



Effect Of Titanium On Corrosion Behavior Of Aluminum Alloy 3104 As a Candidate Material For Radiator Combustion Engines

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ARTICLE INFO

Received 30/03/2021
revision 23/04/2021
accepted 27/05/2021
Available online 29/05/2021

ABSTRACT

Aluminum Alloy 3104 is aluminum usually used for beverage can. By modifying the content of Titanium content in the alloy, it is expected that this material will be suitable for radiator engine combustion. Especially for its corrosion behavior in coolant solution. Aluminum alloy with different content of Titanium was investigated on its crystal structure, morphology and its corrosion behavior in ethylene glycol solution which is usually used as additive in coolant water. X-ray diffractometer, Electron microscope and potentiodynamic were used to investigate the crystal structure, morphology and corrosion behavior respectively. The results show (002) crystal plane dominate the surface of the sample as the Titanium increase. The (111) and (002) crystal plane are very low compare to (022) crystal plane. Crystallite size and micro strain are affected by addition of Titanium. Surface morphology are clearly affected by the addition of Titanium. Addition of Titanium causes corrosion behavior of the samples. It concludes that the aluminum alloy with different Titanium content in this research, can be used for making radiator combustion engine.

Keywords: Aluminum alloy, ethylene glycol, Corrosion, Titanium.

1. INTRODUCTION

Aluminum alloy 3303 is usually used as a radiator in cooling systems of internal combustion engines. This application is due to its high thermal conductivity, good corrosion resistance, lightness and other interesting properties [1].

The combustion engines produce considerable amount of heat and it needed to be removed through radiator [2]. The radiator usually use water as a coolant, which can pass through the cooling system circuit easily and remove the heat from the engine. During operation, aluminum radiators tubes can see reduced life span due to galvanic corrosion. This type of corrosion occurs when this metal is combined with other metals especially in a heating system. The aluminum will be corroded due to its more anodic. In cold seasons, the water in radiator usually is mixed with ethylene

glycol (C₂H₆O₂) to prevent from freezing [2,3]. Beside, ethylene glycol mixture with water as a coolant can also causes corrosion during the use of coolant [4,5]. At the functional temperature of combustion engine, where the coolant temperature is nearly the boiling point of water the Aluminum corrosion is aggravated [6].

Therefore, it is necessary to find method how to protect the aluminum against corrosion [7,8]. Addition of inhibitor in the solution or alloying element in the Aluminum are the common method used by researcher. Addition of corrosion inhibitors along with the ethylene glycol-water mixture is a common method and effective to prevent aluminum from corrosion [9].

Many researches have conducted using inhibitor so far to protect aluminum alloys in various environments and conditions [10–15]. Liu and

Cheng investigated the corrosion behavior of aluminum alloy used in automotive cooling system with various ions in water-ethylene glycol solution [16].

Aluminum alloy 3104 is usually used as beverage can [17]. This alloy have similar properties with Aluminum alloy 3303 which is usually used as a radiator engine [18]. In this research, the raw materials of aluminum 3104 with various Titanium content will be investigated, whether this alloy is suitable or not to be applied as a radiator engine material [19,20]. The potentiodynamic polarization method was used for corrosion investigation of Aluminum 3104 with various Ti content.

2. METHODOLOGY

Aluminum alloy 3104 were obtained from the fabricant on demand. The Titanium content was varied, 0.00, 0.011, 0.013 wt%. Table 1 show the composition Aluminum alloy.

Table 1. Composition of Aluminium alloy 3104

Element	Composition (wt%)	Element	Composition (wt%)
Si	0.13	Cr	0.031
Fe	0.42	Ni	0.016
Cu	0.21	Pb	0.002
Mn	1.00	Sn	0.001
Mg	1.12	V	0.011
Zn	<0.0001	Cd	0.001
Ti	0;0.011; 0.013	Al	balance

Samples with Titanium content 0.00 wt%, 0.011wt% and 0.013wt% were designated as AlTi00, AlTi011 and AlTi013 respectively. The content of Ti was taken according to industrial advice. This research was conducted in conjunction with beverage can industry.

Determination of Crystal structure, and its parameter were carried out using X-ray diffractometer. The radiation Copper $K\alpha = 1.5404$ Angstrom was used. The XRD patterns were analyzed using HighScore Plus software. Rietveld refinement were performed on these patterns. The ICSD was used to for identification of the phase. The structure parameter, crystallite size, and microstrain were obtained.

Scanning Electron Microscope JEOL 5310 were used to investigate the morphology of the samples. Potensiodynamic Digiviv 2310 was used to investigated the corrosion behavior of the samples. The Potensiodynamics cell have three electrode, Platinum as counter electrode, Reference electrode Ag/AgCl and the samples as working electrode. The voltage was scan with scan rate 20 mV/s.

