A Study of the Effect of Electrode Gap on the Production of Hydrogen from Aluminium/Copper Fuel Cell

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Abstract— In this work, we investigated the effects of electrode gap spacing on the amount of hydrogen produced in Aluminium/Copper Fuel Cell and its efficiency. Aluminium/Copper materials were used as the electrodes because of their high performance in the electrolyser systems while Potassium Hydroxide (KOH) was used as electrolyte. 10% concentration of potassium hydroxide was used throughout the experiment. The electrode spacing of 5mm and 10mm were used. It was observed from the graph that 5mm electrode spacing produced maximum efficiency of 29.7% and 10mm electrode spacing produced 17.7% efficiency. This implied that hydrogen production was highly dependent on electrode gap distance. The smaller the gap between the pair of electrodes, the more hydrogen was produced and the more efficient is the system.

Index Terms— Hydrogen Fuel Cell, Electrolyser, Gap distance and Efficiency.

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I. INTRODUCTION

The quest to save our environment from the monster called climate change has called for research into alternative energy sources that are environmental friendly. The use of fossil fuel products have continuously contributed to air pollution, global warming and other environmental hazards. Pollutants from combustion of hydrocarbons now cause more health problems (National Oceanic & Atmospheric Administration (NOAA), 2017). Today, there is urgent need to develop alternative fuels/energy sources. Among various alternatives, hydrogen fuel offers the highest potential benefits in terms of diversified supply and reduced emissions of pollutants and greenhouse gases (Gupta B., 2009). It can be used in fuel cells to generate electricity, with water as the only by product. Major current applications of the commercially produced hydrogen are in oil refining, where hydrogen is used in hydro-treating of crude oil as part of the refining process to improve the hydrogen to carbon ratio of the fuel, in food production for hydrogenation, in treating metals, in producing ammonia for fertilizer and

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other industrial uses (Lipman T., 2011). Hydrogen can be produced using a variety of certain materials, derived from both renewable and non-renewable sources. Example of those sources are coal gasification, natural gas reforming, and nuclear-powered water electrolysis but the production of hydrogen from renewable energy sources has strong sustainability advantages because of low net greenhouse emissions, the long-term availability and security of supply.

Literature has shown that different studies related to the topic have been carried out by many researchers. Most researchers studied the current – voltage relationship for solar hydrogen fuel system, effects of concentration, effect of the electrolyser, electrode materials used, as well as efficiency and power of the system. In this work; we developed a solar-hydrogen generator that has increased performance because we varied the electrode gap using water electrolysis. In this approach, we used aluminium/copper electrodes for the electrolyser in order to achieve the above aim.

II. MATERIALS AND METHODOLOGY

The materials used in this work are; Solar panel, Electrolyser, Aluminium and Copper, Potassium Hydroxide Solution (KOH), Gas drier, Gas Storage Tank, Digital Multi-meter, Gas flow meter and Variable resist.

III. RESULTS AND DISCUSSIONS

The measured results for the V-I characteristics and flow rate are presented in Figures below.

Due to the different levels of solar irradiation, the applied power was not the same at each time interval and hence our curves discussed the following parameters:

Electrolyser Power with respect to time

Hydrogen & oxygen flow rates with respect to time

Electrolyser efficiency with respect to time

Voltage & Current with respect to time

Electrolyser efficiency was determined using the relation;

$$\eta = \frac{Vol_{H_2} \times 28600\,(J/mol)/24000\,(cm^3/mol)}{V \times I \times time}$$

Nikolic m.et al.(2010)   4.1
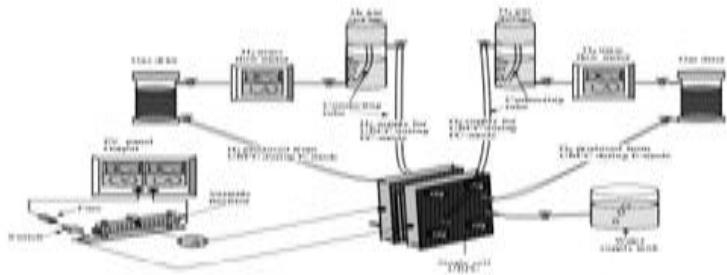
While Power (P) = I x V

