The Effect of More Anodic Metals from Zinc Addition on Cathodic Protection of Iron with Zinc as Sacrificial AnodeAgaints Corrosion Rate

by Ira Kusumaningrum

Submission date: 04-Jun-2023 10:04PM (UTC-0400)
Submission ID: 2108996866
File name: sumaningrum_2019_IOP_Conf._Ser.__Mater._Sci._Eng._494_012086.pdf (819.95K)
Word count: 2329
Character count: 11672

PAPER • **OPEN ACCESS**

The Effect of More Anodic Metals from Zinc Addition on Cathodic Protection of Iron with Zinc as Sacrificial AnodeAgaints Corrosion Rate

To cite this article: I Kusumaningrum and M Usman 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **494** 012086

IOP Conf. Series: Materials Science and Engineering **494** (2019) 012086 doi:10.1088/1757-899X/494/1/012086

The Effect of More Anodic Metals from Zinc Addition on Cathodic Protection of Iron with Zinc as Sacrificial AnodeAgaints Corrosion Rate

I Kusumaningrum and M Usman
Mechanical Engineering Department,Darul'Ulum University, Jombang, East Java, Indonesia

Abstract. Corrosion is one of the problems that is often encountered in the use of ferrous metal materials in everyday life both at home and industrial scale. Many methods for inhibiting the corrosion process in iron, one of which is by cathodic protection with a sacrificial method. The sacrificial material used contains more negative potential energy than iron. In this study AISI 1020 steel which will be protected with zinc as sacrificial anodel, which is assisted by AZ31 magnesium and aluminum 8011 additional metal. The testing process is carried out by the weight loss method, where the material is soaked for 2 months. The results showed no weight reduction in aluminum 8011, AISI 1020 steel and zinc when aluminum 8011 was added to this protection. But a weight reduction occurred in magnesium AZ3 1 when the magnesium was used as additional metal.

1. Introduction

Iron and its alloys are not the first metal that humans use as tools to live their lives, but because they are most widely used, corrosion in iron causes damage to these equipment. Corrosion cannot be prevented but can only be controlled [1-2].Corrosion control is a means to overcome the problem of damage. There are various ways of controlling, including cathodic protection with sacrificial anodes. Cathodic protection with sacrificial anodes has the same principle as galvanic cells [3]. In these cells, metals with a greater or higher potential for oxidation in the series Electromotive-Emf series (more active) become anodic to metals that are less active and consumed during electrochemical reactions. While metals that are less active get cathodic protection on the surface. This is due to the current flow through anodic metal electrolytes [4]

In cathodic protection with sacrificial anodes, there are still metals that are corroded and damaged as well as lost in function. For this reason, it is necessary to take into account the relative area of the anode and cathode and take into account the anodic corrosion rate, so that it can be estimated when replacement must be done [5]

Previous researchers have proven that controlling with the sacrificial anode has been effective in protecting the metal cathode [6-11]. In these researches show the protection of metals protected by corrosion rates which varied according to the metal anode. However, there is still a heavy reduction in the metal anode due to the galvanic corrosion process. Addition of metals with potential energy is more positive than the anode or cathode in zinc-iron anodic cathodic protection has been carried out to protect both iron and zinc. The results of the study showed that by adding a coil of copper wire or lead wire to iron wrapped in zinc there was no corrosion rate on all the metals involved [12]. There needs to be an effort to crush the metal so that it will not be damaged, so there will be no more replacement at a later date. Corrosion control is only carried out at the time of planning, so that corrosion control

IOP Conf. Series: Materials Science and Engineering **494** (2019) 012086 doi:10.1088/1757-899X/494/1/012086

becomes more effective and efficient. In addition to knowing the effect of adding metal whose potential energy is more negative than the anode metal and cathode.

In the research, other metal attachments were made which had more negative potential energy than AISI 1020 and zinc steel in sacrificial anode cathodic protection. AISI 1020 steel which functions as a metal cathode and zinc as its anode metal. Additional metals are AZ31 magnesium and 8011 aluminum. The media used for immersion are river water, piped water and well water. Expression of corrosion rates is indicated by weight loss from each metal.

