ANODE & ELECTROLYTE DEVELOPEMENT AND SYSTEM INTEGRATION FOR MOLTEN CARBONATE FUEL CELL (MCFC)

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ABSTRACT

In this study, the green sheets of the anode, cathode and electrolyte of the Molten Carbonate Fuel Cells system were prepared by the tape casting technique using the Dr-Blade of slurry solutions whose proportional and percentage composition (active material, Ni, Cr, NiO, binder, matrix-electrolyte, plasticizer and etc.) was optimized. First a single cell Molten Carbonate Fuel Cells system was designed using cylindrical geometry (5-7,5 cm active region diameter) rather than the conventional geometry (square or rectangle). In the second phase of the study, the system was produced using stainless steel and installed. Electricity, temperature, gas and water flow control systems and a power production system was added to the current system and test studies were conducted.

1. INTRODUCTION

The fuel cell technology is an important part of the energy equation to reduce CO_2 emissions and to decrease our carbon footprint in sectors where the contribution to global CO_2 emissions are the highest; by reducing fuel consumption in transportation, by increasing the efficiency in power generation and by simplifying the transition from fossil to renewable fuels on the market [1,2].

The Molten Carbonate Fuel Cells (MCFC) that are constant energy production systems and that have fuel consumption flexibility [3,4,5,6] (H_2, natural gas, reformer gas that include CO_2 up to 20%) work between 600-750 ^oC. A single fuel cell is composed of electrolyte, polymeric electrolyte or ceramic matrix, and permeable-pore type anode and cathode electrodes that are in touch with every surface of it. The MCFC layout is presented in Figure 1. The cell is also made of bipolar plates and diffusion layers that transfer the electrical energy of the cell to the outer circuit and fuel and oxidizing homogenous to the inside. The matrix material of the molten electrolyte must be chemical stability in lithium, potassium and sodium carbonates and no electric conductivity. Lithium alumina is still the favored matrix material for MCFC, but there are some problems to be solved such as expensive, poor mechanical strength of ceramic materials when the cells operated at high temperature and high ionic resistance which is cause lowers fuel cell performance.

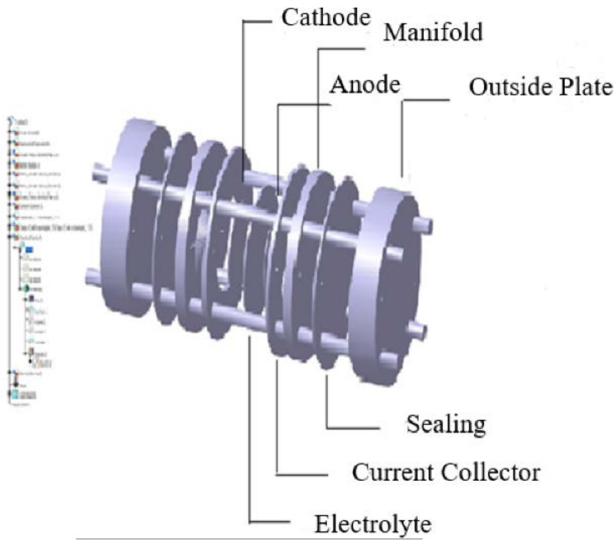

Figure 1 Schematic diagram of MCFC layout with Catia model

Fuel cells operating at elevated temperatures are suitable for medium and large scale applications, thus they have good prospects for commercialization. A fuel cell design is being performed to determine the criteria for considering the following factors; Dimensions for the desired power, weight and volume, cost, operating temperature, humidity, fuel and oxidant pressure, fuel type and storage

In this paper, the testing results of anode, cathode and a composite electrolyte layer based on Lithium/Potassium carbonates for its electrochemical performance as a matrix for MCFC are presented. The voltages and current were collected in a range of temperatures: 650-700^{o}C

2. EXPERIMENTAL INVESTIGATIONS

This study, the green sheets of the anode and cathode of the Molten Carbonate Fuel Cells system were prepared by the tape casting technique using the Dr-Blade of slurry solutions whose proportional and percentage composition (active material, Ni, Cr, NiO, binder, matrix-electrolyte, plasticizer and etc.) was optimized according to Özkan et al [8]

Viscosity of electrode and electrolyte in the system were characterised as pseudo plastic using Herschel–Bulkley model (Equation 1) that allow the sintering and sealing formation.

$$\tau = \tau_0 + k * \gamma^n \qquad (1)$$

Electrode of anode

$$\tau = -44.599 + k^{0.683} \qquad (2)$$

Electrolyte

$$\tau = -20.811 + k^{0.85} \qquad (3)$$

Where τ: shear stress (dyn/cm^2)

τ_0: Initial flow stress (dyn/cm^2)

k: Coefficient of viscosity

γ: Shear rate (s^{-1})

n: Flow behavior index

Sintering processes was performed at 780 ^{o}C .

