ISBN 978-93-5156-328-0
International Conference of Advance Research and Innovation (ICARI-2015)

Corrosion: A General Review

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Article Info

Article history:
Received 4 January 2015
Received in revised form
10 January 2015
Accepted 20 January 2015
Available online 31 January 2015

Keywords

Corrosion,
Cathodic Protection,
Impressed Current Cathodic Protection

Abstract

Corrosion is process of destruction of a metal or material surface by the action of chemical in reaction with atmosphere. Its effect leads to erosion, wear tear of surface of metal. There are various way we can avoid corrosion such as design of proper metal surface, proper protective covering, use of inhibitors & cathodic protection. Among all the methods, cathodic protection is best method to prevent corrosion. Its two types are sacrificial anode cathodic protection & impressed current cathodic protection. Sacrificial anode method tends to sacrifice of an object which corrodes itself in order to save metal structure. Impressed current cathodic protection method employ inert anode while current is passed on to cathode with the help of external DC power source where a rectifier is employed.

1. Introduction

Corrosion is defined as deterioration of a material, because it is a form of destructive attack of a metal by chemical or electrochemical reaction with its environment.

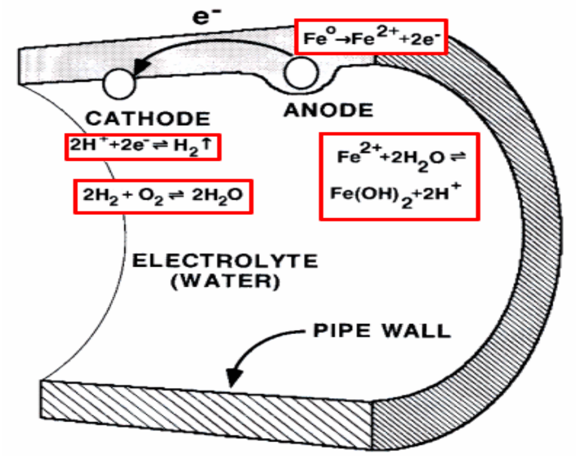

Fig: 1. Corrosion of a Pipeline Due to Localized Anode and Cathode

In the most common use of the word, corrosion means a loss of electrons of metals reacting with water and oxygen but some of the scientists think that deterioration by physical cause is not belong to corrosion so described as erosion, galling, or wear. Suggest that some of the chemical attack will accompany physical deterioration physical deteriorations, for example corrosion – erosion, corrosive wear, or fretting corrosion, included both destruction and deterioration into the concept of corrosion. Corrosion is an electrochemical process in which a current leaves a structure at the anode site, passes through an electrolyte, and reenters the structure at the cathode site as Fig.1 shows. For example a small section of a pipeline may be anodic because it is in a environment with low resistivity compared to the rest of the line. Current would leave the pipeline at the anode site, pass through the environment, and re-enter the pipeline at a cathode site.

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1.1 Damage Caused By Corrosion

1. Disfiguration or loss of appearance
2. Loss of material
3. Maintenance cost
4. Extractive metallurgy in reverse- Loss of precious minerals, power, water and man-power
5. Loss in reliability & safety
6. Plant shutdown, contamination of product etc.

1.2 Mechanism of Corrosion

Basically anodic and cathodic reactions have to balance each other out, resulting in a neutral reaction. Both anodic and cathodic reactions occur simultaneously at the same rates. What's more, the site of these electrodes may consist of either two different kinds of metals or they may be different areas of the same piece of metal, resulting a potential difference between the two electrodes, so that the oxidation reaction of the metal at the anode and formation of negative ions at the cathode can take place at the same time.

Similar electrical potentials may also be developed between two areas of a component made of a single metal as a result of small differences in composition or structure or of differences in the conditions to which the metal surface is exposed. What's more, the presence of an electrolyte is very important in the corrosion process because this provides a medium of ion exchange between anode and cathode. Therefore solutions like acids, bases and others liquid and solid chemicals can forms the typical corrosive environments which are rich in ions. For eg. in H_2O solution, positively charge hydrogen ions within the electrolyte lose their charge by gain electrons to form hydrogen gas. This can result in neutralizing the negatively charged electrons travelling from the anode to the cathode.

