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The Influence of Crevice Gap To The Interface Potential of Aluminium 1100 And Medium Carbon Steel and Its Effect To The Corrosion Rate of Metals

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ABSTRACT

The use of aluminium alloy is increasing significantly in recent 5 decades. Many products made of aluminium are available in market. Aluminium widely used as building material and building construction. A series of experiments and measurements have conducted in relation to cases where the aluminium alloy make contact and make crevice gap to steel. The variable of experiments including the aluminium making contact to steel, make the gap of 0.21 mm and of 0.43 mm. The corrosion rate of Aluminium 1100 found 485.07 MPY. The interface potential of aluminium is -709 mV VS Cu/CuSo4 and Medium Carbon Steel (MCR) is – 698 mV VS Cu/CuSO4 when in contact, and the interface potential when in gap of 0.43 mm is – 610 mV VS Cu/CuSO4 for Aluminium 1100 and -754 mV VS Cu/CuSO4 for Medium Carbon Steel. When aluminium 1100 in contact with steel in chloride environment, the interface potential of steel would polarized and make it being more anodic. The gap width influence the surface potential. The bigger the gap width, the lesser the effect.

KEYWORDS

Aluminium 1100; Medium Carbon Steel; Crevice Corrosion; Gap distance.

INTRODUCTION

Aluminium was first dicovered by Sir Humphrey Davy in 1809 as an element and was first reduced as a metal by H.C. Orsted in 1825 . Industrial process was begin in 1886 where Paul Heroult in France and C.M. Hall in United States of America separatedly extracted the aluminium from aluminae by electrolizing the fused aluminium salt. The process then named as Heroult Hall process and still used up to now to extract aluminium from its oxide [1] [2]. The use of aluminium increasing year by year all over the world. It ranks second after iron and steel in metal trading. The highest rank of non-ferrous metals. Aluminium used in many manufacturing industry because of light and good mechanical properties, good corrosion resistance, good ductility and reproducible. Most known as airplane construction material. The pure aluminium tensile strength is about 90 Mpa, and about 200-600 Mpa for aluminium alloy. Aluminium has good machinability, easily casted, drawn and extrusion for manufacturing. Phisically, it has good heat conductivity corficient and good electric conductivity too. Its use spreads to all engineering fields such as building materials, building construction, aircraft industry, food and drink production, transportation, household utensils, electronic appliances etc [3] [4].

In the application, the pure aluminium maybe contacted with other metals with different surface potentials or form gaps between each other. The main materials that probably match to aluminium is Medium Carbon Steel (MCS) which widely used in engineering tools, machinery, heavy and light construction and building materials [5]. In our daily life, most aluminium window frame used the steel latch lock as fastening tools which combine the aluminium materials and steel. Most of the aluminium in market were alloys. The aluminium of 1000 series is categorized as pure aluminium, where the percentage of aluminium is more than 99,0% . Meanwhile, the other series are alloyed by specific metals to find the specific properties of mechanical or other specific properties of material. The 2000 Series is mainly alloyed by Copper, The 3000 Series mainly alloyed by Mangan, the 4000 Series is mainly alloyed by Silicon, teh 5000 Series is mainly alloyed by Magnesium, the 6000 Series is mainly alloyed by Si and Mg, the 7000 Series is mainly alloyed by Zn . Aluminium in pure state such as Aluminium 1100 or Al-1100 used in this research is to find the close behavior of its electrochemical properties as it in extra pure state [6]. Corrosion is a form of metal quality degradation regarding its interaction to the environment. Aluminium has good corrosion resistance by the passive film formed on its surface. The passive film of aluminium is the Al_2O_3 oxide that adhere, hard and strong layer on aluminium surface. Aluminium will be an active metal when the passive film is broken or peeled off or penetrated by corrosive agents such as chloride. This research is aimed to study the aluminium corrosion when make direct or indirect contact with other metals mainly steel. This research is required in order to make metals perform their function properly [7].

