Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id>

[IJRER] Editor Decision

2 messages

Prof. Dr. ILHAMI COLAK <ijrereditor@gmail.com> 9 December 2016 at 21:35
Reply-To: "Prof. Dr. Ilhami COLAK" <ijrereditor@gmail.com>
To: Adi Susanto <adisusanto@untirta.ac.id>

Dear Adi Susanto:

We have reached a decision regarding your submission to International Journal of Renewable Energy Research (IJRER), "Performance of Zn-Cu and Al-Cu Electrodes in Seawater Battery at Different Distance and Surface Area".

Our decision is to: Revisions are required on your paper. At the end of this email you will find a set of comments from the reviewers.

Please revise the paper in accordance with remarks or give reasonable explanation of ignoring some remark. After doing necessary changes on your paper, please upload it in SEVEN days through the IJRER online system along with a detailed response (a SEPERATE file) in written for the reviewers concerning the performed corrections. Corrections must be provided in OTHER TEXT COLOR in the revised paper.

Note that your revised paper should be in .doc format and should be in accordance with the template for accepted papers. You can download the template from IJRER web page (http://ijrer.org/files/template-2.doc).

Best regards,

Prof. Dr. Ilhami COLAK
Editor in Chief, IJRER
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IJRER is Cited in SCOPUS, EBSCO and WEB of SCIENCE (Thomson Reuters)

Reviewer C:

Is the paper of sufficient originality to warrant publication in the journals?:
Yes

Is the paper clearly and sensibly arranged?:
Yes

Are the analyses and conclusions a logical outcome of the data and discussion?

(If this is not the case, please outline)
:
Yes

Quality and clarity of the writing:
Neutral

Relevance of the topic for renewable energy researches
:
Good

Constructive feedback for the author(s):
1. Page 7: "The shorten distance......efficient process", this has to be explained .
2. The relation between the current and the surface area needs a theoretical justification.
3. In general, for the statement that is based on the experimental results (which are interesting) an analytical explanation should be added using an appropriate mathematical expression.
4. The references should be enriched by other publications, e.g. "Rechargeable Seawater Battery and its Electrochemical Mechanism", ChemPubSoc, Doi: 10.1002/celc.201402344, etc.

:
Accept pending major revisions

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Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id> 10 December 2016 at 05:28
To: "Prof. Dr. Ilhami COLAK" <ijrereditor@gmail.com>

Dear Prof. Dr. Ihami Colak.

Thank you for your email about our manuscript

We will revise based on the comment soon.

Best regards,

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Jl. Raya Jakarta Km. 4 Pakupatan Serang Banten
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[Quoted text hidden]

Performance of Zn-Cu and Al-Cu Electrodes in Seawater Battery at Different Distance and Surface Area

Adi Susanto*‡, Mulyono Sumitro Baskoro**, Sugeng Hari Wisudo***, Mochammad Riyanto****, Fis Purwangka*****

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Abstract- Seawater battery is one of the green electricity sources to fulfil energy need for electrical equipment, especially in the coastal area and fishing activity. The application of this technology is still limited because of the high cost in the electrode production. This study analyzed the performance of Zn-Cu and Al-Cu electrode as cheap material to generate electricity from sea water in the different distance and surface area. The results shown zinc anode produced higher voltage and current than aluminium anode with number of 839 mV and 1.75 mA respectively. Increasing of surface area at the same distance was increase the current output for each material. Distance of electrode was affected to the current density, but it causes fluctuation at the voltage. Application of zinc anode with higher surface area and short distance generate high voltage and current output in the salt water battery.

Keywords: Anode, battery, cathode, electricity, seawater.

1. Introduction

The sustainable energy is one of the key challenges in the modern society and the important part of science and technology development. The performance of sustainable energy technology can be improved to empower the more efficient utilization of renewable electricity sources [1]. Seawater is an important alternative power source to generate low cost and green electricity for several needs. The development of seawater batteries is conducted to enable the efficient and the power full technology of saltwater activated batteries as power sources for underwater instruments including military device and commercial equipment [2,3].

