Why Does Rust Occur?

7.1 IN GENERAL

Rust damage on products costs large sums every year, and can also cause breakdowns through various kinds of corrosion weakening supporting structures. There are therefore strong reasons to think about what type of surface treatment a fastener should be given. Below, an account is given of the mechanism of corrosion, with some general advice which can help in choosing corrosion protection for fasteners. Also, several types of surface treatment on special parts are described.

7.2 WHAT IS CORROSION?

Steel rusts, copper oxidises and other metals, except those which are most inert, are broken down in a similar way. This type of material destruction is given the general name of corrosion. It occurs when the material reacts with its surroundings and is converted into other substances – to corrosion products. Almost all corrosion which occurs in normal working environments is of electrochemical type. It occurs in galvanic cells, corrosion cells, which function roughly in the same way as a flashlight battery. The battery has a carbon rod in its centre, and a casing of zinc plate. The carbon rod is called the cathode, the zinc plate the anode. Inside the battery, there is also a paste or sludge which is called electrolyte.

When you switch on a flashlight, current runs from the carbon rod through the bulb to the zinc plate. From there, the current goes through the electrolyte back to the carbon rod. The current takes with it zinc particles from the plate, which becomes corroded and, in due course, begins to leak. The cathode is inert (- pole), the anode is reactive (+ pole).

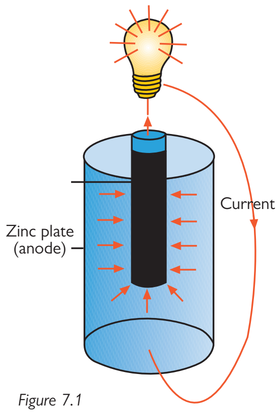

Figure 7.1

Galvanic cells which cause the corrosion can form when two different metals (or one metal and another substance which conducts electricity in the same way as a metal, for example, graphite) come into contact with an electrolyte. Corrosion caused by such material combinations is called by the common name of galvanic corrosion. Galvanic cells, often extremely small, also occur on individual metal surfaces. This is connected to the fact that industrial metals consist of microscopic granules of varying composition, and can also be due to various impurities on the surface, such as oxide scale, slag residue, etc. The granules and particles are, as with various metals, of varying degrees of inertness in relation to one another.

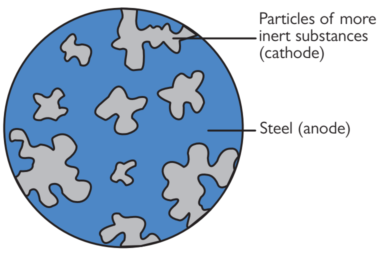

Figure 7.2

In the case of corrosion through galvanic cells, the most inert metal or particle is always a cathode, the most reactive one is always an anode.

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7.3 DAMP AND OXYGEN

Without damp, no corrosion occurs, nor does it occur without oxygen. But oxygen and damp are present in the air. A certain level of damp is necessary for corrosion to occur. If the relative humidity of air exceeds 60%, a very thin film of damp forms on the metal surface, and this functions as an electrolyte.

If a steel surface has impurities on it, such as dust, salt, etc., it can corrode if the relative humidity is less than 60%, because dirt absorbs damp. Outdoors in Sweden, the humidity of the air is always sufficiently high for steel, for example, to rust. Indoors, air is heated, and as a rule, so dry that steel does not rust. When the temperature falls, for example in a factory closed for vacation, there is a risk of corrosion.

7.4 WHEN STEEL RUSTS

When the film of damp covers the steel surface, a very large number of galvanic cells are formed, all functioning in the same way as a flashlight battery.

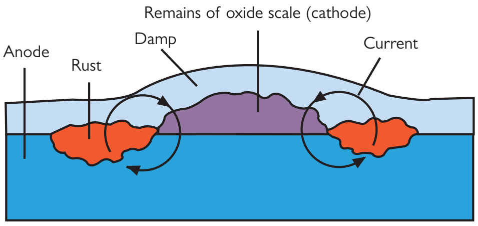

Figure 7.3

A current flows from the more inert granules or particles (cathodes) through the steel to the more reactive parts of the steel surface (anodes). The current returns from the more reactive parts out in the film of damp (electrolyte) and through it back to the more inert parts. Where the current leaves the anode, rust forms.

After a time, the entire surface is covered with rust, which also spreads downwards into the steel. As long as there is access to damp and oxygen, rust will form.

The speed of corrosion depends on the difference of inertness between the metals or metal granules, the electrical conductivity of the electrolyte, the supply of oxygen and differences in size between anode and cathode. A screw can be anode or cathode.

If a steel screw is tightened in a copper plate, the screw becomes anode, because the copper is more inert. The screw will rust more quickly because the "potential difference" is large.

