EXPERIMENTAL INVESTIGATION AND FUZZY LOGIC MODELING OF 8X8 CM^2 MEMBRANE PERFORMANCE OF MICROBIAL FUEL CELL

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***Abstract**: In this study, microbial fuel cell's energy conversion performance experimentally investigated from the chemical energy of the organic waste to electrical energy by means of microorganisms. Microbial fuel cell (MFC) consists of two cells which has 15x15x15 cm3 volume. One part of the cell conserves the mud (anode) the other part conserves the water (cathode). The membrane of the microbial fuel cell has 8x8 cm2 area. Two different samples were used in the experiments which are active and settlement mud. The power, volt and current values of the active and settlement mud for different temperature, resistance and bubble were determined. The temperature values consist of ΔT = 8°C, ΔT = 10°C, ΔT = 12°C, ΔT = 14°C. ΔT=Tenvironment- Tmud. For every ΔT value 2 different bubble values were examined (High=21,5 g/h, low=3,5 g/h). For every bubble effect 7 different resistance values were determined (1. Resistance= 3,75 Ω; 2. Resistance =7,5 Ω; 3. Resistance =10,5; 4. Resistance = 14,5 Ω; 5. Resistance = 16 Ω; 6. Resistance = 19 Ω; 7. Resistance = 21,5 Ω) and the performance of the 8x8 cm2 membrane of the MFC is detected. As a result; with the increase of the temperature, resistance and bubble effect the voltage production increases and correspondingly the current decreases. When all the experimental results are evaluated,the highest voltage production (687 mV) occurred at ΔT = 14°C and 21,5 Ω with the high bubble effect in the settlement mud. Also, in this study, MFCs performances in terms of voltage, current, temperature, power was modeled with Rule-Based Mamdani-Type Fuzzy (RBMTF) modeling technique. Input parameters ΔT and time; output parameter power was described by RBMTF if-the rules. 1792 experimental data sets, which obtained for power according to ΔT and time, were used in the training step. The comparison between experimental data and RBMTF is done by using coefficient of multiple determination (R2). The actual values and RBMTF results indicated that RBMTF can be successfully used in MFC.*

KEYWORDS: MICROBIAL, FUEL CELL, FUZZY LOGIC, ACTIVE MUD

1. Introduction

Fuel cells are developed systems which use hydrogen as a fuel to generate electrical energy. During the energy production no combustion or exhaust gases occur because fuel cells combines hydrogen with oxygen into an electrochemical process to produce electric current. Hence one can say fuel cells are environment-friendly [1].

Microbial Fuel cells (MFCs) –one type of FCs- generate bioelectricity using an active microorganism as a biocatalyst in an anaerobic anode compartment. Active biocatalyst in the anode oxidizes the organic substrates and produces electrons and protons than the protonsa re transfered to the cathode chamber which is physically separated by a proton exchange membrane (PEM) from the anode chamber, and the electrons are conveyed through the external circuit. While oxygen reduces the protons and electrons are reacted in the cathode chamber [2].

Scientists have discovered almost a hundred years ago that bacteria can generate electricity. Nonetheless Microbial Fuel Cells that can produce electricity from organic matters from what would otherwise be considered waste, have been discovered as a new form of renewable energy technology. MFCs use energy much more efficiently than standard combustion engines -which are limited by the Carnot Cycle- and MFCs emissions are well below regulations. The new MFCs convert hydrogen to energy 8 times as high as traditional hydrogen production technologies therefore their energy efficiency is far beyond 50% [3].

In this study, experimental investigation was carried out to determine microbial fuel cell membrane performance. Two different samples were used in the experiments which are active and settlement mud. The power, volt and current values of the active and settlement mud for different temperature, resistance and bubble were determined. Also, in this study, Rule-based Mamdani-type fuzzy (RBMTF) modeling used to evaluate performance of MFCs. Performance parameters are power, current, voltage, temperature and bubble effect. In the developed RBMTF system, outlet parameter power was determined using inlet parameters time, temperature and bubble effect. The rules, which are used to detect the behavior of the fuzzy logic controller and the relationship between system's input and output, are determined. As a result of these rules, every value obtained from the experimental study is also determined by fuzzy logic too. Main objective of the study is to present that it is possible to evaluate performance of MFCs by generating a fuzzy logic model.

2. Material and Models

MFCs use bacteria as the catalysts to oxidize organic and inorganic matter for generating current. The electrons are produced by the bacteria and transferred to the anode (negative terminal) and flow to the cathode (positive terminal). These two terminals are linked by a conductive material containing a resistor, or operated under a load (i.e., producing electricity that runs a device) as shown Figure 1 [4].

