



Uniform Corrosion

Technical White Paper

Description

Uniform corrosion is a generalised form of attack that occurs relatively evenly across a large area. It is perhaps, the most common form of corrosion and occurs in many environments such as in the atmosphere, liquids, and soils. All metals are, to some degree, affected by uniform corrosion and the 'rusting' of steel is probably the most common example.

Mechanism

The generalised attack from uniform corrosion is what would be observed at a 'macro'-scale (i.e. by eye or at low magnification) on the surfaces of a metal that exhibits a homogeneous microstructure and chemical composition. However, at a microscopic scale, small variations in electrical potential may be present, and microanodes and microcathodes will generate corrosion cells, which then result in localised corrosion attack.

The corrosion product developed at the surface will have a marked effect on the subsequent corrosion of the metal. Generally, corrosion products may be 1) thin, highly adherent, and protective to prevent or reduce further corrosion, 2) thick, friable or loosely adhered and offer no protection to further corrosion, or 3) somewhere between the two depending on the local conditions.

The uniform corrosion of iron and steel in wet or atmospheric conditions results in iron-oxides, or 'rust'. These oxides offer no significant protection of the underlying material from continued corrosion. They expand as they form, becoming loosely adhered and eventually detach. Stainless steels on the other hand develop a uniform, thin, and stable chromium-oxide layer which then protects the underlying material from further oxidation (corrosion). If this layer is removed or damaged it can quickly reform and self-heal, when in the presence of oxygen.

The rate of uniform corrosion will also be affected by the concentration of the corrodent, and the temperature. The rate of corrosion will generally increase with the concentration of the corrodent although there may be a point at which continued concentration may lead to a reduction in corrosion, such as with iron or steel in sulphuric or nitric acids. However, the rate of corrosion of iron and steel will continue to increase with ever greater concentrations of hydrochloric acid.

The effect of temperature on the corrosion rate of metals is an important consideration and its effects vary. In some metal-corrodent systems, uniform corrosion rates may rise exponentially with temperature, whilst in other systems there may be a low or static corrosion rate with temperature until a critical point is reached, above which the rate then rapidly increases. Corrosion rates may also fall with increasing temperature and an example of this is steel in water. As the temperature of the water is increased the level of oxygen dissolved in it reduces, and especially as the boiling point is reached, and this reduction in available oxygen reduces the corrosion rate. Increases in temperature may also cause protective scale or films to develop, which then hinder further oxidation or uniform corrosion.

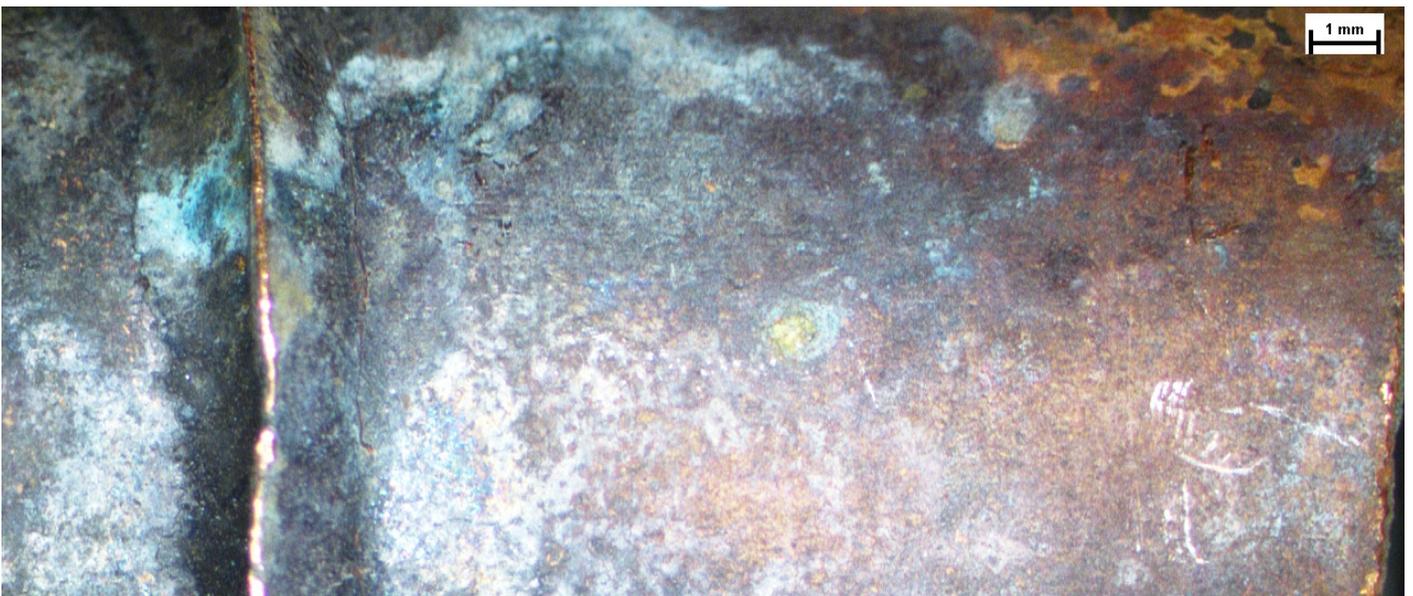
Appearance and Examples

By its nature, uniform corrosion results in an even, or uniform level of corrosion product. The appearance of this will be dependent on the substrate material and the corroding environment.

The cast iron valve shown below had operated in a sewage treatment plant for many decades and had suffered from significant thinning by uniform corrosion leading to heavy scaling and wall thinning.



The image below shows uniform corrosion scale on a copper water pipe. Some variation in the thickness can be seen as shown by the colour variation. This form of scale generally builds up in the early stages of exposure to the water, but which then forms a protective layer reducing the corrosion rate to a negligible level.



Avoiding

The most common method to avoid uniform corrosion is the use of protective coatings such as paint although the integrity of the coating can introduce its own potential problems. For example, any small breaches in the coating could lead to increased corrosion rates at the exposed surface due to crevice effects at the coating-substrate (metal) interface; the uniform corrosion rate may be lower for an unprotected material, compared to localised attack at a breach in the coating, and so leaving the material uncoated may be more desirable. However, if the integrity of the coating can be maintained then this would be clearly beneficial on the life of the material and hence component.

The use of metallic coatings is a common practice either for protection of the underlying material, for aesthetic reasons, or both. Chromium plating on steel protects the steel from corrosion as well as providing a decorative finish. However, if the chromium is damaged to expose the steel, the corrosion attack of the steel is rapid, leading to pitting corrosion. This is due to the difference in electrical potential between the chromium and steel, which are cathodic and anodic respectively in this couple; this is Galvanic corrosion

On large steel structures, zinc coatings are often used, and this protects the underlying steel from corrosion for a period of time. The zinc is intended to uniformly corrode in preference to the steel i.e. it 'protects' the steel as in the steel-zinc couple, the steel is cathodic to the anodic zinc. However, the zinc coating clearly has a finite life and once it has been effectively used up in the corrosion process, the steel will then corrode as normal. The timescales for this point to be reached may be relatively predictable, and based on empirical data.

The deliberate generation of stable oxide layers to protect the surface is often used on materials such as aluminium alloys, in a process known as anodising. Anodised surfaces may also be dyed giving highly decorative finishes.

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