MATERIALS AND METHOD

The materials used in this experiments are Aluminium 1100 and Medium Carbon Steel. The Al-1100 is used to find the behaviour of near 100 percent alunimum to the gap and to the chloride contaminated liquid. The density of Al-1100 series is 2.71 gr/cm3 and density of MCS is 7.86 gr/cm3. The size of the specimens are 40 mm x 20 mm x 3 mm. All the specimens preparations, cleanings and evaluations are based on standard of ASTM G1-90 (Reapproved 1999) [8]. The method of corrosion rate calculation is based on the specimens weight loss as recommended in ASTM Standard G31-72 [9]. All the experiments conducted under the authority of Mechanical Engineering Department of Sriwijaya University. The steps of experiments were as shown in figure 1. The fluid used in this experiments is aquadest contaminated by 3% Chloric Acid (HCl). Chloride element is used to accelerate the corrosion process. Each specimens was immersed in one litre beaker at room temperatur of 28 ^{0}C. Each immersion period is conducted at the same temperatur and each specimen immersed separatedly. The period of immersion is extended intentionally due to get a high accuracy of average oxidation rate and average weight loss over the immersion time. All materials used in this experiments undergo composition test. For the accuracy of measurements, the tools and equipments used in experiments validated. The metals composition were detected by Optical Emissions Spectrometer in Bandung and we get the composition as in Table 1 and Table 2.

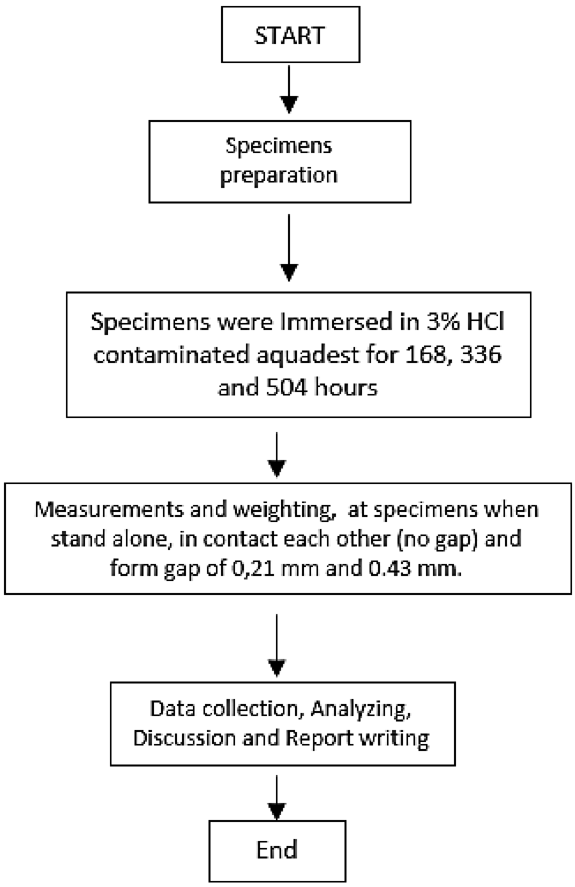


Figure 1. The simply flowchart of experiments

Table 1. The Al-1100 Composition

Unsur	Kandungan (% Berat)
Aluminium (Al)	99,07170
Silicon (Si)	0,21215
Ferro / Iron (Fe)	0,47725
Copper (Cu)	0,11861
Mangan (Mn)	0,01471
Magnesium (Mg)	0,03475
Zinc (Zn)	0,04339
Titanium (Ti)	0,01803
Chromium (Cr)	0,00218
Nickel (Ni)	0,00509
Plumbum / Lead (Pb)	0,00161
Tin (Sn)	0,00294
Natrium (Na)	0,00074
Antimony (Sb)	0,0040