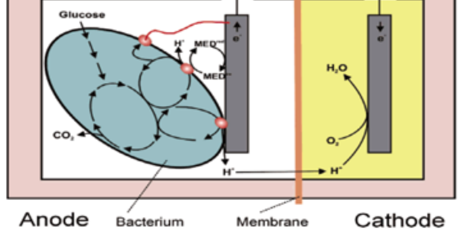


Fig. 1. Operating principles of MFCs [4]

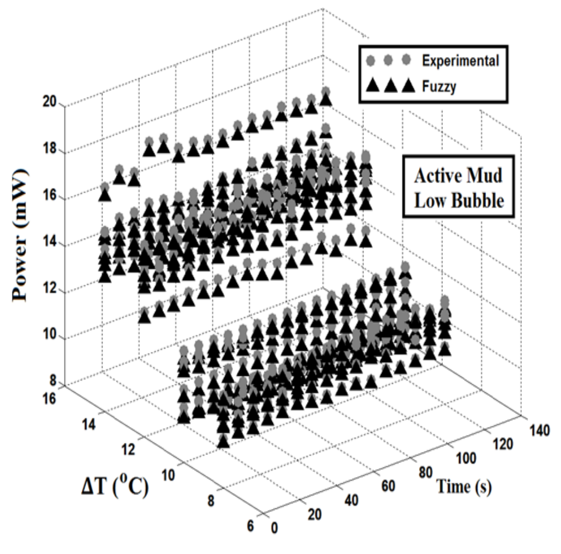
In 1965 Zadeh introduced the fuzzy subsets theory as an extension of the set theory by the replacements of the characteristic function of a set by a membership function whose values range from 0 to 1. RMBTF is fundamentally a multi-valued logic that allows traditional evaluations like yes/no, true/false, black/white, large/small, etc. to be defined as notions like "rather warm" and "pretty cold" and formulate these evaluations mathematically and process them with computers. A fuzzy system is based on three basic concepts; a fuzzy set, fuzzy membership and fuzzy variable. According to the classic theory of sets, if an element is in the set than its logical value is "1" and if an element is not in the set than its logical value "0". Fuzzy IF-THEN rules is the knowledge base of RBMTF which are used to describe the functional dependencies between the input and output variables, following the reasoning with the operators AND, OR and NOT in general linguistic usage [5].

In this study, RBMTF was designed using MATLAB fuzzy logic toolbox. This model is constructed into RBMTF using input, time (s), temperature (^{o}C) and bubble effect; output parameter power (mW) described by RBMTF if-then rules for each sample. Numerical parameters of input and output variables were fuzzificated as linguistic variables: very very low (L1), very low (L2), low (L3), negative medium (L4), medium (L5), positive medium (L6), high (L7), very high (L8) and very very high (L9).

3. Result and Discussion

MFCs are a special type of FC that the microbes added can purify wastewater and convert organic matter into electricity at the same time. Thus may offset the operating costs of wastewater plant. A MFC has separate anode and cathode chamber which in anode the organic material is oxidized by the microbes and in anode the electrons are transferred to cathode either by an added electron carrier or directly from the respiratory enzyme of the bacteria (mediator less). The transport of the electrons is done by external circuit where electrons are consumed by terminal electron acceptors [6].

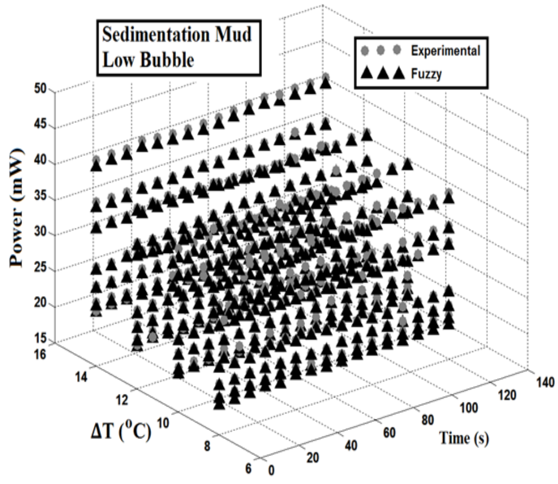
The aim of this study, with the aid of experimental data, MFCs performances in terms of power, temperature, time and bubble effect were modelled with fuzzy logic modelling technique. In the developed RBMTF system, output parameters power (mW) was determined using inlet parameters T, t and bubble effect. Figs. 2-3 shows respectively comparison of experimental data of low bubble and high bubble effect with RBMTF for the variation of time with ΔT of power values for active and sedimentation mud (ΔT =8-14 ^{o}C; t = 0-120 s). From a comparison of the experimental results with the results of the fuzzy logic study, one can see that the results are quite compatible (Figs. 2-3).



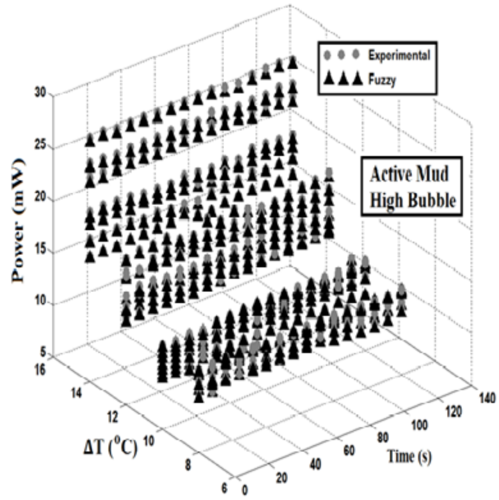
(a)

Fig 2. (a) Comparison of experimental data with RBMTF for the variation of time with ΔT of power values for active mud and low bubble.

