due to.

Galvanic corrosion Galvanic corrosion of aluminium. A 5-mm-thick aluminium alloy plate is physically and hence, electrically connected to a mm-thick mild steel structural support. Galvanic corrosion occurred on the aluminium plate along the joint with the steel. Perforation of aluminium plate occurred within 2 years. In a galvanic couple, the more active metal the anode corrodes at an accelerated rate and the more noble metal the cathode corrodes at a slower rate. When immersed separately, each metal corrodes at its own rate. What type of metal s to use is readily determined by following the galvanic series. For example, zinc is often used as a sacrificial anode for steel structures. Galvanic corrosion is of major interest to the marine industry and also anywhere water containing salts contacts pipes or metal structures. Factors such as relative size of anode, types of metal, and operating conditions temperature, humidity, salinity, etc. The surface area ratio of the anode and cathode directly affects the corrosion rates of the materials. Galvanic corrosion is often prevented by the use of sacrificial anodes. Galvanic series In any given environment one standard medium is aerated, room-temperature seawater, one metal will be either more noble or more active than others, based on how strongly its ions are bound to the surface. Two metals in electrical contact share the same electrons, so that the "tug-of-war" at each surface is analogous to competition for free electrons between the two materials. Using the electrolyte as a host for the flow of ions in the same direction, the noble metal will take electrons from the active one. The resulting mass flow or electric current can be measured to establish a hierarchy of materials in the medium of interest. This hierarchy is called a galvanic series and is useful in predicting and understanding corrosion. Rust removal Often it is possible to chemically remove the products of corrosion. For example, phosphoric acid in the form of naval jelly is often applied to ferrous tools or surfaces to remove rust. Corrosion removal should not be confused with electropolishing, which removes some layers of the underlying metal to make a smooth surface. For example, phosphoric acid may also be used to electropolish copper but it does this by removing copper, not the products of copper corrosion. Resistance to corrosion[edit] Some metals are more intrinsically resistant to corrosion than others for some examples, see galvanic series. There are various ways of protecting metals from corrosion oxidation including painting, hot dip galvanizing, and combinations of these. The materials most resistant to corrosion are those for which corrosion is thermodynamically unfavorable. Any corrosion products of gold or platinum tend to decompose spontaneously into pure metal, which is why these elements can be found in metallic form on Earth and have long been valued. More common "base" metals can only be protected by more temporary means. Some metals have naturally slow reaction kinetics, even though their corrosion is thermodynamically favorable. These include such metals as zinc, magnesium, and cadmium. While corrosion of these metals is continuous and ongoing, it happens at an acceptably slow rate. An extreme example is graphite, which releases large amounts of energy upon oxidation, but has such slow kinetics that it is effectively immune to electrochemical corrosion under normal conditions. The chemical composition and microstructure of a passive film are different from the underlying metal. Typical passive film thickness on aluminium, stainless steels, and alloys is within 10 nanometers. The passive film is different from oxide layers that are formed upon heating and are in the micrometer thickness range "â€” the passive film recovers if removed or damaged whereas the oxide layer does not. Passivation in natural environments such as air, water and soil at moderate pH is seen in such materials as aluminium, stainless steel, titanium, and silicon. Passivation is primarily determined by metallurgical and environmental factors. The effect of pH is summarized using Pourbaix diagrams, but many other factors are influential. Some conditions that inhibit passivation include high pH for aluminium and zinc, low pH or the presence of chloride ions for stainless steel, high temperature for titanium in which case the oxide dissolves into the metal, rather than the electrolyte and fluoride ions for silicon. On the other hand, unusual conditions may result in passivation of materials that are normally unprotected, as the alkaline