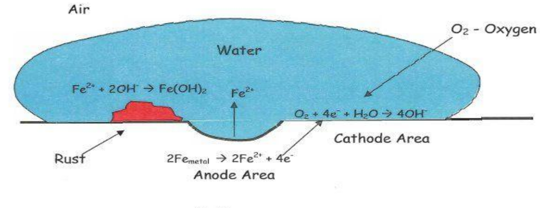

Fig: 2. Simple Model Describing the Mechanism of Corrosion of Iron

ISBN 978-93-5156-328-0

Metal ions go into solution at anodic areas in an amount chemically equivalent to the reaction at cathodic areas. Following reaction takes place on anodic and catholic areas

Anodic reactions:

$Zn = Zn^{2+} + 2e^-$

$Al = Al^{3+} + 3e^-$

$Fe=Fe^{2+} + 2e^-$

Cathodic reactions:

$2\ H_2O = 4\ H^+ + 4OH^-$

$2\ H^+ + 2\ e- = H_2\,(g)$

&

$O_2 + 2\ H_2O + 4\ e- = 4OH^-$

Anode and cathode reactions are always balanced, i.e congestion of electrons does not exist

1.3 Factors Affecting Corrosion

1. Area of the anodic and cathodic elements under contact
2. Electric potential difference of the elements under contact
3. Potential difference between anodic and cathodic areas
4. Environmental condition around the metal
5. Resistivity of the electrolyte

2. Corrosion Controlling Methods

1. Design
2. Materials Selection
3. Inhibitors
4. Protective Coatings
5. Cathodic Protection

2.1 Cathodic Protection

Cathodic protection is a method to reduce corrosion by minimizing the difference in potential between anode and cathode. This is achieved by applying a current to the structure to be protected (such as a pipeline) from some outside source , or current can be passed between the cathode and the anode due to the different in potential When enough current is applied, the whole structure will be at one potential ; thus , anode and cathode sites will not exist.

2.2 The Principle of Cathodic Protection

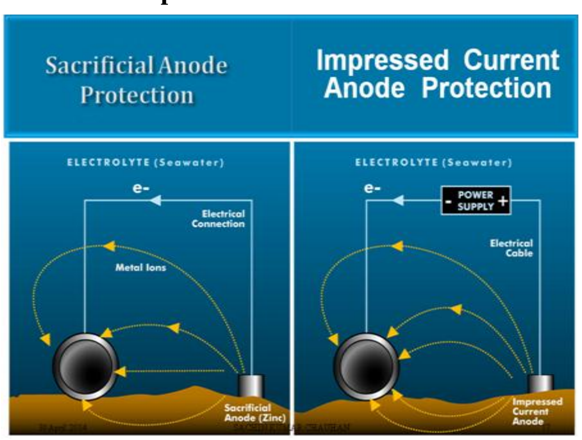

Fig: 3. A & B Sacrificial Anode and ICCP Schemes

The principle of cathodic protection is in connecting an external anode to the metal to be protected and the passing of an electrical dc current so that all areas of the metal surface become cathodic and therefore do not corrode. The current density and the potential are quite high and after applying ICCP the potential decrease with decreasing the current density

2.3.1Types of Cathodic Protection

There are two main types of cathodic protection systems; there are impressed current and sacrificial anode. Both types of cathodic protection have anodes, a continuous electrolyte from the anode to the protected structure, and an external metallic connection (wire). These items are essential for all cathodic protection systems.

A.) Sacrificial Anode Cathodic Protection

A sacrificial anode cathodic protection system in fig 3 (a) makes use of the corrosive potentials for different metals. Without cathodic protection, one area of the structure exists at a more negative potential than another, and results the occurrence of corrosion on the structure. On the other hand, if a negative potential metal, such as Mg is placed adjacent to the structure to be protected, such as a pipeline, and a metallic connection is installed between the object and the structure, the object will become the anode and the entire structure will become the cathode. Anodes materials in this system are usually made of either Mg or zinc because of these metals higher potential compared to steel structures.

