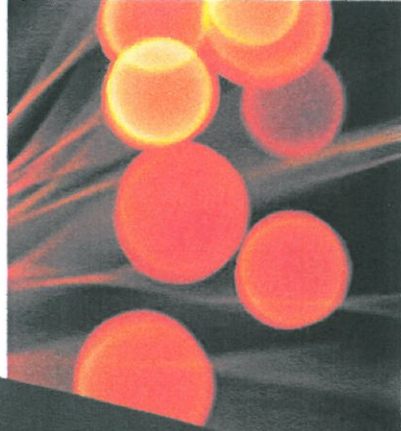


References



Corrosion(Rusting) Theory (incl. Local Corrosion)

General



Corrosion(Rusting) is the gradual destruction of material, usually metal, by chemical reaction with its environment.

In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen.

Rusting, the formation of iron oxides, is a well-known example of electrochemical corrosion.

This type of damage typically produces oxide(s) or salt(s) of the original metal. (Corrosion can also occur in materials other than metals, such as ceramics or polymers)

Rusting is the common term for corrosion of iron and its alloys, such as steel. Many other metals undergo equivalent corrosion, but the resulting oxides are not commonly called rust.

Many structural alloys corrode merely from exposure to moisture in the air, but the process can be strongly affected by exposure to certain substances.

Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is a diffusion controlled process, it occurs on exposed surfaces.

Chemical reactions

Oxidation of Iron metal

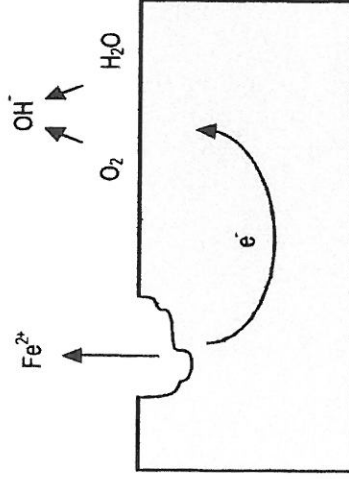
When impure (cast) iron is in contact with water, oxygen, or other strong oxidants and/or acids, it rusts. If salt is present as, for example, in salt water, it tends to rust more quickly, as a result of the electro-chemical reactions.

Iron metal is relatively unaffected by pure water or by dry oxygen.

As with other metals, like aluminium, a tightly adhering oxide coating, a passivation layer, protects the bulk iron from further oxidation. Thus, the conversion of the passivating iron oxide layer to rust results from the combined action of two agents, usually oxygen and water.

Other degrading solutions are sulfur dioxide in water and carbon dioxide in water. Under these corrosive conditions, iron hydroxide species are formed. Unlike iron oxides, the hydroxides do not adhere to the bulk metal. As they form and flake off from the surface, fresh iron is exposed, and the corrosion process continues until either all of the iron is consumed or all of the oxygen, water, carbon dioxide, or sulfur dioxide in the system are removed or consumed.

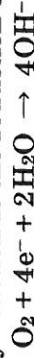
Associated reactions



The rusting of iron is an electrochemical process that begins with the transfer of electrons from iron to oxygen.

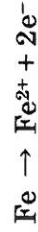
The rate of corrosion is affected by water and accelerated by electrolytes, as illustrated by the effects of road salt on the corrosion of automobiles.

The key reaction is the reduction of oxygen:



Because it forms hydroxide ions, this process is strongly affected by the presence of acid. Indeed, the corrosion of most metals by oxygen is accelerated at low pH.

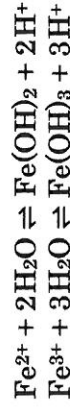
Providing the electrons for the above reaction is the oxidation of iron that may be described as follows:



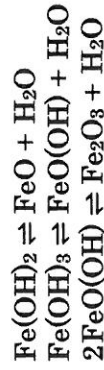
The following redox reaction also occurs in the presence of water and is crucial to the formation of rust:



In addition, the following multistep acid-base reactions affect the course of rust formation:



as do the following dehydration equilibria:



From the above equations, it is also seen that the corrosion products are dictated by the availability of water and oxygen.

With limited dissolved oxygen, iron(II)-containing materials are favoured, including FeO and black lodestone (Fe_3O_4). High oxygen concentrations favour ferric materials with the nominal formulae $\text{Fe}(\text{OH})_{3-x}\text{O}_{x/2}$.