environment of concrete does for steel rebar. Exposure to a liquid metal such as mercury or hot solder can often circumvent passivation mechanisms. Corrosion in passivated materials[edit] Passivation is extremely useful in mitigating corrosion damage, however even a high-quality alloy will corrode if its ability to form a passivating film is hindered. Proper selection of the right grade of material for the specific environment is important for the long-lasting performance of this group of materials. If breakdown occurs in the passive film due to chemical or mechanical factors, the resulting major modes of corrosion may include pitting corrosion , crevice corrosion , and stress corrosion cracking. In the worst case, almost all of the surface will remain protected, but tiny local fluctuations will degrade the oxide film in a few critical points. Corrosion at these points will be greatly amplified, and can cause corrosion pits of several types, depending upon conditions. While the corrosion pits only nucleate under fairly extreme circumstances, they can continue to grow even when conditions return to normal, since the interior of a pit is naturally deprived of oxygen and locally the pH decreases to very low values and the corrosion rate increases due to an autocatalytic process. In extreme cases, the sharp tips of extremely long and narrow corrosion pits can cause stress concentration to the point that otherwise tough alloys can shatter; a thin film pierced by an invisibly small hole can hide a thumb sized pit from view. These problems are especially dangerous because they are difficult to detect before a part or structure fails. Pitting results when a small hole, or cavity, forms in the metal, usually as a result of de-passivation of a small area. This area becomes anodic, while part of the remaining metal becomes cathodic, producing a localized galvanic reaction. The deterioration of this small area penetrates the metal and can lead to failure. This form of corrosion is often difficult to detect due to the fact that it is usually relatively small and may be covered and hidden by corrosion-produced compounds. Weld decay and knifeline attack[edit] Normal microstructure of Type stainless steel surface Sensitized metallic microstructure, showing wider intergranular boundaries Stainless steel can pose special corrosion challenges, since its passivating behavior relies on the presence of a major alloying component chromium , at least Because of the elevated temperatures of welding and heat treatment, chromium carbides can form in the grain boundaries of stainless alloys. This chemical reaction robs the material of chromium in the zone near the grain boundary, making those areas much less resistant to corrosion. This creates a galvanic couple with the well-protected alloy nearby, which leads to "weld decay" corrosion of the grain boundaries in the heat affected zones in highly corrosive environments. This process can seriously reduce the mechanical strength of welded joints over time. A stainless steel is said to be "sensitized" if chromium carbides are formed in the microstructure. A typical microstructure of a normalized type stainless steel shows no signs of sensitization, while a heavily sensitized steel shows the presence of grain boundary precipitates. The dark lines in the sensitized microstructure are networks of chromium carbides formed along the grain boundaries. As its name implies, corrosion is limited to a very narrow zone adjacent to the weld, often only a few micrometers across, making it even less noticeable. Crevice corrosion Corrosion in the crevice between the tube and tube sheet both made of type stainless steel of a heat exchanger in a seawater desalination plant [4] Crevice corrosion is a localized form of corrosion occurring in confined spaces crevices , to which the access of the working fluid from the environment is limited. Formation of a differential aeration cell leads to corrosion inside the crevices. Examples of crevices are gaps and contact areas between parts, under gaskets or seals, inside cracks and seams, spaces filled with deposits and under sludge piles. Crevice corrosion is influenced by the crevice type metal-metal, metal-nonmetal , crevice geometry size, surface finish , and metallurgical and environmental factors. The susceptibility to crevice corrosion can be evaluated with ASTM standard procedures. Microbial corrosion Microbial corrosion , or commonly known as microbiologically influenced corrosion MIC , is a corrosion caused or promoted by microorganisms , usually chemoautotrophs. It can apply to both metallic and non-metallic materials, in the presence or absence of oxygen. Sulfate-reducing bacteria are active in the absence of oxygen anaerobic ; they produce hydrogen sulfide , causing sulfide stress cracking. In the presence of oxygen aerobic , some bacteria may directly oxidize iron to iron oxides and hydroxides, other bacteria oxidize sulfur and produce sulfuric acid causing biogenic sulfide corrosion. Concentration cells can form in the deposits of corrosion products, leading to localized corrosion. Accelerated low-water corrosion ALWC is a particularly aggressive form of MIC that affects steel piles in seawater near the low water tide mark. It is