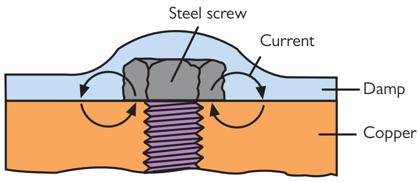

Figure 7.4

If the same steel screw is tightened in a reactive metal, for example, zinc, the screw will be cathode and will not rust. On the hand, the plate will corrode because it is more reactive than the screw.

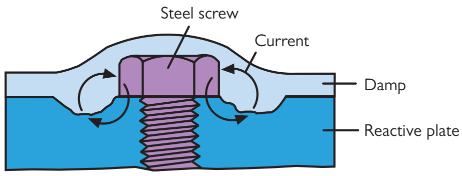

Figure 7.5

The greater the difference of inertness between the metals, the more rapid the corrosion of the more reactive/anode. In the absence of special protection measures, one should therefore only combine metals which have the same, or almost the same, inertness, if they are to be subjected to a damp environment.

In order to be able to assess the relationships of metals against one another more easily, they have been placed on a "ladder" called the galvanic stress series, see Figure 7.6. Through an electrical means of measurement, it has been possible to deduce what is called the potential of the metals.

This is an electrochemical concept which gives an idea of how inert or reactive a metal is. The most common stress series is measured with seawater as electrolyte at a temperature of +20°C. Gold is the most inert metal and is at the top of the ladder. Magnesium is the most reactive and is at the bottom.

Why Does Rust Occur?

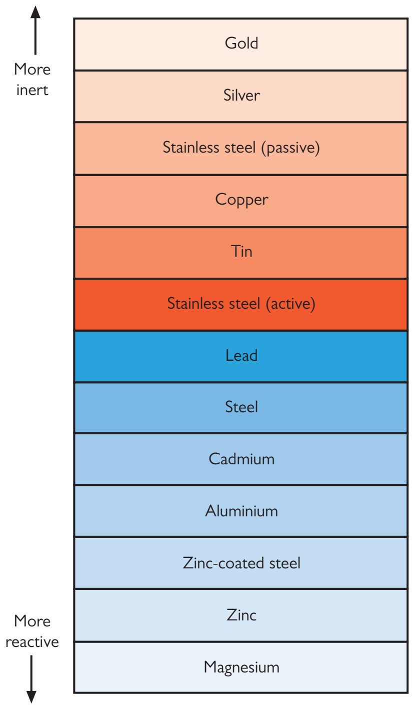

Figure 7.6

7.5 CONDUCTIVITY OF AN ELECTROLYTE

If the electrical conductivity of an electrolyte is poor, as is often the case in fresh water, the corrosion is concentrated to the area closest to the point of contact between the anode and the cathode.

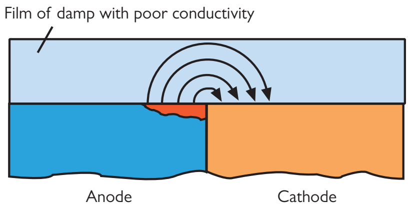

Figure 7.7

On the other hand, if conductivity is good, as in seawater, the spread of corrosion will be greater. Outdoors, the speed of corrosion is affected by impurities in the air. Rusting is worst of all in very contaminated, industrial and city atmospheres, and after that in maritime climates with salt content. Metals last better in the countryside.

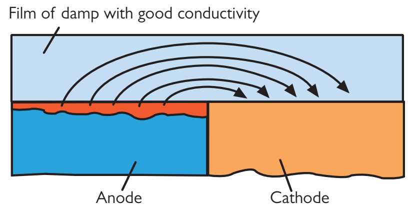

Figure 7.8

7.6 THE EFFECT OF OXYGEN

If oxygen is prevented from reaching a metal surface, the surface does not corrode. The more oxygen that arrives, the faster it corrodes within certain limits. In a hermetically sealed steel beam, for example, no rust can occur, because no oxygen gets in. Similarly, oxygen diminishes or is exhausted in closed heating systems, and corrosion decreases or ceases.

7.7 THE SIZES OF ANODES AND CATHODES

The larger the surface of the cathode, the more oxygen will be in contact with it, and the smaller the surface of the anode in relation to the cathode, the more concentrated the corrosion current will be in the anode.

The combination of small anode surface/large cathode surface therefore involves a greater risk of corrosion.

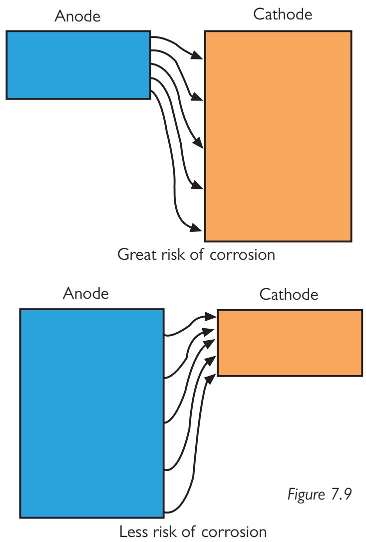

Figure 7.9