2. (b) Comparison of experimental data with RBMTF for the variation of time with ΔT of power values for sedimentation mud and low bubble.



(b)



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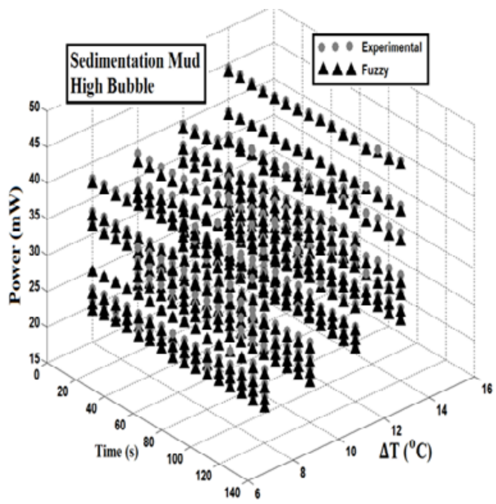

(b)

Fig. 3a) Comparison of experimental data with RBMTF for the variation of time with ΔT of power values for active mud and high bubble.

3b) Comparison of experimental data with RBMTF for the variation of time with ΔT of power values for sedimentation mud and high bubble.

These figures present that;

• For active mud and low bubble, the power values for ΔT=14 °C is higher than other temperature differences. The power value for ΔT=14 °C and t=32 s was 18.78 mW at most but ΔT=8 °C and t=32s was 10.41 mW (Fig.2a).

• For sedimentation mud and low bubble, the power values for ΔT=14 °C is higher than other temperature differences. The power value for ΔT=14 °C and t=32 s was 44.08 mW at most but ΔT=8 °C and t=32s was 19.75 mW (Fig.2b).

• For low bubble, same temperature and same time, sedimentation mud of power value is more than active mud power value. For ΔT=10 °C and t=80 s, active mud power value was 11.1 mW, but sedimentation mud 23.55 mW (Fig.2(a-b)).

• Minimum power values were 10.11 mW and 19.6 mW for active and sedimentation mud respectively with low bubble effect (Fig.2(a-b)).

• For active mud and high bubble, the power values for ΔT=14 °C is higher than other temperature differences. The power value for ΔT=14 °C and t=32 s was 28.36 mW at most but ΔT=8 °C and t=32s was 10.88 mW (Fig.3a).

• For sedimentation mud and high bubble, the power values for ΔT=14 °C is higher than other temperature differences. The power value for ΔT=14 °C and t=32 s was 44.27 mW at most but ΔT=8 °C and t=32s was 20.1 mW (Fig.3b).

• For high bubble, same temperature and same time, sedimentation mud of power value is more than active mud power value. For ΔT=10 °C and t=80 s, active mud power value was 13.29 mW, but sedimentation mud 32.87 mW (Fig.3(a-b)).

• Minimum power values were 10.26 mW and 19.86 mW for active and sedimentation mud respectively with high bubble effect (Fig.3(a-b)).

4. Conclusion

In this study, MFCs performances with active mud and sedimentation mud were experimentally investigated and modeled with fuzzy logic technique. In the experimental study, for sedimentation mud, high bubble and low bubble, the maximum power values determined as 45.5 mW and 43.9 mW; the minimum power values determined as 19.28 mW and 19.6 mW respectively. For active mud, high bubble and low bubble, the maximum power values determined as 28.29 mW and 18.87 mW; the minimum power values determined as 10.11 mW and 10.26 mW respectively. For sedimentation mud, low and high bubble power values nearly close. For ΔT=14 °C and t=32 s, the power value was 43.9 mW for low bubble but for same time and ΔT, the power value was 45.5 mW for high bubble. For active mud, low and high bubble power values were more different than other. For ΔT=14 °C and t=24 s, the power value was 18.45 mW for low bubble but for same time and ΔT, the power value was 28.36 mW for high bubble. Also, in this study, fuzzy logic modeling used to evaluate performance of MFCs. In the developed RBMTF system, outlet parameter power was determined using inlet parameters ΔT, t and bubble effect. The rules, which are used to detect the behavior of the fuzzy logic controller and the relationship between system's input and output, are determined. As a result of these rules, every value obtained from the experimental study is also determined by fuzzy logic too. The comparison between fuzzy logic and experimental data is done using statistical methods. The coefficient of multiple determination (R2) is 98.79% for the all data. The actual values and fuzzy results indicated that fuzzy logic modelling can be successfully used for the specification MFCs performances.

5. References

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