characterized by an orange sludge, which smells of hydrogen sulfide when treated with acid. Corrosion rates can be very high and design corrosion allowances can soon be exceeded leading to premature failure of the steel pile. For unprotected piles, sacrificial anodes can be installed locally to the affected areas to inhibit the corrosion or a complete retrofitted sacrificial anode system can be installed. Affected areas can also be treated using cathodic protection, using either sacrificial anodes or applying current to an inert anode to produce a calcareous deposit, which will help shield the metal from further attack. Sulfidation High-temperature corrosion is chemical deterioration of a material typically a metal as a result of heating. This non-galvanic form of corrosion can occur when a metal is subjected to a hot atmosphere containing oxygen, sulfur, or other compounds capable of oxidizing or assisting the oxidation of the material concerned. For example, materials used in aerospace, power generation and even in car engines have to resist sustained periods at high temperature in which they may be exposed to an atmosphere containing potentially highly corrosive products of combustion. The products of high-temperature corrosion can potentially be turned to the advantage of the engineer. The formation of oxides on stainless steels, for example, can provide a protective layer preventing further atmospheric attack, allowing for a material to be used for sustained periods at both room and high temperatures in hostile conditions. Such high-temperature corrosion products, in the form of compacted oxide layer glazes, prevent or reduce wear during high-temperature sliding contact of metallic or metallic and ceramic surfaces. Metal dusting Metal dusting is a catastrophic form of corrosion that occurs when susceptible materials are exposed to environments with high carbon activities, such as synthesis gas and other high-CO environments. The corrosion manifests itself as a break-up of bulk metal to metal powder. The suspected mechanism is firstly the deposition of a graphite layer on the surface of the metal, usually from carbon monoxide CO in the vapor phase. This graphite layer is then thought to form metastable M₃C species where M is the metal, which migrate away from the metal surface. However, in some regimes no M₃C species is observed indicating a direct transfer of metal atoms into the graphite layer. Protection from corrosion[edit] The US military shrink wraps equipment such as helicopters to protect them from corrosion and thus save millions of dollars Various treatments are used to slow corrosion damage to metallic objects which are exposed to the weather, salt water, acids, or other hostile environments. Some unprotected metallic alloys are extremely vulnerable to corrosion, such as those used in neodymium magnets, which can spall or crumble into powder even in dry, temperature-stable indoor environments unless properly treated to discourage corrosion. Surface treatments[edit] When surface treatments are used to retard corrosion, great care must be taken to ensure complete coverage, without gaps, cracks, or pinhole defects.

Chapter 2 : Wiley: Corrosion and Corrosion Control, Fourth Edition

Complemented with numerous examples to help illustrate important points, Corrosion and Corrosion Control, Fourth Edition enables readers to fully understand corrosion and its control and, in turn, help reduce massive economic and environmental loss. It is a must-read for advanced undergraduates and graduate students in engineering and materials.

