Corrosion and Cathodic Protection Problems

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Abstract

We want to make known natural and artificial proceedings in which metallic structures return to their stable current condition.

Considering corrosion as a phenomenon, undesirable in this particular case, we will avoid all exposures of any metallic surface to any stray current (electrical currents, magnetic, thermical, amongst other human factors), because they can speed up and cause a corrosion process.

Using the adequate instruments, corrosion can be detected long before causing damages to a structure. Join the active corrosion cell or mitigate it, in its premises, using an adequate Cathodic Protection System. Nowadays, with the technological advances, a Cathodic Protection System can be real time monitorized, from every place in the world, assuring a complete effectiveness.

A Cathodic Protection System can be as complex and automated as desired, it is the case of Impressed Current Cathodic Protection System. On the other hand, Cathodic Protection Systems made of galvanic anodes, designed and supplied by ZINETI, S.A. assure versatility in its design, set-up and maintenance. This versatility has been tested through years in several areas of naval industry, more lately in marking buoys, propelling force generation, etc.

Keywords: Galvanic Anodes, Corrosion, Cathodic Protection, Cathodic Protection Systems.

1. Introduction

Oxide, is the most stable form in most of metals used in industry which can be found in nature. It is also the material condition to which most metallic parts of modern machinery tend to, causing huge losses of energy during this natural process. These losses represent, in terms of security, time and production, an important annual cost for the economy of any industrialized and developing country.

The metal loss in a steel structure (see Fig. 1) shows a clear example of its returning gradually to its natural condition. Fortunately, there are simple, efficient and economic ways of counteracting this phenomenon, without endangering the structure and with a minimal environmental impact.

Figure 1: Corroded structure.

2. Corrosion

Corrosion is a daily fact, completely assumed by the human being, which sometimes goes unnoticed or is accepted as something irreparable, as our ageing. Anyhow, it can be defined as an electrochemical process related to the current of ions and electrons between anodes and cathodes. The loss of metal (corrosion) takes place in the anode, metal is not lost in the cathode.

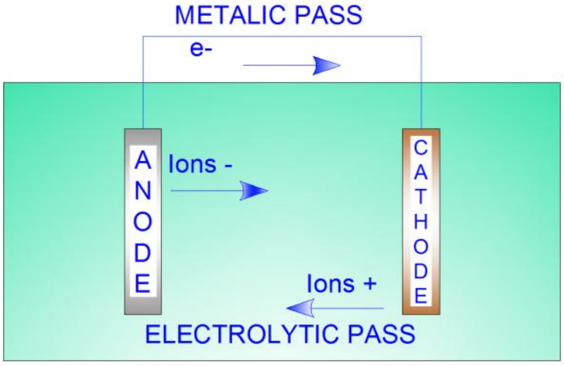

Figure 2: Corrosion cell

The electrochemical corrosion is related to the electrons transfer through the interfaces metal/electrolyte, taking place inside a corrosion cell (see Fig.2).

The cell is composed of four parts:

- ✓ Anode
- ✓ Cathode
- ✓ Electrolyte
- ✓ Metallic Pass

3. Corrosion causes

In almost every case, corrosion can be divided in two types:

3.1 Natural or spontaneous corrosion.
3.2 Corrosion due to stray currents.

3.1 Natural or spontaneous corrosion.

It is due to corrosion cell local action over the surface of a structure, see Fig. 3. These cells, made of a sole metal, are generated by potential variations due to factors such as irregularities on the surface, differences between the natural power levels, variations in the alloy composition, metal sheeting, oxygen concentrations, variations around the electrolyte structure, etc.

Figure 3: Natural corrosion

3.2 Corrosion due to stray currents

Stray currents are one of the human factors which can speed-up or cause a corrosion process, it occurs when a direct or alternate electrical current source is close to a structure. A clear example of stray currents can be shown as an Impressed Currents Cathodic Protection System which protects a structure. The protective flow of electrical current can affect any nearby structure despite the cathodic protection system.

4. Detecting corrosion problems

There are many ways to detect a corrosion problem, the most common are:

4.1 Polarized potential measuring
4.2 Wall thickness checking using ultrasound

4.1 Polarized potential measuring

The National Association of Corrosion Engineers (NACE) has set up worldwide used criteria to check if a metallic structure is in process of corrosion or not.

Figure 4: Reference electrode

These criteria are validated using a Reference Electrode, see Fig.4, and are the following:

- ✓ **A -850mV negative potential (cathodic) with cathodic protection applied**

This potential is measured regarding a reference electrode made of copper/copper sulphate (Cu/CuSO4) connected to the electrolyte.