Table 2. The MCS Composition

Unsur	Kandungan (% Berat)
Carbon (C)	0,371
Silikon (Si)	0,217
Sulfur (S)	0,016
Pospor (P)	0,014
Mangan (Mn)	0,951
Nikel (Ni)	0,06
Choromium (Cr)	0,32
Molybdenum (Mo)	0,045
Vanadium (V)	0,008
Copper (Cu)	0,113
Wolfram (W)	0,007
Titanium (Ti)	0,003
Tin (Sn)	0,006
Aluminium (Al)	0,007
Plumbum (Pb)	0,0040
Niobium (Nb)	0,005
Zirconium (Zr)	0,001
Zinc (Zn)	0,034
Ferro / Iron (Fe)	97,816

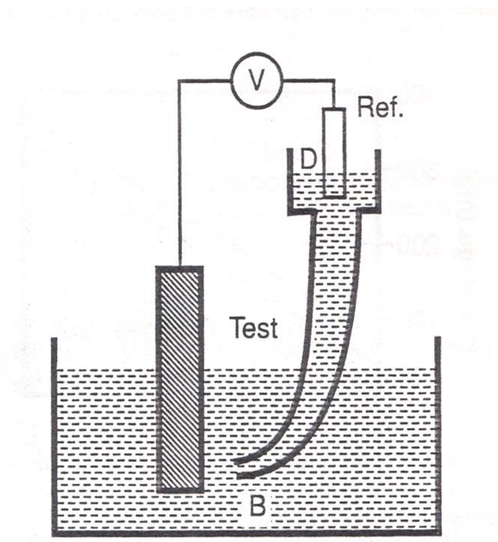


Figure 2. Lugin capillary interface potential measurement principle [10]

The measurements of specimens interface potentials were conducted by using the Cu/CuSO4 reference electrode. This electrode is simple and easy to assemble. The mesurements were conducted at different formation specimens as planned. These planned were intended to clearly saw the influence of gap formation to the specimens surface potentials and how it reflected to the metals corrosion current density, which at last clearly expressed in weight loss of metals [11]. The interface potential of specimens were measured by lugin cappillary where 1 mm spaced from the surface to prevent IR drop. Schematicaly the measurements as shown in Figure 2.

RESULTS AND DISCUSSION

To differentiate the results of experiments and the discussion, the matters presented in separated sub-heading.

Weighting and Measuring results

The results of measurements and weighting are presented below. Those results include, the weight loss of specimens at planned formation, the interface potentials of specimens at related formation. The weight loss method was chosen as qualitative method which the accuracy comparable to other methods of calculation [12]. The results are as followings.

Table 3. Interface potential of specimens at varying formation

Specimens Formation	**Specimens Material**	**Interface potential (mV) VS Cu/CuSO4**
Specimens were full contacted (no gap)	MCS	- **698**
	Al-1100	- **709**
Specimens form gap width 0.21 mm	MCS	- **594**
	Al-1100	- **725**
Specimens form gap width 0.43 mm	MCS	- **610**
	Al-1100	- **754**
Specimens standing alone	MCS	- **598**
	Al-1100	- **741**

The weight loss of specimens found by digital balance. The aluminium specimens were clean as recommended by ASTM Standard G1-90. Cleaning was done by combining the mechanical cleaning and chemical cleaning. Mechanical cleaning was done by soft brush on the specimens surface and then immersed in hot Nitric Acid

(HNO3) solution for 5 minutes for Al-1100. The Medium Carbon Steel was cleaned by soft brush previously and then immersed in Hydrochloric Acid (HCl) for 20 minutes at room temperature. The results found were as follows:

Table 4. The weight loss of Medium Carbon Steel

Time (hour)	**Gap width (mm)**	**Aquadest with 3% HCl contamination**		
		Initial weight (W_0) (gram)	**Post immersion weight (W_1) (gram)**	**Weight loss (ΔW) (gram)**
168	Stand alone	26,0329	24,2153	1,8176
	In contact (No gap)	26,196	23,5904	2,6056
	0,21 mm gap	25,5863	23,3165	2,2698
	0,43 mm gap	25,8876	23,7108	2,1768
336	Stand alone	26,1014	22,3282	3,7732
	In contact (No gap)	25,7894	22,3662	3,4232
	0,21 mm gap	26,6349	23,4179	3,217
	0,43 mm gap	25,8871	23,4794	2,4077
504	Stand alone	26,5104	20,807	5,7034
	In contact (No gap)	24,4119	20,8262	4,5857
	0,21 mm gap	26,8144	22,6289	4,1855
	0,43 mm gap	25,6612	22,4779	3,1833