Previous research is shown the high possibility to generate electricity from seawater. Magnesium and zinc alloy in each composition generate current of 50-75 mA with potential of 0.4-0.6 V and suitable enough to be developed as seawater battery [2]. Application of hard carbon and Sn-C nanocomposite electrodes are successfully applied as anode materials in hybrid-seawater fuel cell, generate highly stable cycling performance and reversible capacities exceeding 110 $m.Ah.g^{-1}$ and 300 $m.Ah.g^{-1}$, respectively [1]. The Mg-6%Al-1%Sn alloy obtains the most negative discharge potential of average -1.611 V with an electric current density of 100 mA cm^{-2} [3].

The electrochemical mechanism of a rechargeable seawater battery uses seawater as the cathode material. Sodium is harvested from seawater while charging the battery and the harvested sodium is discharged with oxygen dissolved in the seawater, functioning as oxidants to produce electricity. The seawater showed 4.05 V with Cl_2 evolution during charge and the discharge potential was 2.9 V with O_2 participation into the discharge reaction [4].

Meanwhile, application of seawater battery technology as a commercial product is still limited due to of high cost in the electrode material. The common electrode is produced by combination of several metals such as magnesium, nickel, stannum or lithium which are expensive and restricted. Moreover, the performance of seawater battery to generate electricity is highly affected by the proper combination of electrode.

In this study, we analyzed the performance of zinc and aluminium as anode and copper as cathode to generate electricity in the same salinity of seawater (31 psu). As an anode material, zinc and aluminium are abundant, environmentally friendly and cheap [5]. Copper is a material which is commonly used as cathode in galvanic cell because it has high efficiency and suitable in seawater [6]. Moreover, zinc and aluminium also become inert anode and may generate high output electricity in seawater battery.

2. Materials and Methods

2.1. Experimental set-up

The experiment was conducted on July to August 2016 in Fishing Technology Laboratory, Faculty of Fisheries and Marine Science Bogor Agricultural University, in the set up shows in **Fig. 1.** Four different materials were chosen as electrode. The copper plate used as cathode. The anodes consisted of zinc and aluminium plate respectively. The study used four surfaces area of electrodes (5 cm², 10 cm², 20 cm², 30 cm²) and three distances of electrodes (1.0 cm, 2.0 cm, 3.0 cm). The electrodes were connected with digital multimeter (Sanwa Cd 771) to measure voltage and current from the system.

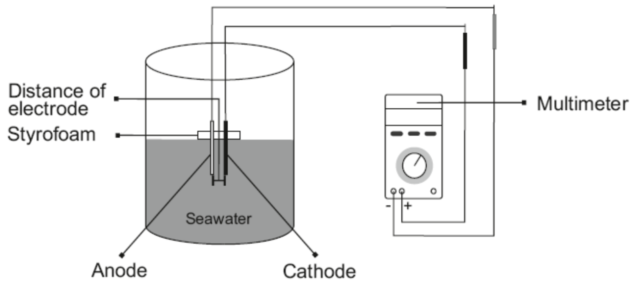

Fig.1. The experimental set-up

2.2. Procedure

In all experiment, seawater was prepared in same salinity (31 psu) of volume 1.0 litre and drop to the experiment tank. One side of all electrodes were layered by cellophane tape. The pair of electrodes put on styrofoam (7.0x8.0) cm at the different distance based on experiment set-up. Furthermore, the electrodes put into the tank and connected with multimeter for one hour to amount voltages and currents in 10 minutes interval [3,7]. Seawater, surface area, and distance of electrode combinations were replaced every one hour after the experiment has finished. All experiment was conducted in 3 times replications to measure the average of current, voltage and current density respectively. The current density was calculated as:

$$\mathit{Current\ density} = \frac{\mathit{Current}\ (mA)}{\mathit{Surface\ area}\ (cm^2)}$$

3. Results and Discussion

3.1. Voltage

The results of average voltage using zinc and aluminium anode is shown in Table 1. There were significant different of output voltage between zinc and aluminium anode for all experiment combinations. Voltage with zinc anode was higher than aluminium anode ($p<0.05$). The highest voltage used zinc anode was found at the distance of 2 cm and surface area of 5 cm² by 839 mV. Meanwhile, aluminium anode has highest voltage at the same distance and surface area by 547 mV.