Fig. 1 Schematic of the experimental apparatus used to produce Solar-Hydrogen Fuel Cell, (Nikolic M. et.-al., (2010)

Table 1 Data from con. %=10%, δ = 10 mm

Table 1: Result of the experiment using 10% concentration of the electrolyte at 10 mm electrode diameter.

| Time (hr)	Voltage (V)	Current (A)	Power (W)	H$_2$ (Liter/hr)	O$_2$(Liter/hr)	Efficiency %
8am	9.1668	4.9875	45.8292	2.7778	1.3889	12.066363
08:30	10.0834	5.4986	55.4586	3.0525	1.5263	12.2422754
9am	11.0001	5.9985	65.9841	3.3333	1.6667	16.7219683
09:30	11.5797	6.4965	75.2275	3.5015	1.7507	15.4008103
10am	12.1593	6.9945	85.0424	3.6667	1.8335	14.2712634
10:30	13.0544	7.6556	99.9362	4.0515	2.0257	13.4148083
11am	13.9487	8.3167	116.075	4.4333	2.2167	12.6501199
11:30	12.2215	7.2941	89.1483	3.7167	1.8584	13.8010959
12pm	10.4943	6.2714	65.8953	3.0001	1.5005	15.0893331
12:30	11.1459	7.1115	79.2668	3.1065	1.5533	12.9487749
1pm	11.7975	7.9508	93.7995	3.2012	1.6006	11.2970301
01:30	10.61223	7.0366	74.6963	2.9395	1.4697	13.0018686
2pm	9.4333	6.1223	57.7534	2.6667	1.3335	15.2843931
02:30	8.4463	5.0233	42.4282	2.0151	1.0076	16.3838501
3pm	7.4593	3.9243	29.2725	1.5333	0.7667	17.3388046
03:30	7.4593	3.4883	25.4454	1.3695	0.6848	17.7305766
4pm	7.1297	3.0522	21.7612	1.1926	0.5963	14.141068
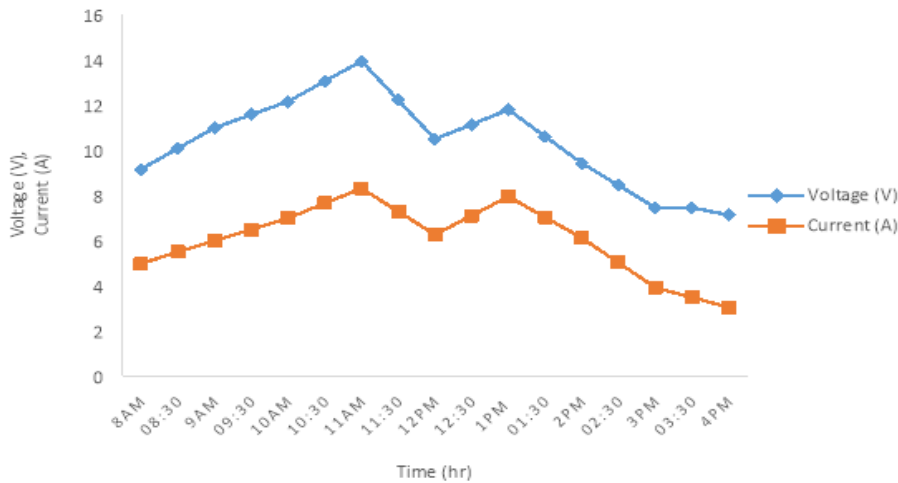
Fig. 2: Voltage and current distribution for δ =10mm and 10% concentration.