Table 5. The weight loss of Aluminium 1100

Time (Hour)	**Gap widt (mm)**	**Aquadest with 3 % HCl contamination**		
		Initial weight (W_0) (gram)	**Post immersion weight (W_1) (gram)**	**Weight loss (ΔW) (gram)**
168	Stand alone	12,5239	12,4082	0,1157
	In contact (No gap)	12,8917	10,7501	2,1416
	0,21 mm gap	12,5276	10,8137	1,7139
	0,43 mm gap	12,3729	11,2752	1,0977
336	Stand alone	12,8583	12,6183	0,24
	In contact (No gap)	12,4286	9,8533	2,5753
	0,21 mm gap	12,8639	10,3053	2,5586
	0,43 mm gap	12,5237	11,381	1,1427
504	Stand alone	12,9003	12,5057	0,3946
	In contact (No gap)	12,4286	9,6526	2,776
	0,21 mm gap	12,806	10,33	2,476
	0,43 mm gap	12,5661	10,8308	1,7353

DISCUSSIONS

Interface potential of secimens and the influence of specimen formation

From the results of interface potential presented above, it is clearly showing a value change at each formation of specimens. When both specimens full contacted, so no space between each or no gap, the potential of both metals tend to close each other. Where the MCS potential is – 698 mV Vs Cu/CuSO4 and the potential of Al-1100 is – 709 mV VS Cu/CuSO4. We can compare it to surface potential of both specimens when each specimens standing alone, where MCS potential is – 598 mV and the Al-1100 potential is -741 mV. It evidently shows that polarisation occur on both specimen when contacted. The potential of steel tend to downgraded from -598 to -698 mV and the Al-1100 tend to upgraded from – 741 mV became – 709 mV. Normally, in the environment with no chloride, the Al-1100 should be anodic to Steel. In this case, the opposite happens.

The Al-1100 became cathodic to carbon steel because passive film at the surface of Al-1100 able to protect the mother metal. On the other side, the steel unable to form the passive film on its surface at 3% HCl contaminated liquid. The steel oxide is porous and not resist to corrosion attack. In this case, MCS is at harm position. It became more active than when it stand alone. It surface potential decrease from – 598 mV to -698 mV. It means that more oxidation reaction occur on its surface. This phenomenon is readable from the weight loss. When MCS stand alone, the weight loss is 1,8176 gram for 168 hours immesion. Otherwise, when contacted the weight loss became 2,6056 gram for 168 hours of immersion. It means, MCS became more active and the consequently the more dense the corrosion current come out of its surface. From this experiments results we can conclude that in 3% chloride environment the contact between pure aluminium and the steel, will harm the steel.

Passive film and Cathodic behaviour of Al-1100 to Steel

On the other side the Al-1100 weight loss is 0,1157 gram when standing alone and 2,1416 gram when full contacted. It means the corrosion rate of aluminium also increased when contacted. This phenomenon could understood as the passive layer of Al-1100 inside the gap is not able to do reformation along the immersion process. Crevice corrosion occur only at the interface between MCS and Al-1100. At the side and at the back of Al-1100 specimen, corrosion seem not happen. This mechanism let the oxidation reaction process goes continously and constantly along the immersion time.