The nature of rust changes with time, reflecting the slow rates of the reactions of solids.

Furthermore, these complex processes are affected by the presence of other ions, such as Ca^{2+} , both of which serve as an electrolyte, and thus accelerate rust formation, or combine with the hydroxides and oxides of iron to precipitate a variety of Ca-Fe-O-OH species.

Local Corrosion

In some situations, corrosion may occur only at localized regions on a metal surface. This type of corrosion is characterized by regions of locally severe corrosion, although the general loss of thickness may be relatively small.

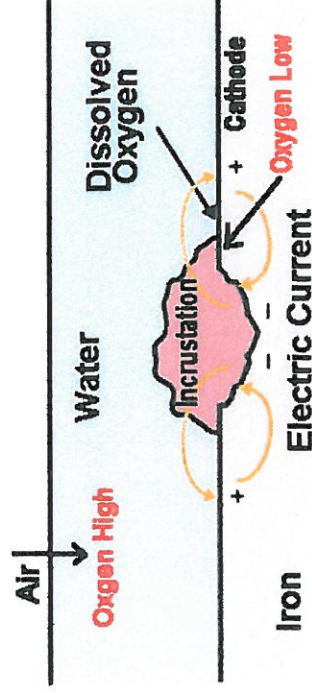
Pitting corrosion is usually associated with passive metals, although this is not always the case. Pit initiation is usually related to the local breakdown of a passive film and can often be related to the presence of halide ions in solution.



Crevice corrosion occurs in restricted or occluded regions, such as at a bolted joint, and is often associated with solutions that contain halide ions. Crevice corrosion is initiated by a depletion of the dissolved oxygen in the restricted region. As the supply of oxygen within the crevice is depleted, because of cathodic oxygen reduction, the metal surface within the crevice becomes activated, and the anodic current is balanced by cathodic oxygen reduction from the region adjacent to the crevice. The ensuing reactions within the crevice are the same as those described for pitting corrosion: halide ions migrate to the crevice, where they are then hydrolyzed to form metal hydroxides and hydrochloric acid.

Corrosion can also be accelerated in situations where two dissimilar metals are in contact in the same solution. This form of corrosion is known as galvanic corrosion. The metal with the more negative potential becomes the anode, while the metal with the more positive potential sustains the cathodic reaction. In many cases the table of equilibrium potential can be used to predict which metal of galvanic couple will corrode.

Differential Aeration Corrosion



Corrosion of metals arising as a result of the formation of an oxygen concentration cell due to the uneven supply of air on the metal surface is known as differential aeration corrosion.

Differential aeration corrosion occurs when a metal surface is exposed to differential air concentrations or oxygen concentrations. The part of the metal exposed to higher oxygen concentration acts as cathodic region and part of the metal exposed lower oxygen concentration acts as anodic region. Consequently, poorly oxygenated region undergoes corrosion.

At the anode (less O₂ concentration) M → Mⁿ⁺ + ne

At the cathode (more O₂ concentration) H₂O + ½ O₂ + 2e⁻ → 2OH⁻

Waterline Corrosion



Waterline corrosion as a case of differential aeration corrosion, more prevalent in cases such as ocean going ships, water storage steel tanks, etc., in which a portion of the metal is always under water.

The waterline corrosion takes place due to the formation of differential oxygen concentration cells. The part of the metal below the water line is exposed only to dissolved oxygen while the part above the water is exposed to higher oxygen concentration of the atmosphere. Thus, part of the metal below the water acts as anode and undergoes corrosion and part above the waterline is free from corrosion. A distinct brown line is formed just below the water line due to the deposition of rust.

Standards of Surface Preparation (for existing steel structures)

Mostly all of coatings supplier will always designate the degree of surface preparation required for the materials you are using.

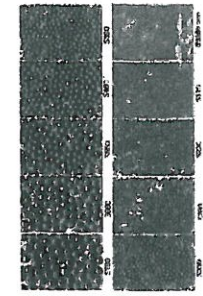
The basic standards for preparing metal substrates are designated by the industrial standards as described below ;

- *NACE : National Association of Corrosion Engineers
- *SSPC : Steel Structures Painting Council(U.S.A.)
- *SIS : SVENSK STANDARD (same as ISO)
- *JIS : Japanese Industrial Standards (same as ISO)
- *GOST : Gosudarstvennyy Standart(Russia)

etc.