A single cell MCFC system was designed using cylindrical geometry (5-7,5 cm active region diameter) rather than the conventional geometry (square or rectangle). The shape of the channel affects the flow of water and collect the gas in the cell. The dimensions of the channels was used as 1 mm. A larger scale is seen to varying degrees between 0.1 to 3 mm. This total varies according to the size.

Gas flow plates are not only the performance of the cells is taken into account in the selection of easy manufacturability. Different fuel cell materials such as carbon composites, graphite, aluminium, stainless steel, nickel, titanium is used in materials cylindrical cell system for molten carbonate fuel.

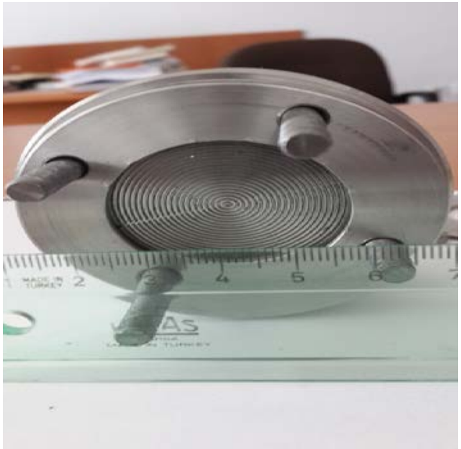

Figure 2. Gas flow plate

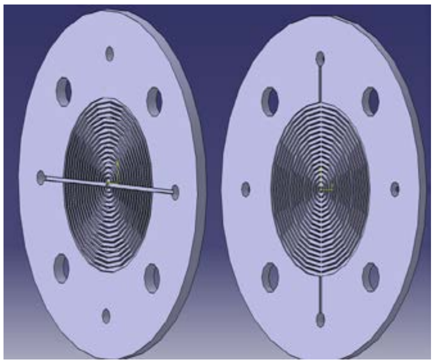

Figure 3. Catia model for the gas flow plate

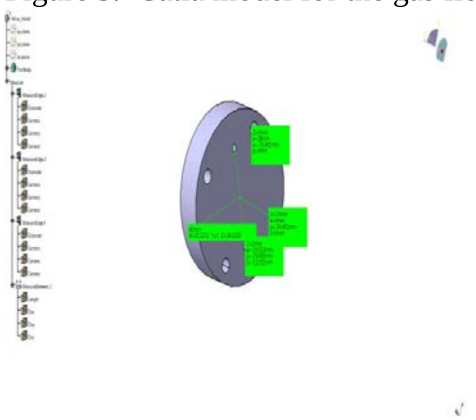

Figure 4.Catia model for the end plate

In this work, gas flow cell plates were used in the production by using stainless steel (SS316). The gas flow channels in the literature smooth, serpentine (curved), parallel, perforated design and interlocking shapes are available. Interlocking circular design that have been done in fuel cells or snail types were used (Figure 2-3).There is some flow configurations to ensure the transfer of the reaction gases to the cylindrical MCFC. It was designed to provide sufficient pressure drop for the cell gas channels. Because they designed in this way produced very thin layer of cells in order to minimize their own weight to avoid breakage. Voltage value in each cell is approximately 0.2 to 0.7 volts. If the increases are connected in series can be used to raise the voltage. In this connection the anode and cathode is formed by connecting multiple cells on a straight line. Electron flow is able to traverse the electrode surface and are collected by the current collectors. In this case, there is no voltage loss.

In this study, design and production of gas flow channels formed on plates in a circular manner by providing gas transportation to the center. The smallest channel wall in the center of the plate is closed and the gas directed toward the exit. When the gas reached the hole on the end plate in the cell, fuel and oxidant gas flow channels through the holes in the same manner on the sealing material and gas can reach to the electrodes. End fuel cell plates that was the top and bottom of the support plate was screwed together (Figure 4). End Plates are used together in a relatively large number of plates and used for holding together. Gas inlet and outlet holes are located on this. Resistant to high compression force, vibration and shock resistance, and high temperature resistance, low cost and mechanical strength are important parameters in the production of these plates.