B.) Impressed Current Cathodic Protection

Impressed-current systems in Figure 3 (b) employ inert (zero or low dissolution) anodes and use an external source of DC power (rectified AC) to impress a current from an external anode onto the cathode surface. In addition to the structure to be protected and the electrolyte (soil, water, etc.), impressed current cathodic protection systems consist of the following essential components:

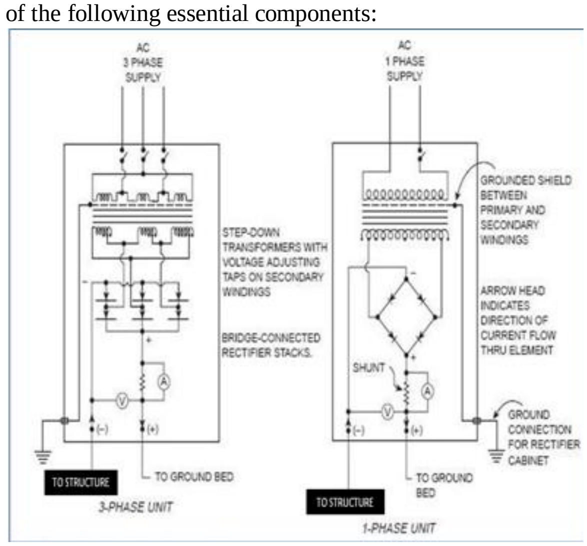

Fig: 4. Scheme of Cathodic Protection using 3-phase & 1-Phase Supply

1. The current source, such as transformer/rectifiers, solar generators, etc.
2. The impressed current anodes buried in soil or immersed in water.
3. The interconnecting cables

An ICCP uses a rectifier (an electrical device for converting alternating current into direct current) to provide direct current through anodes to the metal tank, piping, or other underwater components to achieve corrosion protection. The system may also be provided with a current control circuit to regulate the protection level. Such regulation is particularly useful when different structures are protected by the same current source.

2.4 Essentials of Impressed Current Cathodic Protection

1. Current Sources
2. Transformer/Rectifiers
3. Circuit Breaker
4. Distributed Anode Cables

2.5 Comparison between Sacrificial and Impressed Current Cathodic Protection

Sacrificial Anode Method	ICCP METHOD
• It requires no external source	• External power is essential
• It can be easily installed and maintained	• More complicated system for installation
• It can be used in areas where the soil resistivity is low	• Limited to use below a soil resistivity of 3000 ohms-cm
• It is economical for small structure	• Less economical for small structure
• Commonly used for small structures	• Always preferred for big structures
• More no. of anode required	• Lesser no. of anode required

2.6 Advantages and Disadvantages of ICCP

❖ **Advantages:**

There are several important advantages of using ICCP systems, for example unlimited current output capacity, lower cost per ampere of cathodic protection current. It's usually cost effective to justify the adoption of an ICCP system in long term for large structure, it is easier to build an ICCP system than to locate and repair the underground structure leaks. In an ICCP system, an external source of electrons is provided to the metal/electrolyte combination. In order to achieve protection from the corrosion the sources of electrons must be sufficient to raise potential of the structure to a level at which negligible corrosion occurs

1. High driving voltage (30)
2. Few anodes – reduced resistance
3. Suitable for those media having low conductivity.
4. Cheapest for large strucyures in long term

❖ **Disadvantages**:

Besides all of the above advantages there are some disadvantages also to which an ICCP system under goes

1. Need for regulation/control system
2. Risk of overprotection of highly charged materials
3. Coating damages – cathodic accouplement
4. Interference to the transmission line

2.7 Application of ICCP

Now a days ICCP system is being used in the different areas of industry, construction and development. some of major applications are listed below & as shown in fig.

- Oil & gas Pipelines and Oil Platforms in steel and concret
- Ship Hull
- Quay structures and sheet pile curtains
- Concrete bridges placed in seawater
- Huge building
- Towers etc.

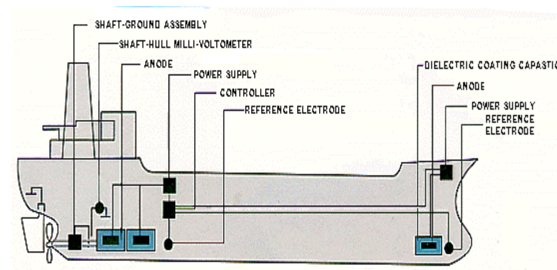

Fig: 5. Protection of sea ship outer body using ICCP

3.0 Conclusions

Impressed current cathodic protection and coating gives optimum protection for metal in comparison of other methods of corrosion prevention .In this the potential of steel shifted from less negative values to more negative until it reached the optimum protection level when ICCP system applied. Cathodic protection method of element protection is cheaper than other type of protection method in long run & it can be used in every condition and for any size of structure along this , It can be applied to those areas too , which are not safe for daily maintenance purpose .

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