According to SSPC's surface preparation has a 10 degree of purification. Each explanation in detail is described next page

Degree of surface preparation	Description	
SP-1	<p data-bbox="215 1074 248 1305">Solvent Cleaning</p> <p data-bbox="277 106 371 1305">Removal of all detrimental foreign matter such as oil, grease, dirt, soil, salts, drawing and cutting compounds, and other contaminants from steel surfaces by the use of solvents, emulsions, cleaning compounds, steam or other similar materials and methods which involve a solvent or cleaning action.</p>	<p data-bbox="396 1038 430 1305">Hand Tool Cleaning</p> <p data-bbox="459 129 575 1305">Removal of all rust scale, mill scale, loose rust and loose paint to the degree specified by hand wire brushing, hand sanding, hand scraping, hand chipping or other hand impact rods or by a combination of these methods. The substrate should have a faint metallic sheen and also be free of oil, grease, dust, soil, salts and other contaminants.</p>
SP-2	<p data-bbox="799 1032 833 1305">Power Tool Cleaning</p> <p data-bbox="862 106 978 1305">Removal of all rust scale, mill scale, loose paint, and loose rust to the degree specified by power wire brushes, power impact tools, power grinders, power sanders or by a combination of these methods. The substrate should have a pronounced metallic sheen and also be free of oil, grease, dirt, soil, salts and other contaminants. Surface should not be buffed or polished smooth.</p>	<p data-bbox="1225 1091 1258 1305">Flame Cleaning</p> <p data-bbox="1288 106 1382 1305">Removal of all loose scale, rust and other detrimental foreign matter by passing high temperature, high velocity oxy-acetylene flames over the entire surface, followed by wire brushing. Surface should also be free of oil, grease, dirt, soil, salts and other contaminants.</p>
SP-3	<p data-bbox="1406 933 1440 1305">White Metal Blast Cleaning</p> <p data-bbox="1469 106 1615 1305">Removal of all mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels. A White Metal Blast Cleaned Surface Finish is defined as a surface with a gray white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coatings. The surface, when viewed without magnification, shall be free of all oil, grease, dirt, visible mill scale, rust, corrosion products, oxides, paint, or any other foreign matter.</p>	<p data-bbox="1619 1378 1653 1447">SP-5</p>



SP-6	<p>Commercial Blast Cleaning</p> <p>Removal of mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree specified. A Commercial Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, rust scale and foreign matter have been completely removed from the surface and all rust, mill scale and old paint have been completely removed except for slight shadows, streaks, or discolorations caused by rust stain, mill scale oxides or slight, tight residues of paint or coating that may remain: if the surface is pitted, slight residues of rust or paint may be found in the bottom of pits: at least two-thirds of each square inch of surface area shall be free of all visible residues and the remainder shall be limited to the light discoloration, slight staining or tight residues mentioned above.</p>
SP-7	<p>Brush-Off Blast Cleaning</p> <p>Removal of loose mill scale, loose rust, and loose paint, to the degree hereafter specified, by the impact of abrasives propelled through nozzles or by centrifugal wheels. It is not intended that the surface shall be free of all mill scale, rust, and paint. The remaining mill scale, rust, and paint should be tight and the surface should be sufficiently abraded to provide good adhesion and bonding of paint. A Brush-Off Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, rust scale, loose mill scale, loose rust and loose paint or coatings are removed completely but tight mill scale and tightly adhered rust, paint and coatings are permitted to remain provided that all mill scale and rust have been exposed to the abrasive blast pattern sufficiently to expose numerous flecks of the underlying metal fairly uniformly distributed over the entire surface.</p>
SP-8	<p>Pickling</p> <p>Removal of all mill scale, rust and rust scale by chemical reaction, or by electrolysis, or by both. It is intended that the pickled surface shall be completely free of all scale, rust, and foreign matter. Furthermore, the surface shall be free of unreacted or harmful acid or alkali, or smut.</p>
SP-9	<p>Weathering Followed By Blast Cleaning</p> <p>Weathering to remove all or part of the mill scale followed by one of the blast cleaning standards.</p>
SP-10	<p>Near-White Blast Cleaning</p> <p>Removal of nearly all mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree hereafter specified. A Near-White Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been completely removed from the surface except for very light shadows, very slight streaks or slight discolorations caused by rust stain, mill scale oxides, or light, tight residues of paint or coating that may remain. At least 95 percent of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discoloration mentioned above.</p>