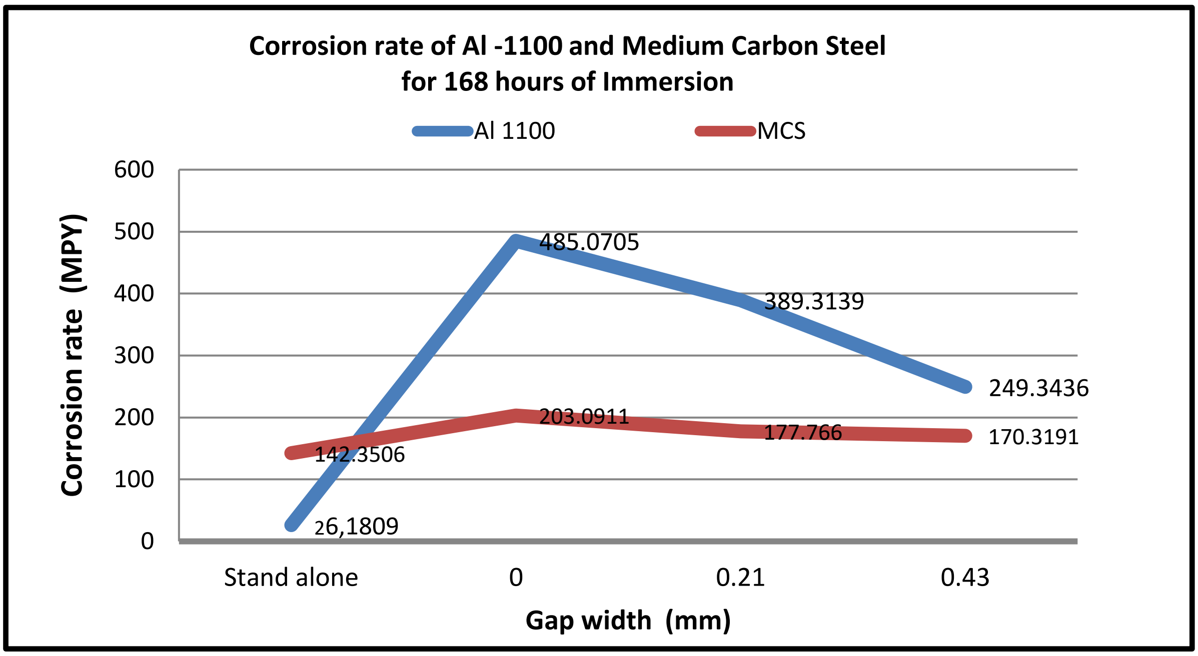
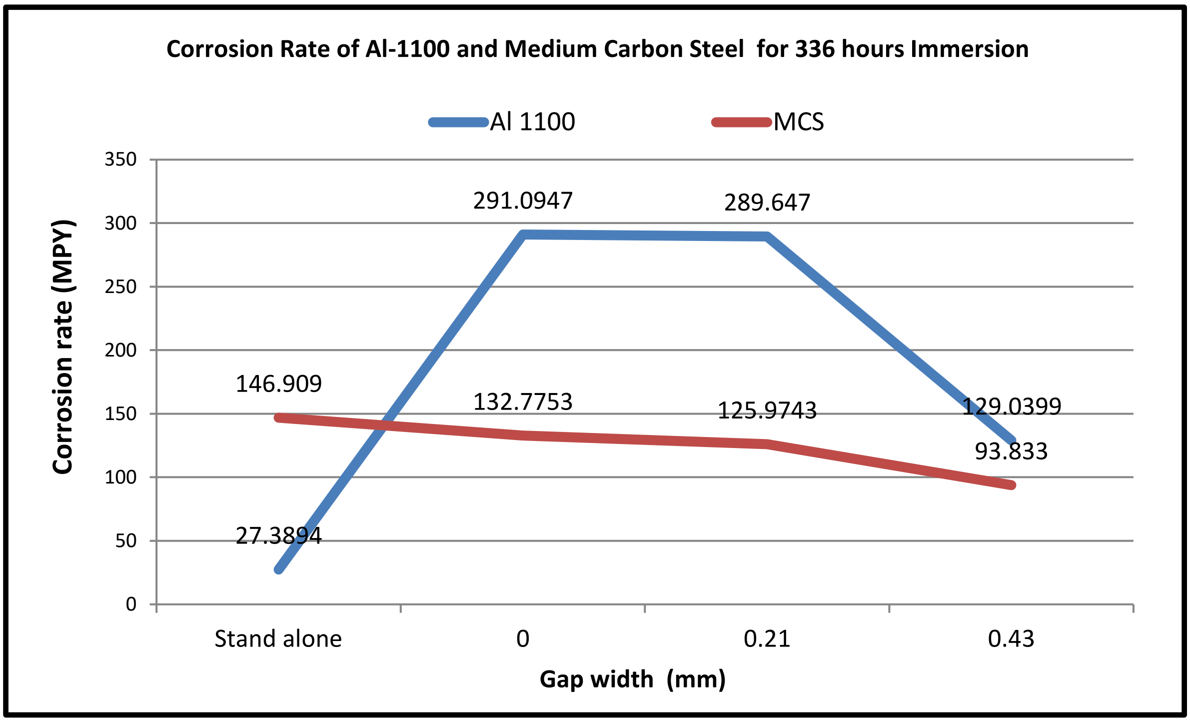
