In the name of God

Technical English Language

for Materials Engineering and Metallurgy

Lesson 5: Corrosion and Surface Engineering

Taught by:

Dr. Reza Ghanavati

r_ghanavati@sbu.ac.ir

Faculty of Mechanical and Energy Engineering, Shahid Beheshti University (SBU)

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1. Introduction to Corrosion

Corrosion is the disintegration of an engineered material into its constituent atoms due to chemical reactions with its surroundings. In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Formation of an oxide of iron due to oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion, commonly known as rusting (Fig 1). This type of damage typically produces oxide(s) and/or salt(s) of the original metal. Corrosion can also refer to other materials than metals, such as ceramics or polymers. In other words, corrosion is the wearing away of metals due to a chemical reaction.

Fig. 1. Rust, the most familiar example of corrosion.

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. As a result, methods to reduce the activity of the exposed surface, such as passivation and chromate-conversion, can increase a material's corrosion resistance. However, some corrosion mechanisms are less visible and less predictable.

2. Forms of Corrosion

✓ ***Uniform Corrosion***

This is also called general corrosion. The surface effect produced by most direct chemical attacks (e.g., as by an acid) is a uniform etching of the metal. On a polished surface, this type of corrosion is first seen as a general dulling of the surface and, if allowed to continue, the surface becomes rough and possibly frosted in appearance. The discoloration or general dulling of metal created by its exposure to elevated temperatures is not to be considered as uniform etch corrosion. The use of chemical-resistant protective coatings or materials that are more resistant will control these problems.

✓ *Galvanic Corrosion*

Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path and it occurs when dissimilar metals are in contact. It is recognizable by the presence of a buildup of corrosion at the joint between the dissimilar metals. For example, when aluminum alloys or magnesium alloys are in contact with steel, galvanic corrosion can occur and accelerate the corrosion of the aluminum or magnesium. The two metals that are in contact with each other must be widely separated on the galvanic series (see Fig. 2).