The cell stack has been created resistant and firmly. Thus, gas leakage can be prevented engagement with the plate surface of the sealing member is provided in a very good way. The electrical connection cable is fixed anode and cathode gas flow plates screwed to the side wall of the drill hole. These cables inside the oven to outside electrical measurements were carried out by using condensation cable.

Gas flow plates, electrodes, fittings, sealing materials in fuel cell was modelled and system design was carried out by using of Catia (computer aided three-dimensional interactive application) software program. It was shown in Figure 1

Sealing Materials is used to provide a gas leak and insulator. Deterioration of the chemical form, strength, uninteract with the fuel gas, vibration and shock resistance, low cost are important functional properties for the sealing material at high temperature.

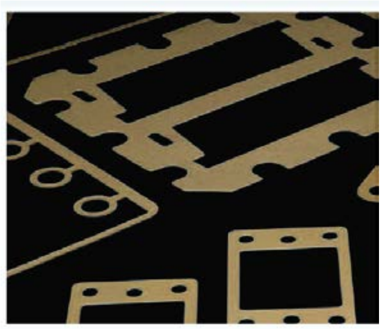

Figure 5.Thermiculite 866 Sealing Material

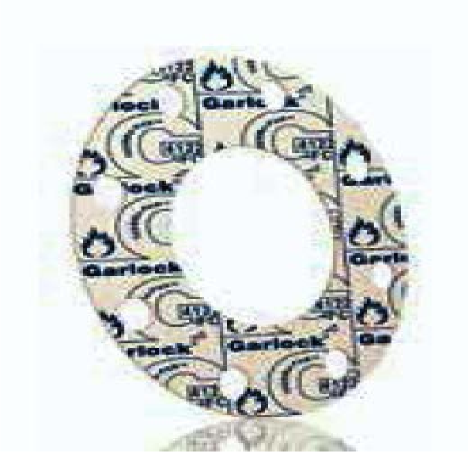

Figure 6 GarlockThermapur Sealing Material

Thermiculite 866/ Flexitallic-England (Figure 5) and Thermapur/ Garlock-Germany (Figure 6) products were used as a high temperature sealing material in this MCFC.

Hence, the system was produced using stainless steel and installed according to Table 1. Electricity, temperature, gas and water flow control systems and a power production system was added to the current system shown in Figure 7 and test studies were conducted.

Figure 7. Molten Carbonate Fuel Cell

Table1. MCFC System Design Parameters

Cell	**Material**	**Thickness (mm)**	**Diameter (mm)**
Fuel	H_2		
Oxidizer	CO_2,Air		
Outlet-Inlet Gas Plate	Stainless Steel SS316	15	70
Anode/ Cathode Plate	Stainless Steel SS316	5	70
Electrolyte	$LiAlO_2$	5	70
Matrix	Li_2CO_3/ K_2CO_3	2	70
Anode	Ni	1,5	38
Cathode	NiO	1,5	38

The temperature of the system was measured using thermocouples. Cell voltages and cell resistance were measured using Solarton Current system. Two series of test were performed at 650 and 700 ^oC.

3. RESULTS AND DISCUSSION

The effect of the hydrogen and air flow rates were evaluated on the voltage difference. The results obtained were compared against flow rate. The influence of hydrogen flow rate at constant air flow rate was shown in Figure 8. The hydrogen flow rate varied in the 21.4 cc/min-37.5 cc/min. Resistance value was measured between 4,11 and 4,61 Ω. Current was 0,02 mA. Variable voltage values (170 mV to 330 mV) were measured the highest flow rate (37,5 cc/ min)of the hydrogen in Figure 8.

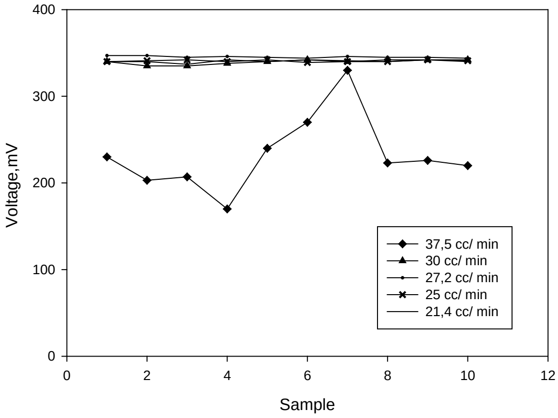

Figure 8. Effects of hydrogen flow rate at 700 ^oC, and 42.8 cc/min air flow rate

N_2 flow rate was 20 cc/ min and CO_2 flow rate was 11 cc/ min. Highest voltage value was measured at the 700 ^oC and 27,2 cc/ min hydrogen flow rate. It was observed that stoichiometric flow rate of the gases was effected the voltage.