- ✓ **A -850mV negative polarized potential**

The polarized potential will be measured regarding a Cu/CuSO4 electrolyte.

- ✓ **A 100 mV minimum cathodic polarization**

Between the structure surface and a stable reference electrode connected to the electrode and naturally polarized.

4.2 Wall thickness checking using ultrasound

The structure is checked using the Pulse – Eco technique. This technique is relatively simple, see Fig.5.

Figure 5: Ultrasonic holyday detector “Smart Pig”

An ultrasound signal is sent weighing up its return with a sample of the structure in its original thickness, if the signal decreases in time; it is clearly a corrosion problem.

After detecting areas possibly corroded areas, the problem has to be mitigated in order to avoid damages to the structure. Therefore, it will be necessary to define a Cathodic Protection System in accordance with the problem, the structure, the location, the electrolyte, etc.

5. Cathodic Protection

The Cathodic Protection is the cathodic polarization of all areas with noble potentials (cathodes), including the most active one, over the metallic surface. The cathodic protection is obtained by turning the structure into the cathode of a direct current circuit. Most of the structures immersed in an electrolyte can be secured by cathodic protection, see Fig.6.

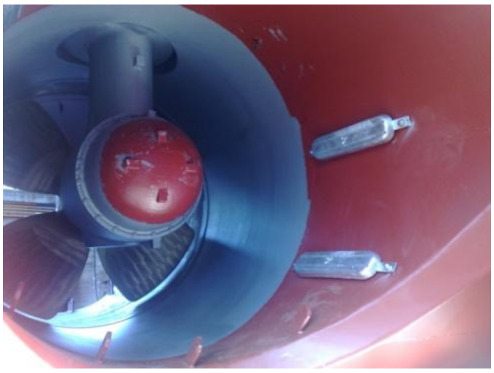

Figure 6: Protection by means of galvanic anodes in a manoeuvring tunnel

Some examples of structure to which cathodic protection is generally applied:

- ✓ Buried tanks and pipes
- ✓ Buried or submerged steel, aluminium, pre tensed concrete pipes, etc.
- ✓ External bottoms of level storage tanks
- ✓ Water tanks interiors
- ✓ Hulls
- ✓ Ballast tanks
- ✓ Springs
- ✓ Table stakes
- ✓ Foundation pilings on and off shore
- ✓ Bridges carriageways
- ✓ Sanitary hot water storage tanks interiors
- ✓ Heat exchangers boxes and pipes
- ✓ Crude heaters internal surfaces
- ✓ Steel made of reinforced concrete
- ✓ Electrical wires, phone wires and lead or steel covered wires.

The most common Cathodic Protection Systems are the following:

5.1 Cathodic Protection by means of Galvanic Anodes

5.2 Impressed Current Cathodic Protection System

5.1 Cathodic Protection by means of Galvanic Anodes

The galvanic cathodic protection or galvanic anodes use the corrosion of several metals according to the galvanic series, see Table 1. The galvanic anode is connected directly to the structure, see Fig.6, or through a measuring station, in order to monitorize.

Metal	Volts vs. Cu/CUSO$_4$	Volts vs. Ag/AgCl
Anodic or active end.		
Magnesium	-1.60 to -1.75	-1.59 to -1.74
Zinc	-1.10	-1.09
Aluminium	-1.05	-1.04
Clear Steel	-0.50 to-0.80	-0.49 to -0.79
Oxidized Steel	-0.20 to -0.50	-0.19 to -0.49
Ductil Steel	-0.50	-0.49
Lead	-0.50	-0.49
Concrete Steel	-0.20	-0.19
Copper	-0.20	-0.19
Iron – Silicon	-0.20	-0.19
Carbon, Graphite	+0.30	+0.31
Cathodic or noble end.		

Table 1: Galvanic series

Zinc, aluminium and magnesium alloys are the ones used to design galvanic anodes. Galvanic anodes are versatile for the following reasons:

- ✓ They do not need an external power source
- ✓ Maintenance is almost useless
- ✓ They drain little current, therefore there is no probability of interferences due to stray currents
- ✓ Easy to set up
- ✓ Anodes can be added or removed upon request
- ✓ They supply an uniform current distribution
- ✓ They do not outer screen since they can be set up in almost every place

A Cathodic Protection System by means of galvanic anodes has the following constraints:

- ✓ Little current drainage and low output potential
- ✓ They are not effective in high resistivity environments
- ✓ The cost per amp is higher

5.2 Impressed Currents Cathodic Protection System.

Impressed Current Cathodic Protection System involves an external power source, as well as anodes, see Fig.7. The external source moves the current from the anode towards the structure, through the electrolyte. The anodes used in an impressed current system are basically made of inert material.