3. RESULTS AND DISCUSSION

3.1 X ray diffraction

X-ray diffractometer (XRD) were used to investigate the crystallographic parameter.

Figure 1 show the XRD pattern of the samples. It show that (002) plane peaks increase as the Titanium content increase. The surface of the alloy mostly dominated by (002) plane.

After analyzing the XRD pattern with HighScore Plus software, the crystal parameter was obtained. Table 2 show the crystal parameter, crystallite size and micro strain. From Figure 1, it shows that increasing Titanium content in Aluminum alloy shift the diffraction pattern to the left. It means that the distance crystal plane increase and it led to increase in crystal parameter. The crystallite size is also increase.

The XRD patterns of the Aluminum alloy are all have the similar crystal structure (Face Centered Cubic) and similar Space group Fm-3 m. The small different among them are usually the crystal parameter, the crystallite size and probably the second phase. The ICSD 98-060-6006 data base was used as first data during rietveld refinement.

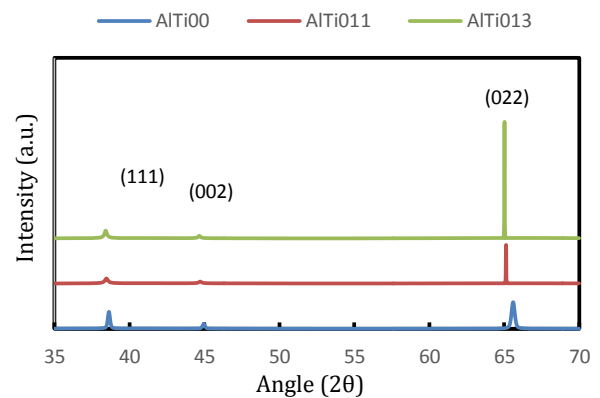


Figure 1. XRD pattern of the Aluminum alloy with d Titanium content: AlTi00, AlTi011, and AlTi013

Table 2. Crystal parameter of the samples

Crystal Parameter	AlTi00	AlTi011	AlTi013
Lattice constant(A)	4.0099	4.0470	4.0534
Space group	F-m-3m	F m-3m	F-m-3m
Crystallite size (nm)	40	1117	1123
Micro Strain (%)	0.27	0.71	0.31
GOF	1.1	1.3	1.5

3.2 Morphology

Morphology of all the samples was observed by using scanning electron microscope (SEM) as we

seen in figure 2. It is seen that Titanium content in Aluminium alloy have affect the morphology of the samples. Increasing the Ti content increase the number of second phase or precipitate. The number of precipitates will influence the draw ability.