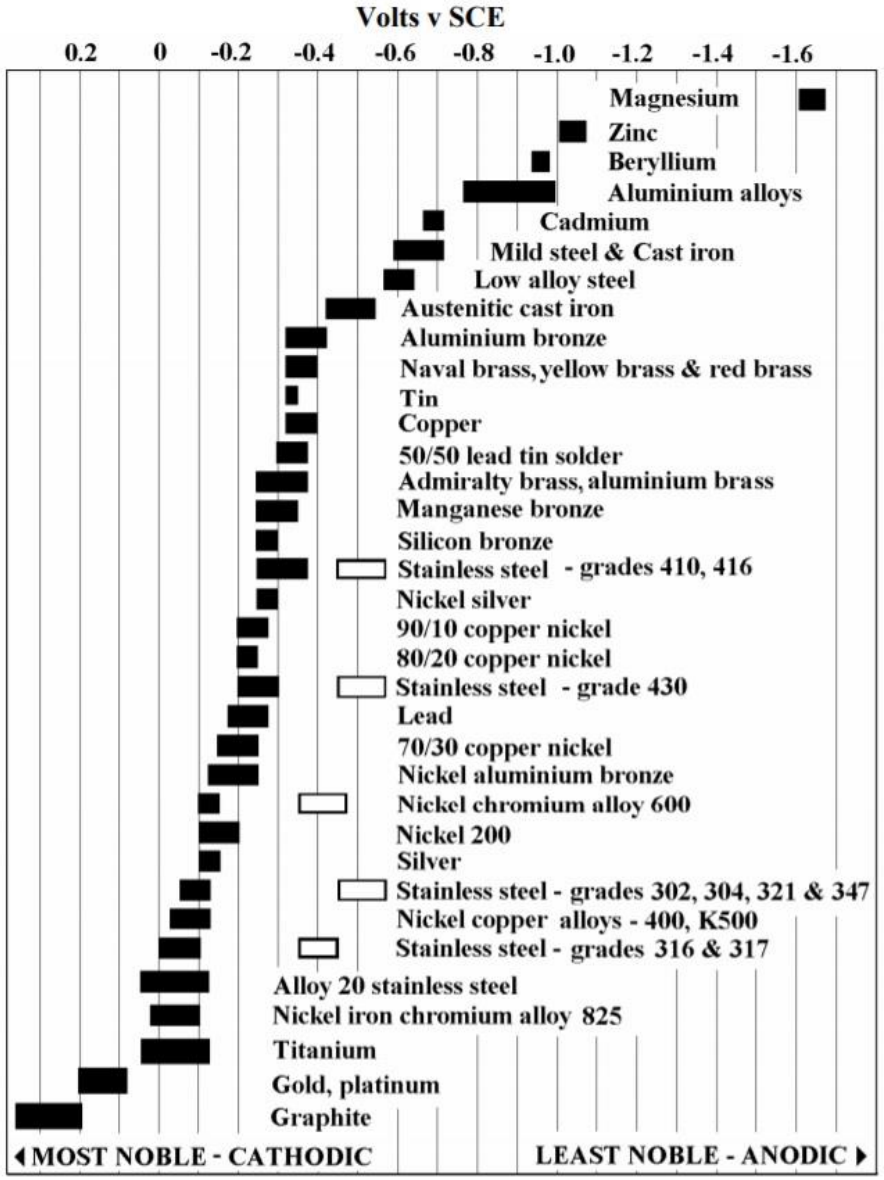

Fig. 2. Galvanic series**.**

✓ ***Concentration Cell Corrosion***

Concentration cell corrosion occurs when two or more areas of a metal surface are in contact with different concentrations of the same solution. There are three general types of concentration cell corrosion:

1) Metal ion concentration cells
2) Oxygen concentration cells
3) Active-passive cells.

✓ ***Pitting Corrosion***

Passive metals, such as stainless steel, resist corrosive media and can perform well over long periods. However, if corrosion does occur, it forms at random in pits. Pitting is most likely to occur in the presence of chloride ions, combined with such depolarizers as oxygen or oxidizing salts. Methods that can be used to control pitting include maintaining clean surfaces, application of a protective coating, and use of inhibitors or cathodic protection for immersion service. Molybdenum additions to stainless steel (*e.g.* in 316 stainless steel) are intended to reduce pitting corrosion.

✓ ***Crevice Corrosion***

Crevice or contact corrosion is the corrosion produced at the region of contact of metal-metal or metal-nonmetal. It may occur at washers, under barnacles, at sand grains, under applied protective films, and at pockets formed by threaded joints. Whether or not stainless steels are free of pit nuclei, they are always susceptible to this kind of corrosion because a nucleus is not necessary. Cleanliness, the proper use of sealants, and protective coatings are effective means of controlling this problem. Molybdenum-containing grades of stainless steel (*e.g.* 316 and 316L) have increased crevice corrosion resistance.

✓ ***Filiform Corrosion***

This type of corrosion occurs under painted or plated surfaces when moisture permeates the coating. Lacquers and "quick-dry" paints are most susceptible to the problem. Where a coating is required, it should exhibit low water vapor transmission characteristics and excellent adhesion. Zinc-rich coatings should also be considered for coating carbon steel because of their cathodic protection quality.

✓ ***Intergranular Corrosion***

Intergranular corrosion is an attack on or adjacent to the grain boundaries of a metal or alloy. A highly magnified cross section of most commercial alloys will show its granular structure. This structure consists of quantities of individual grains, and each of these tiny grains has a clearly defined boundary that chemically differs from the metal within the grain center. Heat treatment of stainless steels and aluminum alloys accentuates this problem.

✓ ***Stress corrosion cracking (SCC)***

The simultaneous effects of tensile stress and a specific corrosive environment cause stress corrosion cracking (SCC). Stresses may be due to applied loads, residual stresses from the manufacturing process, or a combination of both. Cross sections of SCC frequently show branched cracks (Fig. 3). This river branching pattern is unique to SCC and is used in failure analysis to identify when this form of corrosion has occurred.

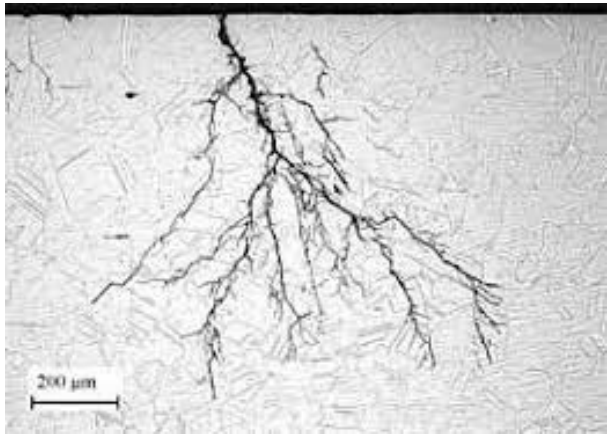

Fig. 3. Cross section of stress corrosion cracking (SCC).