Increasing of the surface area of zinc anode and aluminium anode was not significantly affected to the voltage output. The farther distance of electrode also caused fluctuation of voltage level. It means the distance and surface area of electrode was not a main factor to generate high voltage from galvanic seawater cell. However, the level of voltage was determined by electrode material [8,9,10], especially at the value of negative standard electrode potential (NSEP). Zinc has a value of NSEP which is more negative than aluminium [10]. Zinc also has an energy density as high as 1,480 $W.h.kg^{-1}$ in primary zinc–air batteries [5]. However, aluminium has an energy density of

400 W.h.kg^{-1} in aluminium-air battery [11]. Application of zinc electrode at seawater galvanic cell has efficient performance and produced 0.5-0.6 V for 150 days [12].

Zinc was suitable enough to be developed as anode in seawater galvanic cell to generate the high voltage level. It was reasonable due to zinc is abundant, environmentally friendly, and cheap [5], compatible with seawater, easy to be obtained and very familiar for the society. Meanwhile, copper is a material which commonly used as cathode in galvanic cell because it has high efficiency and suitable in seawater [6]. Combination of copper cathode and zinc anode would be appropriate pair electrode to generate high voltage in galvanic seawater cell.

3.2. Current

The pair of electrode generates a different current based on material and surface area as presented in Table 2. Zinc anode produced a higher current (mA) than aluminium anode in all experiment combinations. The highest current using zinc anode was found at 30 cm² of surface area and 1 cm of distance as high as 1.75 mA. Moreover, aluminium anode has the highest current (0.72 mA) was reached at surface area of 30 cm² with the distance of 2 and 3 cm.

The changing of the surface area in the same anode material was followed by increase of current output as shown in **Fig. 2.** The high current was reached at the large surface area, especially at the short distance. Current in electrochemical seawater cell is closely related to the effectiveness of electron flow and it is dependent on how good is the electro-catalytic property of the anode [13]. The short distance of electrode can be produce high current because the electron flows between anode and cathode became efficient process. It was related to the number of internal area resistance per cell. The internal resistance increases slowly to an asymptotic value as the flow rate increases, and grows to the largest contribution in distances of electrodes. Small electrode distances give a significant decrease in ohmic resistance and consequently also in the total internal resistance [14]. The closer electrode spacing would reduce the resistance and significantly increase energy efficiency [15]. Increasing of surface area in the short distance will increase the current output to generate electricity based on needs [16,17].

Table 1. Voltage (mV) using zinc anode and aluminium anode at combination of distance and surface area (number in average ± SE)

	Surface area (cm²)			
Distance (cm)	5	10	20	30
	Zinc anode			
1	836.90±0.74	812.10±1.03	832.54±1.54	802.00±1.73
2	839.38±0.86	807.54±1.00	807.31±1.74	821.08±1.32
3	819.76±0.96	812.85±1.66	825.33±1.92	818.51±1.59
	Aluminium anode			
Distance (cm)	5	10	20	30
1	545.08±1.11	521.23±0.73	519.72±6.39	523.54±1.64
2	547.67±4.62	530.38±0.93	531.00±2.74	507.10±2.25
3	539.85±0.84	530.23±1.18	537.97±2.89	525.69±1.58

Table 2. Current (mA) using zinc anode and aluminium anode at combination of distance and surface area (number in average ± SE)

	Surface area (cm²)			
Distance (cm)	5	10	20	30
	Zinc anode			
1	0.28±0.01	0.49±0.07	0.93±0.11	1.75±0.17
2	0.33±0.02	0.61±0.05	1.14±0.11	1.25±0.18
3	0.33±0.02	0.50±0.04	0.91±0.11	1.28±0.14
	Aluminium anode			
Distance (cm)	5	10	20	30
1	0.19±0.02	0.24±0.05	0.58±0.16	0.65±0.13
2	0.22±0.03	0.29±0.05	0.50±0.14	0.72±0.16
3	0.17±0.02	0.20±0.04	0.48±0.13	0.72±0.17