Figure 2: shows current-voltage characteristics for 10% electrolyte concentration at electode distance of 10mm. the graph shows a uniform variation of current and voltage. From 8:00 am to 11:00 am, steady increment was observed with voltage value of 9V to 14.1V respectively, while the current increased from 5A to 8.2A within the time stated above. There was simulteneous fluctuation untill a voltage of 7.9V and current of 3.2A were obtained at 4:00am respectively. The peak current and voltage was observed at 11:00am. The day was partly cloudy as could be understood from the figure. The continuous decrement on current – voltage characteristics between 11.00am and 4:00pm was as a result of the sun been covered by cloud, the low solar radiance decreased the current generation of the array dramatically.
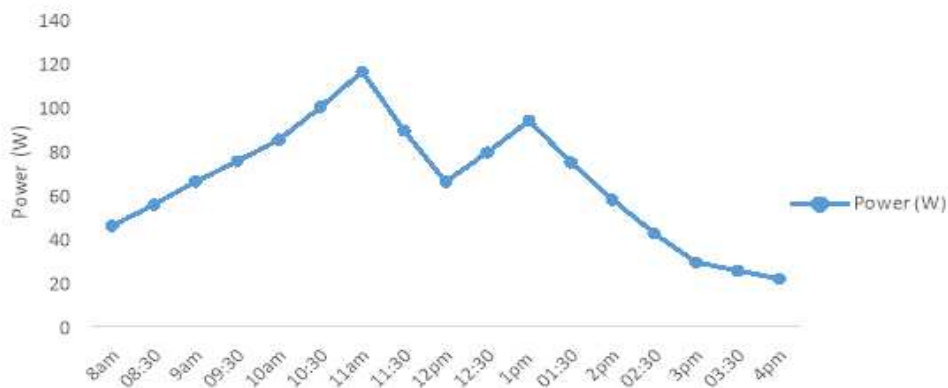

Fig. 3: Electrolyser Power for δ =10mm and10% concentration

Figure 3 shows the electrolyser power variation with time for 10mm electrode spacing and 10% electrolyte concentration. The figure showed that the maximum power required to produce hydrogen from solar energy using solar energy was 99.9W and this was observed at 11:00am. Also, the minimum power for the hydrogen gas production was 21.8W observed at 4:00pm.
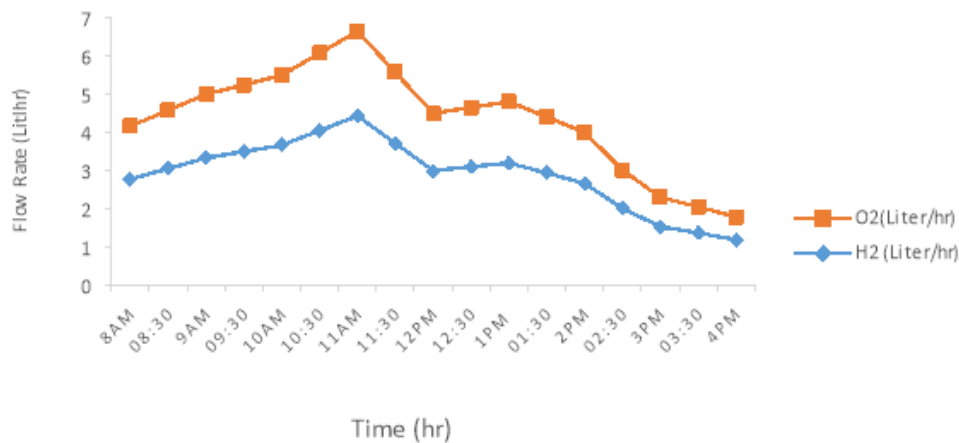
Fig. 4: H₂, O₂ flow rates for δ =10mm and 10% concentration.