✓ ***Corrosion Fatigue***

Corrosion fatigue is a special case of stress corrosion caused by the combined effects of cyclic stress and corrosion. No metal is immune from some reduction of its resistance to cyclic stressing if the metal is in a corrosive environment. Damage from corrosion fatigue is greater than the sum of the damage from both cyclic stresses and corrosion. Control of corrosion fatigue can be accomplished by either lowering the cyclic stresses or by corrosion control.

✓ ***Erosion Corrosion***

Erosion corrosion is the result of a combination of an aggressive chemical environment and high fluid-surface velocities. This can be the result of fast fluid flow past a stationary object; also, it can result from the quick motion of an object in a stationary fluid, such as happens when a ship's propeller churns the ocean.

3. Corrosion control

There are a number of means of controlling corrosion. The choice of a means of corrosion control depends on economics, safety requirements, and a number of technical considerations.

✓ ***Resistance to corrosion***

Some metals are more intrinsically resistant to corrosion than others, either due to the fundamental nature of the electrochemical processes involved or due to the details of how reaction products form. If a more susceptible material is used, many techniques can be applied during an item's manufacture and use to protect its materials from damage.

✓ ***Design***

Engineering design is a complicated process that includes design for purpose, manufacturability, inspection, and maintenance. One of the considerations often overlooked in designing manufactured products is drainage. All of the other methods of corrosion control should be considered in the design.

✓ ***Protective Coatings***

Protective coatings are the most commonly used method of corrosion control. Protective coatings can be metallic, such as the galvanized steel, or they can be applied as a liquid "paint."

✓ ***Cathodic Protection***

Cathodic protection is an electrical means of corrosion control. Cathodic protection can be applied using sacrificial (galvanic) anodes or by means of more complicated impressed current systems.

- Choose the best choice using your knowledge of metallurgy and the details in the previous reading.

1. Chemical engineers look for more highly corrosion …… materials.

a) choice ✓ b) resistant c) facing d) goods

2. Corrosion is the …….. of a metal due to chemical or electrochemical reactions with its environment.

a) definition b) contradiction ✓ c) deterioration d) contamination

3. Anyone who has worked with corrosion and corrosion testing will agree that slight changes in metals, or their environment can make significant differences in the ……. behavior of the metals.

a) schematic ✓ b) corrosive c) complicated d) catastrophic

4. Stainless steels owe their corrosion resistance to formation of an oxide layer which is …… and resistant to chemical attack.

a) emitted loosely b) loosely emitted ✓ c) extremely adherent d) adherent extremely

5. Pitting corrosion is a form of …… localized attack that results in …….. in the metal.

a) light, rigid b) severe, coating ✓ c) extremely, holes d) depth, through

6. Stainless steels owe their corrosion resistance to formation of a layer which is extremely adherent and resistant to chemical attack, the so-called …….. .

a) repassivation ✓ b) passive film c) sensitized area d) chromium depletion

7. Sodium is very soft metal which reacts ……. With water and corrodes rapidly in air.

a) slowly b) hardly c) quick ✓ d) vigorously

8. One of complicating factors in studying corrosion is that there are many types of corrosion, and usually at least two different types are progressing …….. .

a) flexibly b) previously c) schematically ✓ d) simultaneously

4. Selected vocabulary

En	Fa	En	Fa
Cathodic/Anodic protection	حافظت کاتدی	Inspection	بازرسی
Cladding	روکش‌کاری	Intrinsically	ذاتاً
Coating	پوشش‌دهی	Passivation	غیرفعال‌سازی
Cavitation	کاویتاسیون، ایجاد حباب/حفره	Wear	سایش
Deterioration	زوال، تخریب	Decay	پوسیدگی
Sacrificial anode	آند فداشونده	Merely	به طور محض
Aggressive	تهاجمی	Enameling	لعاب دادن
Crevice corrosion	خوردگی شیاری	Sealant	درزگیر
Disintegration	گسستگی، فروپاشی	Lifespan	طول عمر
Erosion	فرسایش	Pitting	حفره/خال زدن
Exposure	در معرض قرار دادن	Interference	تداخل
Frost	برفک	Drainage	خشک کردن
Rust	زنگ‌زدگی	Overlook	چشم پوشی کردن
Inhibitor	ممانعت کننده، بازدارنده	Susceptible	حساس، مستعد