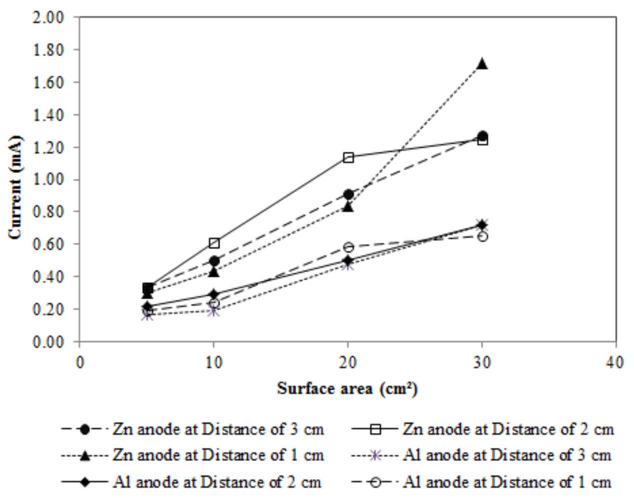

Fig. 2. Current output using zinc and aluminium anode related to surface increased

Positive ions are move from the anode to the cathode through the electrolyte in electrochemical cell during discharge. The ability of a cell to produce a given current depends on the area of the electrode [18]. The anode builds up negative charge and the cathode builds up positive charge, creating the cell voltage V(t). Negative electrons flow through an external load from the anode to the cathode and creating a current in the opposite direction. The sign convention for positive current is in the opposite direction of the. The current of it cell is proportional to the electrode area as an active material. The large area of electrode can accelerate the electrochemical reaction and generate higher current [19]. The larger surface area are deliver more current and also has significant effect to the capacity of electrochemical battery [11,20, 21].

A linier relationship between current (y) and surface area (x) uses zinc and aluminium anode shows in Table 3. There was strong correlation in all electrode combination with the number of correlation coefficient range 0.9630 to 0.9988. Increasing of surface area with the same distance accelerates the higher current at zinc anode than aluminium anode.

Table 3. Linier relationship between surface area and current

Distance (cm)	Linear Equation	Correlation coefficient (r)
Zinc anode		
1	y = 0.0577x - 0.0773	0.9856
2	y = 0.0375x + 0.2240	0.9812
3	y = 0.0383x + 0.1335	0.9995
Aluminium anode		
1	y = 0.0205x + 0.0826	0.9630
2	y = 0.0202x + 0.1041	0.9988
3	y = 0.0233x + 0.0125	0.9896

The current output with aluminium anode was lower than zinc anode. There was related to the property of aluminium which has thermodynamic potential of −1.662V in neutral (saline) electrolytes and −2.31V in alkaline electrolytes that is more positive than zinc [22]. It caused the same electrode combination using aluminium will generate lower current output than zinc anode. Moreover, the increasing surface area produced high current output. The higher surface area of aluminium anode has better performs in aluminium-air battery with the current density 6 mA cm^{-2} [23].

3.3. Current density

Zinc anode has higher current density than aluminium anode in all experiment as shown in **Fig. 3.** The maximum current density reached at distance of 2 cm and surface area 5 cm^2 with the number 0.067 mA cm^{-2} and 0.043 mA cm^{-2} for zinc and aluminium anode respectively. The different distance of electrode caused fluctuation of current density. At the limited surface area, short distance caused fluctuation of current densities wherein 1 cm distance has lowest number. Moreover, increasing of electrode distance at the higher surface area affected to the decreasing of average current densities. It was related to the current distribution at the electrode area. Increasing the surface area of electrode substance generally decrease the current densities because the current would be distributed equally to the surface area [8,24,25].

A long-term test of aluminium anode in different percent of NaCl solution and in seawater showed stationary behavior reached over 400 h. The increasing percent of NaCl and seawater salinity generate high voltage and current density at the same surface area [22]. Zinc and aluminium is a common inert metal which was applied at the commercial battery. The application of inert electrode to generate electricity in the salt water battery will increase energy output and made long life time of cells [26]. The results from this experiment confirmed about the potential application of zinc and aluminium as an anode to develop the high capacity electrochemical seawater battery. Copper is constantly used as cathode material due to large amount and easily available. Moreover, zinc and aluminium have highest output current after magnesium anode [27].

The salt water batteries are suitable for special applications, such as emergency lighting, reserve power, long-lasting silent power for communication equipment and lighting on yachts and other marine objects, lighting for camping [22] and fishing lamp for small scale fisheries. The batteries application in small scale fisheries are still developed through fishing lamp inovation using Light Emitting Diode (LED). LED lamp has a high intensity, however it has low energy consumption [28,29,30]. The combination of LED lamp and salt water batteries are expected to become an efficient and effective technology to develop fishing activity for small scale fisheries.