Figure 4 is the hydrogen – oxygen flow rate at 10mm electrode spacing and 10% electrolyte concentration. Here, the highest flow rate of 3.64 Litr/hr was observed at 11:00 am. A decrease was observed from 11:30 am until 1.56 Litr/hr was obtained at 4:00 pm.
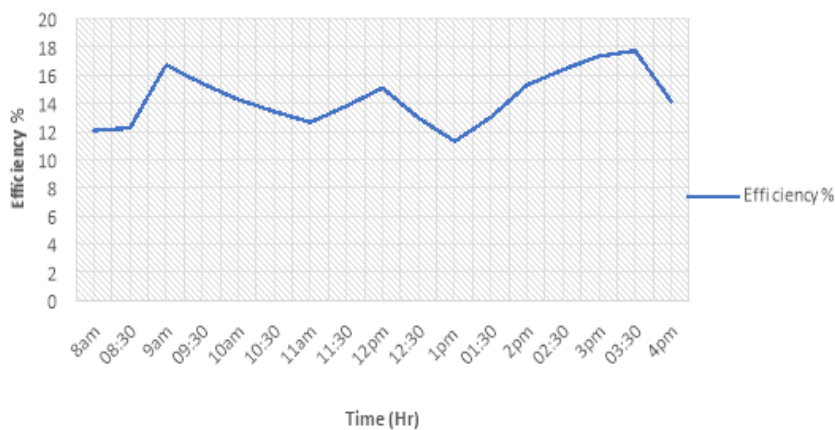

Fig. 5: Electrolyser efficiency for δ =10mm and 10% concentration.

Figure 5 shows the electrolyser efficiency for 10mm electrode spacing at 10% concentration of electrolyte. There was a constant efficiency of 12% from 8:00 am to 8:30 am after which increment on efficiency was observed from 8:30 am to 9:00 am. There was a sharp decrease in the electrolyser efficiency from 9:00 am to 11:00 am. The highest efficiency of the system was observed at 3:30 am with the value of 17.7% which is lower when compared with the system that contained 5 mm electrode spacing and 10% electrolyte concentration which is much higher.

IV. EXPERIMENTAL RESULTS

Table 2 Data from con. %=10%, δ = 5 [mm]

Time (hr)	Voltage (V)	Current (A)	Power (W)	H₂ (Liter/hr)	O₂ (Liter/hr)	Efficiency %
8am	11.8081	5.2012	61.41629	1.9853	0.99265	10.700273
08:30	12.3333	5.3652	66.170621	2.1235	1.06175	10.6228083
9am	12.7535	5.3535	68.275862	2.2667	1.13335	10.9895306
09:30	13.4403	6.2013	83.347332	2.8335	1.41675	11.2534012
10am	14.0806	6.8726	96.770332	3.4425	1.72125	11.7756262
10:30	14.4053	7.1753	103.36235	3.3332	1.6666	10.6745922
11am	14.7333	7.8708	115.96286	3.0253	1.51265	8.63578515
11:30	14.6404	7.9869	116.93141	3.6403	1.82015	10.305244
12pm	14.5535	8.0958	117.82223	3.6016	1.8008	10.1186028
12:30	11.9251	7.0229	83.748785	2.7633	1.38165	10.921991

1pm	9.3323	5.9015	55.074568	1.8666	0.9333	11.2189561
01:30	8.5019	4.8121	40.911993	1.8333	0.91665	14.8332116
2pm	7.7038	3.6467	28.093447	1.8353	0.91765	21.6249105
02:30	6.4919	2.8355	18.407782	1.6565	0.82825	29.7880626
3pm	5.28308	4.0125	19.619519	1.5012	0.7506	28.7935502
03:30	9.2755	3.9255	36.410975	1.8675	0.93375	16.9777678
4pm	13.275	5.8535	77.705213	2.2275	1.11375	9.48898698

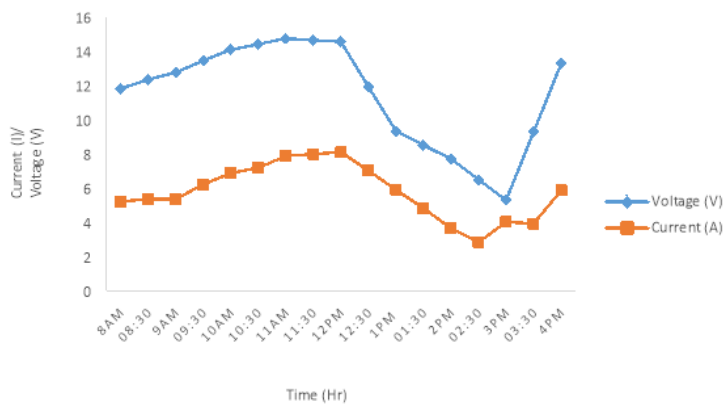Table 1.2 above, shows the data obtained from electrolyte concentration at 10% with diameter of 5mm.