2. Method

2.1. Material

The material used is AISI 1020 Steel with chemical composition (wt%): 0.23 C, 0.60 Mn, 0.040 P, 0.050 S, Bal. Fe. Steel AISI 1020 has a size of 20 x 20 x 10 mm. While the Aluminimum 8011 chemical composition is (wt%): 0.50 Si, 0.6 Fe, 0.20 Mn, 0.1 Cu, 0.05 Mg, 0.05 Cr, 0.1 Zn, 0.08 Ti, Bal. Al. The size of the Aluminum 8011 specimen is 20 x 60 x 0.04. Magnesium AZ31 (Mg) specimens have chemical composition (wt%): 3.00 Al, 1.00 Zn, 96.00 Mg. Magnesium AZ31 specimen dimensions are 20 x 20 x 0.08 mm. The Zn specimen used is pure zinc with a chemical composition Zn (wt%) 100. Zinc has a size of 20 x 20 x 0.9 mm. Electrolytes used in this experiment were well water (pH = 6.28), PDAM water (pH = 7.04) and river water (pH = 7.21). The experimental procedure is shown in Figure 1.

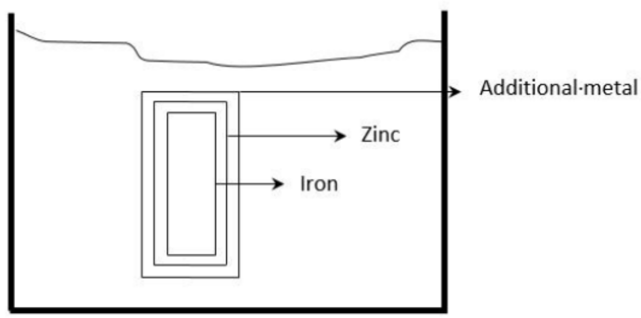

Figure 1. Trial procedure

2.2. Measurement

The corrosion rate expression used in this experiment is the calculation of weight loss per unit time. Specimens submerged in water within 2 months. All three metals weighed their initial weight before being coupled and soaked. The coupling was done with an easy-to-disassemble arrangement, making it easier to measure metal after immersion. The corrosion rate is expressed as follows:

$$CR = \frac{\Delta W}{t} x\ 100\% \quad (1)$$

In which: CR =Corrosion Rate, ΔW = Weight loss (gram), t = Immersion time (Month)

3. Results And Discussions

The results of this study were the corrosion rates on AISI 1020, Zinc and Magnesium AZ31 steels, when magnesium AZ31 is used as an additional metal in cathodic protection of Steel AISI 1020 with zinc sacrificial anodes as shown in Table 1 and Figure 2. Corrosion rates were also calculated when metal Additional was replaced with aluminum 8011 as shown in Table 2 and Figure 3. The results were as follows:

IOP Conf. Series: Materials Science and Engineering **494** (2019) 012086 doi:10.1088/1757-899X/494/1/012086

Table 1. Corrosion Rate on AISI 1020, Zinc and Magnesium AZ31 Steel with Magnesium AZ31 as addition metal

Electrolyte	Corrosion rate (%)		
	River water	PDAM water	Well water
Iron	0	0	0
Zync	0	0	0
Magnesium	0.0138667	0.0083	0.0444333

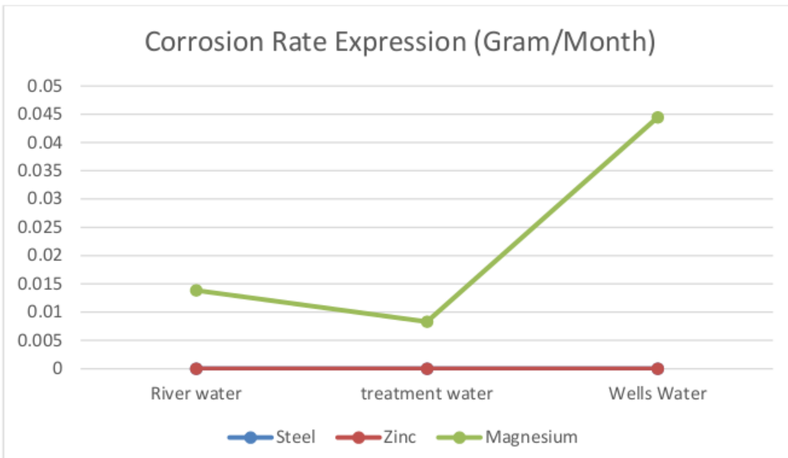

Figure 2. Corrosion Rate on AZ31 AISI 1020, Zinc and Magnesium Steel with additional metal Magnesium AZ31

Table 2. Corrosion Rate on AISI 1020 Steel and Aluminum 8011 with additional metal Aluminum 8011

Electrolyte	Corrosion rate (%)		
	River water	PDAM water	Well water
Iron	0	0	0
Zync	0	0	0
Magnesium	0	0	0