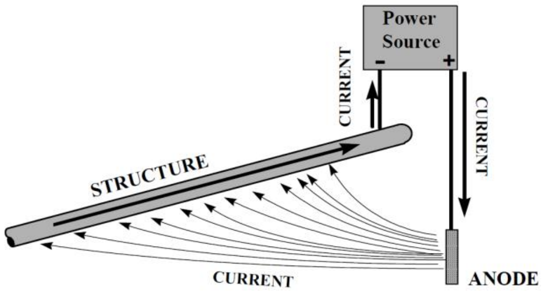

Figure 7: Impressed Current Cathodic Protection System.

Impressed Currents Cathodic Protection System has the following advantages:

- ✓ Flexible, provided with the capacity to operate with a wide range of output voltages and currents
- ✓ Current high requirements can be satisfied with a sole set up
- ✓ Bare or badly covered structures efficiently protective
- ✓ Effectives in high resistivity environments

Impressed Current Cathodic Protection has the following constraints:

- ✓ High checking and maintenance costs
- ✓ External power sources required
- ✓ Power supply constant cost
- ✓ The probabilities to generate interferences due to stray currents are high
- ✓ They can cause cathodic overprotection, triggering damages to the coating and fragility due to hydrogen

6 Cathodic Protection Systems checking and monitorizing

The most obvious reason to check and monitorize a cathodic protection system is to ensure that the corrosion is under control. When a structure is not checked, a corrosion process can be triggered, causing structural damages despite the cathodic protection system, generating damages to the environment, public health, unexpected stops of a production process, etc. Many industries and countries, in order to regulate, have ensured all structures which contain dangerous products and, in general, have suitably protected them. Nowadays, we use many remote monitorization systems, but it is still necessary to periodically record the data in order to ensure that the cathodic protection system operates correctly and supplies the adequate protection to the structure.

The data to be recorded are the following:

- ✓ Potential measuring of the structure-electrolyte with adequate galvanic anodes located in several places
- ✓ Current drainage of the galvanic anodes
- ✓ Current magnitude and direction within the drainage places
- ✓ Output voltage and current within the grinding
- ✓ Diffusing anodes resistance
- ✓ Grinding integrity, insulating joints, electrical joints and other system physical features

The potential measuring of the structure-electrolyte remains the only way to determine if the adequate cathodic protection is reached.

7 ZINETI, S.A. Anodes

The efficiency and effectiveness of a galvanic anode is proportional to its alloy and shape. Zinc alloy anodes are 95% efficient (η = 0, 95), however, their effectiveness will be about 70% to 85%, depending on the factors and features of the installation place.

Aluminium alloy anodes are η = 0,90 efficient and effective. Magnesium alloy is η = 0,60. In ZINETI, S.A., we consider alloys efficiency and effectiveness; we design our anodes according to US MIL A18.0001: K regulations. However, our technical area keeps working on the alloy to make it optimum, cast after cast. We are ISO 9001:2008 certified, see Fig. 8, we are members of The National Association of Corrosion Engineers (NACE), see Fig. 9, we work with a qualified staff according to this Organization.

CERTIFICATE OF APPROVAL

This is to certify that the Quality Management System of:

ZINETI, S.A.
Loiu, Bizkaia
Spain

has been approved by Lloyd's Register Quality Assurance to the following Quality Management System Standards:

ISO 9001:2008

The Quality Management System is applicable to:

Marketing and management of the manufacturing of zinc, aluminium and magnesium anodes.

Approval Certificate No: SGI 1204685

Original Approval: 02 May 2005
Current Certificate: 02 May 2010
Certificate Expiry: 01 May 2011

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Figure 8: ISO Certificate

Figure 9: NACE Certificate

8 The Firm

ZINETI, S.A. is a local firm, created 33 years ago, we own foundry, we adapt ourselves to the needs of any client and we are insurmountably fast. We design and realise Cathodic Protection Systems not only to recommend kind of anode to use (depending on shape, dimension and installation) but also to indicate the best way to protect a structure.

Given the context, we are leaders; our anodes are well known by most of the peninsula and European shipyards. Besides, ZINETI's brand is well known within the tidal force generation, since we are protecting the OPT buoys in Santoña, Cantabria, see Fig. 10.

Figure 10: Santoña OPT buoy

In ZINETI, S.A. we firmly bet for quality to set up our anodes in each tidal force generator, marking and beaconing buoys, conductive wires, as well as any buried or submerged metallic structure to set up on the Basque Coast.

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