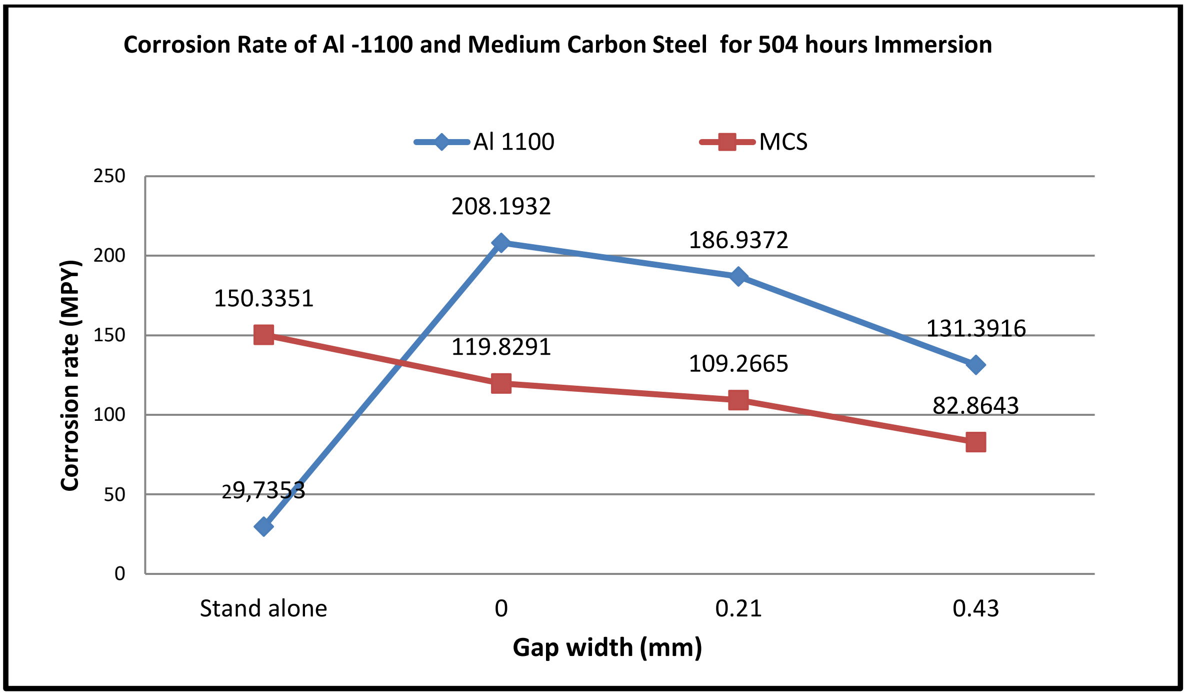