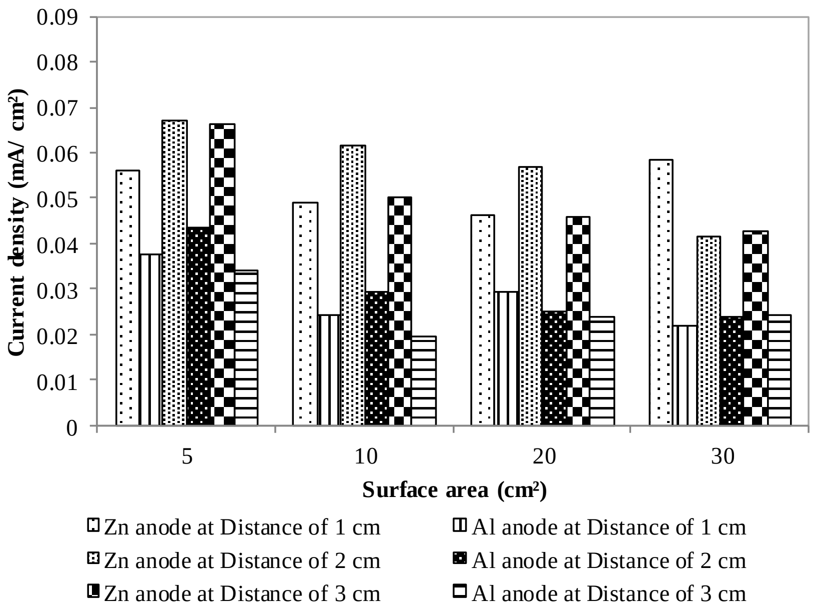

Fig. 3. Current density using zinc and aluminium anode related to surface increased

4. Conclusion

The zinc anode has better performance than aluminium anode to generate voltage and current in seawater battery with the number 839 mV and 1.75 mA respectively. The increasing of surface area at the short distance of electrode is the main aspect to produce high voltage and current using zinc anode.

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[IJRER] Editor Decision

8 messages

Prof. Dr. ILHAMI COLAK <ijrereditor@gmail.com> 15 December 2016 at 18:00
Reply-To: "Assist. Prof. Dr. Mehmet Yesilbudak" <myesilbudak@nevsehir.edu.tr>
To: Adi Susanto <adisusanto@untirta.ac.id>

Dear Adi Susanto:

We have reached a final decision regarding your submission to International Journal of Renewable Energy Research (IJRER), "Performance of Zn-Cu and Al-Cu Electrodes in Seawater Battery at Different Distance and Surface Area".

Our final decision is to: Accept

Thank you for your contribution to IJRER and we hope you will consider submitting an article to IJRER again in the future.

Assist. Prof. Dr. Mehmet Yesilbudak
Nevsehir Haci Bektas Veli University
myesilbudak@nevsehir.edu.tr
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Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id> 15 December 2016 at 18:44
To: "Assist. Prof. Dr. Mehmet Yesilbudak" <myesilbudak@nevsehir.edu.tr>

Dear Prof. Dr. Ilhami Colak

Thank you for the decision.
It is a great news for us.

Can we get the letter of acceptance (LOA) of the manuscript for our administration?

Best regards,

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Jl. Raya Jakarta Km. 4 Pakupatan Serang Banten
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International Journal of Renewable Energy Research-IJRER

#5506 Review

SUMMARY **REVIEW** EDITING

Submission

Authors	Adi Susanto, Mulyono Sumotro Baskoro, Sugeng Hari Wisudo, Mochammad Riyanto, Fis Purwangka
Title	Performance of Zn-Cu and Al-Cu Electrodes in Seawater Battery at Different Distance and Surface Area
Section	Articles
Editor	Ilhami COLAK Mehmet Yesilbudak

Peer Review

Round 1

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Initiated	2016-11-11
Last modified	2017-01-04
Uploaded file	None

Editor Decision

Decision	Accept Submission 2016-12-15
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