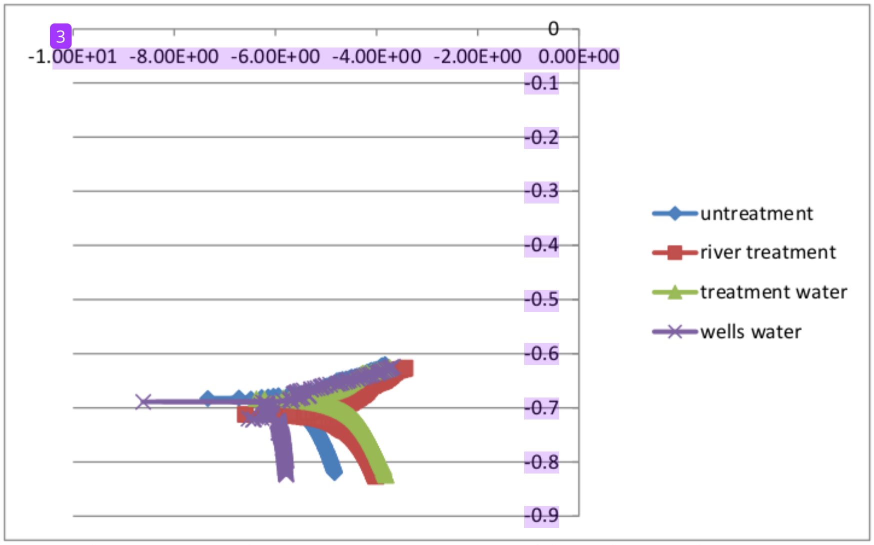

Figure 3. Corrosion Rate on AISI 1020 Steel in various environments

When AISI 1020 Steel protection with zinc sacrificial anode coupled with additional Magnesium AZ31 metal and submerged in electrolytes for 2 months, steel and zinc did not experience corrosion. This is different from Magnesium when it is soaked on all three electrolytes. However, when additional metal was replaced with aluminum 8011 and was given the same treatment; steel, zinc and aluminum did not experience corrosion

When zinc comes into contact with iron, steel acts as a cathode that receives electrons and zinc acts as an anode. The reactions that occur are as follows:

Zn □ $Zn^{+} + e^{-}$ (e^{o} = +0.762 V vs SHE) (2)

$Fe^{2+} + 2e^{-}$ □ Fe (e^{o} = -0.44 V vs SHE) (3)

At the same time, zinc came into contact with aluminum, so zinc acts as a cathode that accepts electrons and aluminum acts as an anode. The reactions that occur are as follows:

$Zn^{+} + e^{-}$ □ Zn (e^{o} = -0.762 V vs SHE) (4)

Al □ $Al^{3+} + 3e^{-}$ (e^{o}= +1.662 V vs SHE) (5)

Thus, two anodes and two cathodes occur. Zinc acts as an anode at the same time as a cathode. The potential value of the cell is as follows

$$E^0_{sel} = E^0_{Fe/red} + E^0_{Zn/oks} + E^0_{Zn/red} + E^0_{Al/oks} \quad (6)$$

$$E^0_{sel} = (-0.44) + 0.762 + (-0.762) + 1.662 \quad (7)$$

= +1.222 V vs SHE

Because E^0_{sel} value is positive then the Gibbs free energy value is negative. This shows that corrosion will occur spontaneously. Thus aluminum will experience corrosion. However aluminum is a passivation metal, so that the corrosion film layer on the aluminum surface will block the electrons to flow towards the steel [3,5].

Corrosion still occurs in Aluminum when Aluminum is added / affixed to zinc which is coupled to steel. However, a corrosion film product layer from aluminum that blocks electrons flows to the anode, so the corrosion rate stops [5]. In this case the steel is protected because of its role as a cathode. The crushed zinc should be corroded by flowing the electrons towards the steel. At the same time zinc functions as a cathode that receives electrons from aluminum. Thus zinc does not undergo corrosion [5].

The same thing will happen when additional metal is replaced with magnesium. Magnesium will act as an anode when attached to zinc, the anodic reaction is as follows

$$Mg \rightarrow Mg^{2+} + 2e^{-} (e^{o} = +2.363 \text{ V vs SHE}) \quad (8)$$

The potential cell values are as follows:

$$E^0_{sel} = E^0_{Fe/red} + E^0_{Zn/oks} + E^0_{Zn/red} + E^0_{Mg/oks} \quad (9)$$

$$E^0_{sel} = (-0.44) + 0.762 + (-0.762) + 2.363 \quad (10)$$

= +1.923 V vs SHE

Thus the free energy value is negative and magnesium will corrode spontaneously

Corrosion occurs in magnesium when magnesium is added / affixed to zinc which is coupled to steel. In this case the steel is protected because of its role as a cathode. The crushed zinc should be corroded by flowing the electrons towards the steel [5]. At the same time zinc functions as a cathode that receives electrons from aluminum. Thus zinc does not experience corrosion.