Figure 3. Corrosion rate of Al-1100 and Medium Carbon Steel immersed in 3% chloride electrolyte.

Meanwhile, when Al-1100 standing alone, the passive layer is firmly protective in 3% chloride electrolyte. The oxidation reaction on Al-1100 constantly low. The total weight loss is only 0,1157 gram or 26,1809 MPY for 168 hours immersion. The data clearly indicating that the Al-1100 passive layer is stable and keep protective during the immersion. We can also saw it from the weight loss at three different immersion span of time. The weight loss at 168 hours immersion is 0,1157 gram, weight loss at 336 hours immersion is 0,24 gram and at 504 hours immersion is 0,3946 as shown in Figure 3. This phenomenon clearly indicating that the chloride content electrolyte can pass the electric current between both metals surface, consequently it influence the specimen surface potentials. The effect could observed on each specimen corrosion rate at each formation. The more closer the gap distance, the bigger the influence, and vice versa.



(a)



(b)

Figure 4. Corrosion Rate of Al 1100 and Medium Carbon Steel after immersed in 3% chloride electrolyte (a) 336 hours of immesion and (b) 504 hours of immersion

Table 6. Corrosion rate of Medium Carbon Steel and Al-1100 in aquadest with 3% chloride content.

Time (hour)	Specimen formation	Corrosion rate	
		Baja (Mpy)	Aluminium 1100 (Mpy)
168	Stand alone	142,3506	26,1809
	In contact (No gap)	203,0911	485,0705
	0,21 mm gap	177,766	389,3139
	0,43 mm gap	170,3191	249,3436
336	Stand alone	146,909	27,3894
	In contact (No gap)	132,7753	291,0947
	0,21 mm gap	125,9743	289,647
	0,43 mm gap	93,833	129,0399
504	Stand alone	150,3348	29,7353
	In contact (No gap)	119,8291	208,1932
	0,21 mm gap	109,2665	186, 9372
	0,43 mm gap	82,8643	131,3916

A slight increment of corrosion rate of Al-1100 and Medium Carbon Steel in 3% HCl contaminated electrolyte reflected from the weight loss data. MCS corrosion rate is calculated as 142,3506 mpy when immersed 168 hours. It became 150,3348 mpy after 504 hours of immersion. Average increment is 0,098733 mpy/hour. A slight increment also happen on Al-1100. Its averagingly about 0.007193 mpy/hour.