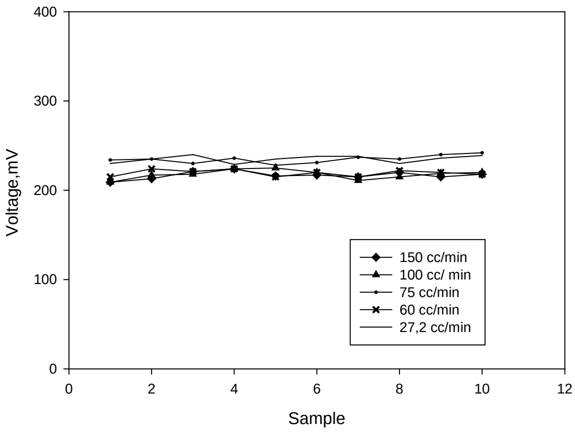

Figure 9. Effects of air flow rates at 700 ^oC and 25 cc/min hydrogen flow rate

The influence of air flow rate at constant hydrogen flow rate was shown in Figure 9. The air flow rate varied in the 27.2.4 cc/min-150 cc/min. Highest voltage value was measured at 700 ^oC with 75 cc/ min air flow rate. Also, 60 cc/ min air and 25 cc/min hydrogen flow rates were optimum stoichiometric flow rate in Figure 9. When the flow rate of the air was increased, voltage value (150 cc/ min) was decreased. Optimum stoichiometric air flow rate has a better performance on the molten carbonate fuel cell.

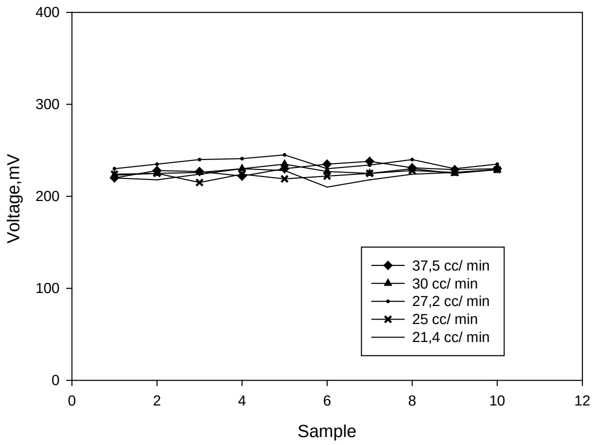

Figure 10. Effects of Hydrogen Flow Rates Diagram at 650 °C and 60 cc/min Air Flow Rate

The influence of hydrogen flow rate at 650 °C was shown in Figure 10. Resistance was 9,8 Ω and current was 0,02 mA. The influence of temperature on MCFC performance was shown in Figure 8 and 10. The temperature varied in the range 650-700 °C. Voltage value was decreased according to the temperature that was decreased from 700 °C to 650 °C. Similar idea was shown in the literature [9]. Highest voltage value was measured at 650 °C with 27,2 cc/ min hydrogen flow rate. Molten Carbonate Fuel Cell has a best performance at 700°C with this optimum gas flow rates .

CONCLUSIONS

The testing results are presented for a single cell MCFC. The voltage- current were collected in the range of temperature 650-700 °C and different hydrogen/air flow rate. According to experimentation, we got some idea as: Ohmic losses must be reduced to a minimum for a better electrical performance of the cell. Therefore, the current path was chosen as short as possible. The contact surface between the components should be sufficient.

So as to ensure the flow of current collectors and the current distribution should be well designed. Gas leaks, transition jump and electrical short circuits was eliminated in the molten carbonate fuel cell. Transition of all components in the fuel and oxidizer in the stack must be uniform. Gas mass transfer in the reaction area must be reached as quickly as possible to minimize losses. Thermal distribution should be homogeny and uniform. Cell design must be able to provide as high temperature gradients. Mechanical structure and installation will occur during operation with sufficient strength for structural adjustment cell stack will be resistant to thermal stress. Optimum stoichiometric flow rate of gases increased performance of the fuel cell. Voltage value was changed according to the temperature of the cell. Optimum operating temperature is 700 °C for molten carbonate fuel cell with high performance.

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