Corrosion Test Corrosion Related Water Chemistry It is impossible to provide a comprehensive water chemistry list for corrosion purpose. Too many constituents in the water depending on the sources, which cannot be fully explored in detail. Therefore the source of water is critical for the review to understand the trace element and suitability for particular application. Many of water constituents are interactively either positively or negatively regarding to the corrosion process pH pH is an indicator of hydrogen ions concentration in the water, which is an index of water corrosivity. The lower the pH, the more aggressive the water in corrosion. Low pH may increase corrosion rate and the strength of oxidizing agents; high pH may protect pipes by favoring effective passivation films and decrease corrosion rates; high pH leads to pitting and SCC and faster degradation of biocide in use. Passivating inhibitors are used in low pH sulphuric and phosphoric acid. Non-passivating inhibitors or cathodic inhibitors, e. It is an indicator of scale tendency. It is also an important factor for assess the risk of corrosion in water cooling system and boiler, since the higher alkalinity suggested lower corrosivity in water chemistry. There are also P alkalinity phenolphthalein alkalinity and M alkalinity methyl orange alkalinity , which is more based on the indicator used in titration analytical method. P alkalinity titrated with acid to pH 8. M alkalinity titrates to pH 4. May help form protective carbonate or hydroxyl carbonate films; helps control pH changes by adding buffering. Low to moderate alkalinity reduces corrosion of most materials. High alkalinity promote high suspended solid, which may adversely affect the efficacy of biocide and filming amine. Corrosion of steel in alkaline solution is controlled by the rate of oxygen diffusion. Steel is easily passivated in diluted alkaline solution. Metal Cations Sulfonate Monovalent cations have no measurable effects on inhibitors. Most of divalent cations will form protective precipitates with bicarbonate and sulphate. Higher concentration of divalent cations will precipitate some corrosion inhibitors e. Unfortunately, it is also a time consuming method. Turbidity method is normally utilised in the field to give the indication of TSS. However, there is no general correlation between TSS and turbidity. TSS may settle in the bottom of pipe and promote the growth of bacteria. TSS also adversely affects the efficacy of the filming amine corrosion inhibitor Total Dissolved Solids TDS TDS is a surrogate for ionic strength, which increases conductivity and corrosion rate unless offset by the formation of passivating films. Temporary hardness usually refers to the carbonate, which can be precipitated as carbonate scale in heating. Permanent hardness refers to the portion cannot be removed by heating, which is mostly sulphate. Ca may precipitate as CaCO_3 and thus provide protection and reduce corrosion rates. May enhance buffering effect in conjunction with alkalinity and pH. High chloride concentration also increased the risk of stress corrosion cracking in austenitic stainless steel. Field experience showed that corrosion in chloride rich environment tends to be more severe in fouling surface or surface with deposition. Sulphate sulphate scale is normally been taken as hard scale. It can not be easily removed by acid or heating. High levels increase corrosion of iron. The sulphate also promotes the depassivation the metals surface and growth of biofilm, which is the cause for the deep pin hole leak. Sulphate may also cause interference with certain aliphatic long carbon chain biocide and corrosion inhibitors. Silica Silica dissolved in water while water contacts with sand and rock. However, silica is an effective corrosion inhibition additives for water distribution systems. Hydrogen sulphide Increases corrosion rates; may convert to sulphite and promote growth of bacteria Ammonia May increase solubility of some metals, also a nutrient for bacteria, in higher pH range, acting as pH buffer Polyphosphates May reduce tuberculation of iron and steel, and provide smooth pipe interior. May enhance uniform iron and steel corrosion at low dosages, Prevents CaCO_3 formation and deposition. Sequesters ferrous iron and reduced manganese, especially at pH below 7. May help form better passivating oxide films on some materials, such as iron. Organic inhibitors are not generally effective against oxygen caused corrosion unless they contain passivating groups such as benzoates or sulfonates. In some case, extreme high concentration of filming amine

maybe used for oxygen corrosion inhibition. Chlorine residual Increases metallic corrosion, particularly for steel. Temperature Typically concern while water is sourced from industrial process, such as RO or power plant recycling. Leave a Comment Your email address will not be published.

Chapter 3 : Corrosion Related Water Chemistry - Corrosion and Corrosion Control

AC corrosion became a known issue since more and more pipelines are sharing ROW with HVAC transmission lines. It is caused by the metal loss due to AC current leaving the pipeline.

Chapter 4 : Corrosion Prevention and Control Management e-Course

Corrosion Control. Controlling corrosion damage through effective inspection and treatment. By Joe Escobar September The average age of the aircraft in use today is getting older.

Chapter 5 : Corrosion - Wikipedia

This standard work in corrosion science and engineering, Uses a quantitative approach (including basic equations--explained and derived--and illustrative problems), to discuss the basic thermodynamic and electrochemical principles that cause corrosion and treats practical corrosion problems and methods of protection and prevention.

Chapter 6 : What is Corrosion Control? - Definition from Corrosionpedia

1 [CORROSION&PROTECTION/BM] A SHORT INTRODUCTION TO CORROSION AND ITS CONTROL CORROSION OF METALS AND ITS PREVENTION WHAT IS CORROSION Corrosion is the deterioration of materials by chemical interaction with their environment.