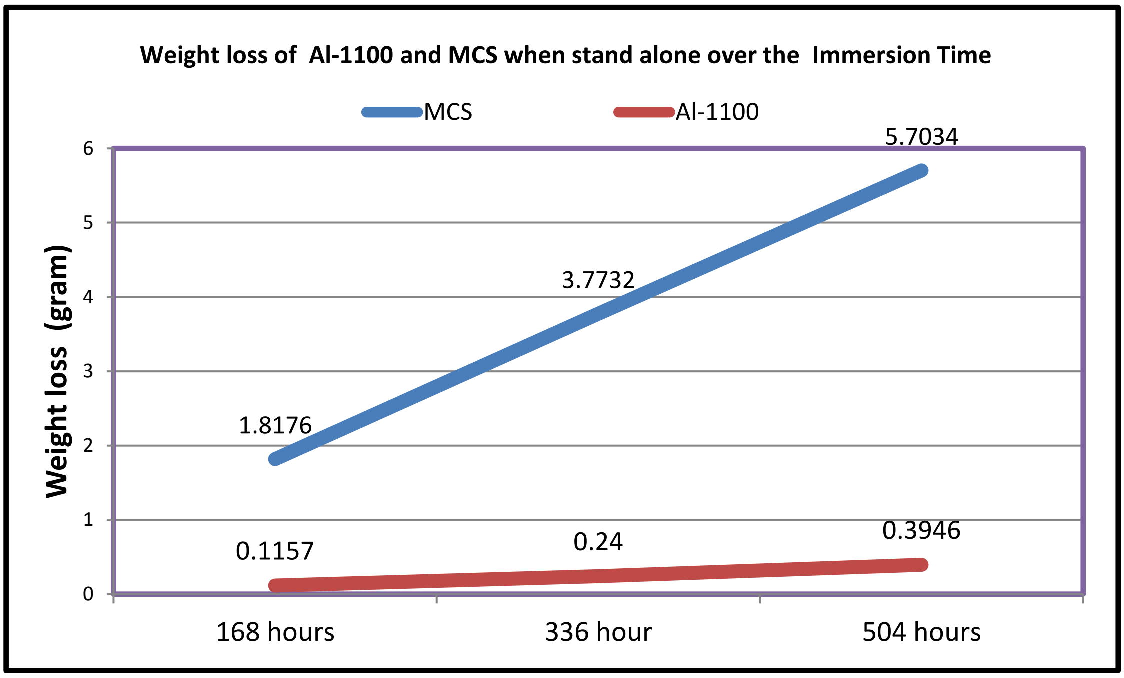


Figure 5. The weight loss of Al-1100 and Medium Carbon Steel when stand alone in electrolyte with 3% chloride.

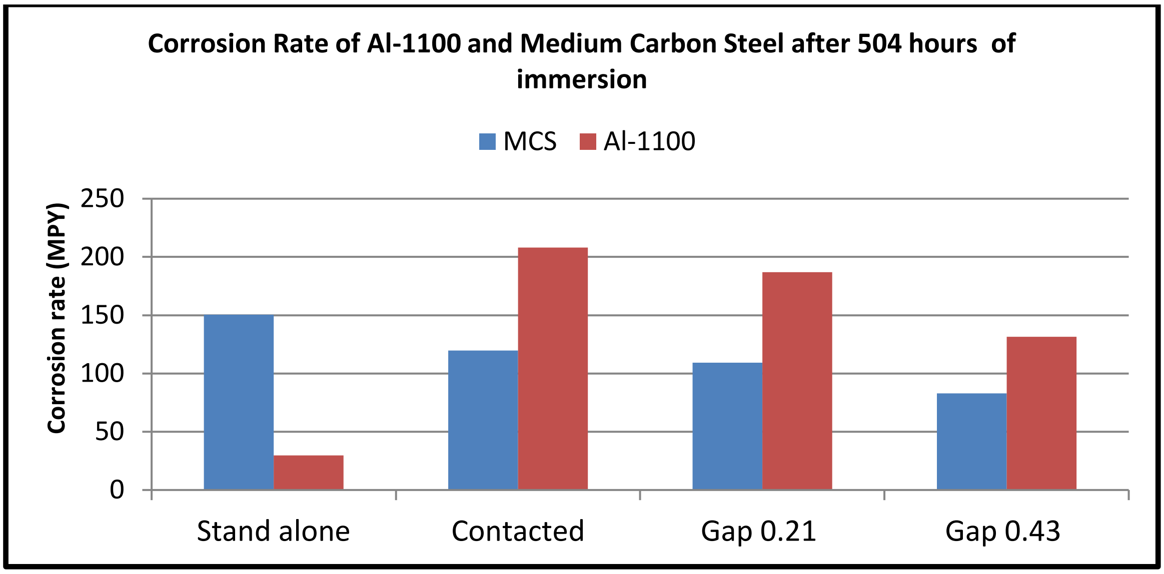


Figure 6. Average corrosion rate of Al-1100 and Medium Carbon Steel after immersion of 504 hours.

CONCLUSIONS

From the measurements and the experiments results, we can draw some conclusions:

a. Al-1100 passive layer tend to protective in aquadest with 3% HCl contamination, even an increment in corrosion rate is observed as big as 0,007193 mpy/ hour.
b. Medium Carbon Steel tend to continously corroded in aquadest with 3% HCl contamination where an increment of corrosion rate is observed as big as 0,0987333 mpy/hour.
c. The direct contact of Al-1100 to Medium Carbon Steel in chloride environment tend to harm steel, where the corrosion rate of steel increase as big as 2,731485 mpy/hour.
d. The interface potential of Al-1100 and Medium Carbon steel tend to polarized by the inter influencing between each other. In this case the steel material tend to harmed.
e. Gap width between Al-1100 and Medium Carbon Steel influencing each other, where the more the gap width, the lesser the effect.
f. Al-1100 is susceptible to corrosion attack when direct contacted to steel.

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