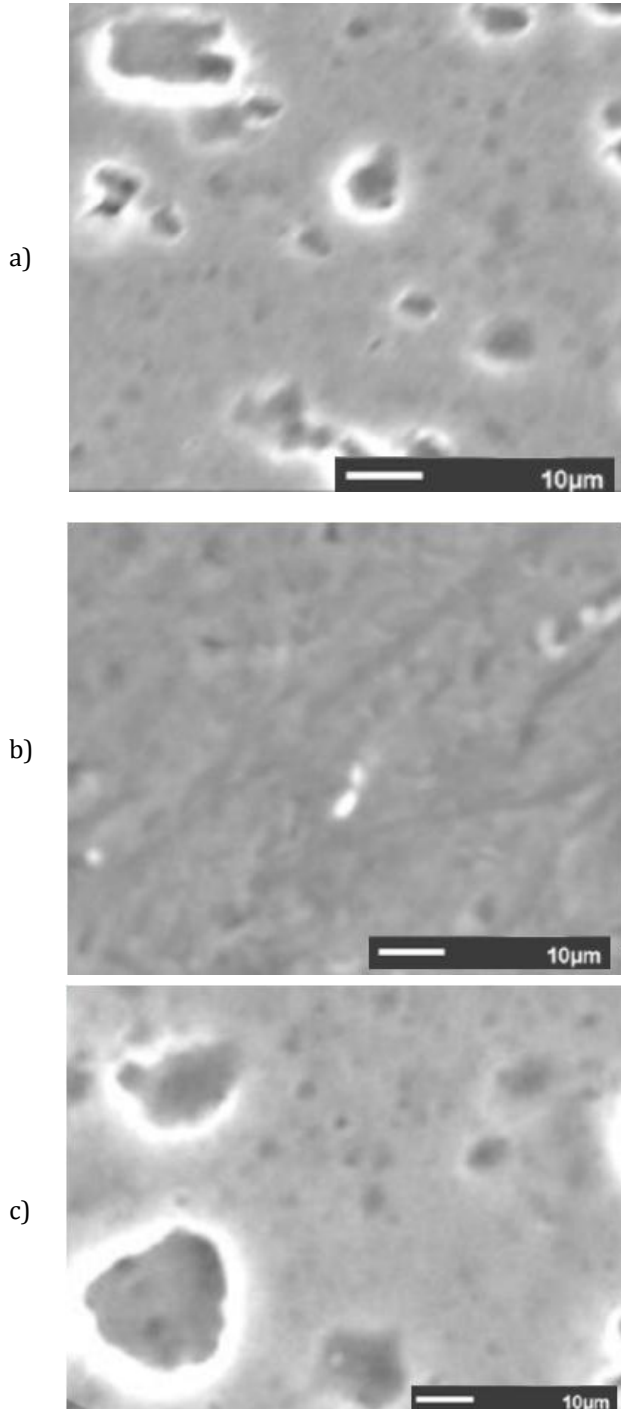


Figure 2. Morphology of the Aluminum alloy with different Titanium content, a) AlTi00, b). AlTi011, and c). AlTi013

From table 2, it is seen that increasing the titanium content causes the increase of crystallite

size. The highest micro strain is seen on the sample AlTi011.

3.3 Potensiodynamic

Potensiodynamic was used to investigate the corrosion behaviour of the Aluminum alloy with different titanium content. Figure 3 show the Tafel plot of the three samples which have different Titanium content. The horizontal axis and vertical axis of the Tafel plot are voltage (volt) and logarithmic of Current density (A/cm^2).

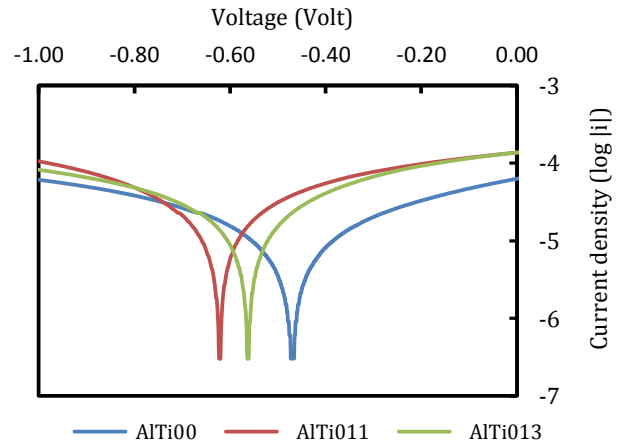


Figure 3. Tafel Plot Current density (A/cm^2) versus voltage (Volt) of the samples with different Titanium content: AlTi00, AlTi011, and AlTi013.

Table 3. Corrosion data obtain from potentiodynamic analysis of the samples

Result	AlTi00	AlTi011	AlTi013
E_{ox} (Volt)	-0,469	-0,622	-0,562
I_{ox} (Ampere ($\times 10^{-6}$))	2,95	6,92	6,15
R_{ox} (Ohm ($\times 10^3$))	8,68	3,71	4,17
Corr rate (10^{-2} .mmpy)	2,28	5.35	4.75

4. DISCUSSIONS

The results show that addition of the Titanium affect the properties of the samples. The X ray diffractometer pattern show strongly influence of crystal parameter, crystallite size micro strain due to the presence of the Titanium. Morphology shows totally different between the samples. So, it is clear that corrosion behavior affected by crystal parameter, crystal plane orientation. Crystal orientation determine the rate of the corrosion. Each crystal plane has its own surface energy.

The lowest surface energy among the three peaks is (111) plane. So Due increase in peak height of (022) crystal plane, causes the increase in corrosion rate. The morphology influences the corrosion rate. If the number of in homogeneity

increase, it seems that the corrosion rate increase. Electrochemical corrosion appears when there is oxidation potential different between one part and other part. If we look the results of the corrosion rate, the value is almost all very small. So, we may consider that this alloy might be used as a radiator combustion engine. We cannot compare our result with other researcher since the publication concerning the corrosion rate of the same samples are rare.

4. CONCLUSION

The alloying Titanium in aluminum alloy 3104 have affect the corrosion rate. The order of the corrosion rate of the three samples are still classified in "very good" corrosion resistance. The corrosion current change while the corrosion potential shift to the higher potential. Addition of Titanium in the 3104 aluminum alloy do not show the change on crystal structure. But the crystal parameter shifts a little bit.

We conclude that the aluminum alloy with different Titanium content in this research, can be used for making radiator combustion engine.

ACKNOWLEDGEMENT

The authors acknowledge with gratitude the financial support from the Ministry of Research, Technology, and Higher Education of Indonesia (RISTEK-DIKTI), under the grant Hibah Penelitian Disertasi Doktor No. NKB-1826/UN2.R3.1/HKP.05.00/2019.

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