4. Conclusions

Corrosion still occurs in Aluminum when Aluminum is added/affixed to zinc which is coupled to steel. However, the corrosion film layer of aluminum that blocks electrons from flowing to the anode, so the corrosion rate stops. In this case the steel is protected because of its role as a cathode. The sacrifised zinc should be corroded by flowing the electrons towards the steel. At the same time zinc functions as a cathode that receives electrons from aluminum. Thus zinc does not experience corrosion.

Corrosion also occurs with magnesium when magnesium is added/affixed to zinc which is coupled to steel. In this case the steel is protected because of its role as a cathode. The sacrificed zinc should be corroded by flowing the electrons towards the steel. At the same time zinc functions as a cathode that receives electrons from aluminum. Thus zinc does not experience corrosion.

5. Reference

[1] Gapsari F, Wahyudi S, Sumawan 2014Applied Mechanics and Materials.*The Influence of High Content of Silicon in Austenitic Stainless Steel to Corrosion Rate in Sulphuric Acid*.**493** 727-732

[2] Wahyudi S, Gapsari F, Awali H, 2014 Applied Mechanics and Materials. *Corrosion Rate of Sulfuric Acid Resistant Alloy Metal (SARAMET) Using Response Surface Methodology*.**493**733-738

[3] Popov, B N 2015.*Corrosion Engineering*.(California: Elsevier)

[4] Suprapto W, Soenoko R, Gapsari F 2018 Engineering Review. *Comparation of the analytical and experimental models of 304SS corrosion rate in 0.5 m H_2SO_4 with bee wax propolis extract*. **38** No. 2

[5] McCafferty E 2010 USA.*Introduction to Corrosion Science, Springer Science and Business*

[6] Tang D, YanxiaD, Xiangxi L, Yi L, Minxu L 2016Material & Design. *Effect of alternating current on the performance of magnesium sacrificial anode*. **93** 133-145

[7] FerdianD,Yudha P, Inez T, Ira A2017Procedia Engineering. *Development of Al-Zn-Cu alloyfor low voltage aluminiumsacrificial anode*.**184** 418-422

[8] Song G, Birgir J, Sarah H,David St J2004Corrosion Science. *Galvanic corrosion of magnesium alloy AZ9010 in contact with an aluminium alloy*, *steel and sinc*. **46** 955-977

[9] Bertolini L., Matteo C, Maria P,EllenaP R. 2002Corrosion Science. *Prevention of in concrete exposed to seawater with submergeredsacrificial anode.***44** 1497-1513

[10] He J, Jiuba W, Xudong L 2011Corrosion Science. *Effect of precipitates on the electrochemical performance of Al sacrificial anode*.**53** 1948-1953
[11] Zang X G 1996J. Electrochem. Soc.*Galvanic Corrosion of zinc and its alloy*.**143** No. 4
[12] Mouanga M, PuiggaliM B, Tribollet V, Vivier, Pébère N, Devos O, 2013 ElectrochemicalActa. *Galvanic corrosion between zinc and carbon steel investigated by local electrochemical impedance spectroscopy.***88** 6–14

The Effect of More Anodic Metals from Zinc Addition on Cathodic Protection of Iron with Zinc as Sacrificial AnodeAgaints Corrosion Rate

ORIGINALITY REPORT

18%	17%	15%	16%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Brawijaya Student Paper	7%
2	bth.diva-portal.org Internet Source	2%
3	emidius.mi.ingv.it Internet Source	2%
4	ojs3.unpatti.ac.id Internet Source	1%
5	eprints.undip.ac.id Internet Source	1%
6	P Astuti, K Kamarulzaman, R S Rafdinal, H Hamada, Y Sagawa, D Yamamoto. "Influence of Rust Removal Process on The Effectiveness of Sacrificial Anode Cathodic Protection in Repair Concrete", IOP Conference Series: Materials Science and Engineering, 2020 Publication	1%

Submitted to University of Leeds

7	Student Paper	1 %
8	Submitted to University of Aberdeen Student Paper	1 %
9	Femiana Gapsari, Puth H. Setyarini, Khairul Anam, Siti Azizah, Ria Yuliati. "The Effect of Hot Dip Galvanizing Temperature to Corrosion Rate of Steel as the Material for Chopper Machine", Solid State Phenomena, 2019 Publication	1 %
10	kyutech.repo.nii.ac.jp Internet Source	1 %
11	www.steeldata.info Internet Source	<1 %
12	Al-Samman, Talal, and GÃ¼nter Gottstein. "Deformation Conditions and Stability of the Basal Texture in Magnesium", Materials Science Forum, 2007. Publication	<1 %

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		