Fig. .6: voltage and current distribution (I-V Characteristics) of the electrolyser for δ =5mm and 10%concentration

The purpose of drawing the I-V characteristics of the electrolyser was to determine the operating voltage and corresponding current at which hydrogen production commenced. Below this voltage, there was insufficient energy to cause water molecules to dissociate. The input I-V characteristics (response) of the electrolyser in figure 1.6 was obtained by adjusting the power source. The input currents were defined at different applied voltages (0 – 14.73 V). The current only began to flow at a certain voltage of about 3 Volts and then fluctuated. The maximum current flow was observed at 12:00 am with the value of approximately 8.1 Amp, while the Peak voltage was observed at 11:00 am with the value of approximately 14.7 Volts.
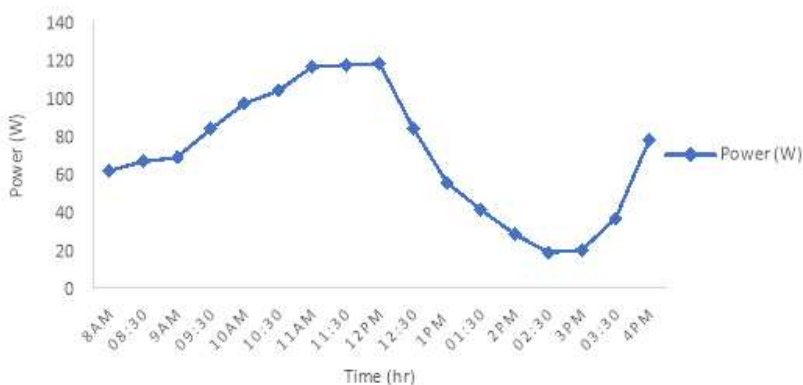

Fig. 7: Electrolyser Power distribution for δ =5mm and 10%concentration.

Fig. 7 shows the power required by the electrolyser to produce a certain volume of hydrogen fuel. The minimum power needed to produce hydrogen was 18.4W and this was observed at 2:30 am, while the volume of hydrogen produced was 1.5 Litre/hr. The maximum power attained by the electrolyser during the production of hydrogen fuel was 117.8 W at 12:00 pm.
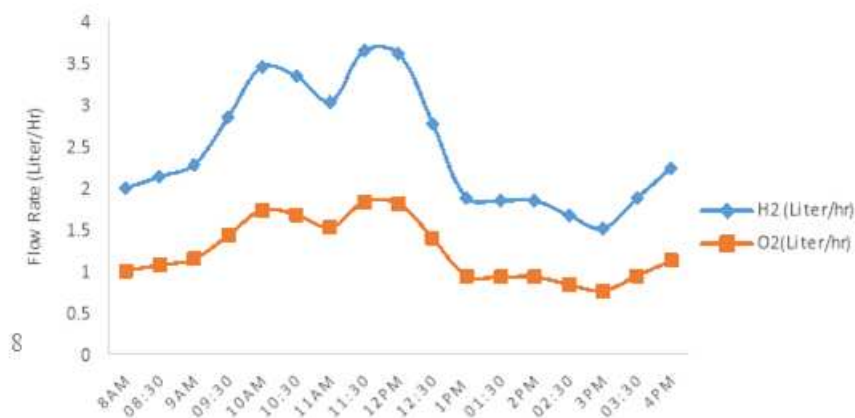
Fig. 8 shows hydrogen and oxygen flow rate variation. The maximum hydrogen flow was observed at 11.30 am with flow rate value of 4.43 Litre/hr. Hydrogen flowed less at 3 pm which may be as a result of cloudy weather.

Fig. 9: Electrolyser efficiency for δ =5mm and 10%concentration.

Figure 9 shows the electrolyser efficiency variation with time. It can be observed from the graph that from 8:00 am the efficiency remained constant with a value 11.1% until 10:00 am when a little improvement was observed. The fluctuation continued till 1:30 am when the efficiency increased to 15%, with continuous increment to 2:30 pm with an efficiency of 30% which is an improvement when compared with Roy L.'s work whose maximum efficiency was 20.5%. A simultaneous decrease was noticed at 3:00 pm with efficiency of 28% and further decrease was observed till 9% efficiency was observed at 4:00 pm. The lowest frequency observed was 8.1% at 11:00 pm.

Table 3: Electrolyser efficiency comparison for δ = (5mm /10%) and (10mm / 10%)

Time (hr)	Efficiency % 5mm, 10%	Efficiency % 10mm, 10%
8am	10.700273	12.066363
8:30	10.6228083	12.2422754
9am	10.9895306	16.7219683
9:30	11.2534012	15.4008103
10am	11.7756262	14.2712634
10:30	10.6745922	13.4148083
11am	8.63578515	12.6501199
11:30	10.305244	13.8010959
12pm	10.1186028	15.0893331
12:30	10.921991	12.9487749
1pm	11.2189561	11.2970301
01:30	14.8332116	13.0018686
2pm	21.6249105	15.2843931
02:30	29.7880626	16.3838501

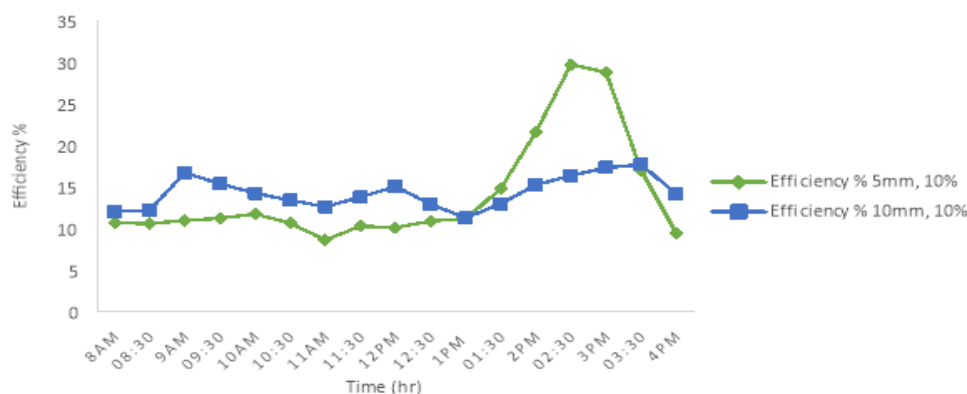| 3pm	28.7935502	17.3388046
03:30	16.9777678	17.7305766
4pm	9.48898698	14.141068

Figure 10 shows the efficiency comparison for the electrolyser when the electrode spacing was 5mm and 10mm respectively. It was observed from the graph that with 5mm electrode spacing, the maximum efficiency achieved was 29.7%, while the maximum efficiency achieved with 10mm electrode spacing was 17.7% which is lower compared to the former. The result has shown that increasing the gap distance between electrodes caused the efficiency to decrease.

CONCLUSION

In table 1, data obtained from 10% concentration of electrolyte against 10 mm electrode gap distance gave us maximum efficiency of 17.7% and it was recorded at 3.30 pm with hydrogen flow rate of 3.36litr/hr with oxygen production of 2.2 litr/hr. Table 2, shows data obtained from 10% concentration of electrolyte against 5 mm electrode gap distance. Here the maximum efficiency achieved was 29.7% for electrolyte concentration of 10% against electrode gap distance of 5 mm with hydrogen flow of 4.43 litr/hr which was recorded at about 2.30 pm. This showed that the minimum electrode gap spacing of 5 mm caused the efficiency to improve with electrolyte concentration of 10% with increased hydrogen production. This implies that increasing the gap distance between electrodes resulted to decreased efficiency.

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