Examination of Non-contacting Measurement Method of Generation Current inside Polymer Electrolyte Fuel Cell using Heuristic Search

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Abstract — A polymer electrolyte fuel cell (PEFC) is one of desired clean energy converters. In order to raise the power generation efficiency of PEFC, it is necessary to monitor the generation of current inside MEA (membrane electrode assembly). In this paper, a non-contacting technique for detecting the distribution of power generation current inside the MEA using the static magnetic field around the PEFC is examined. A heuristic search of the current distribution inside MEA of PEFC using 3D FEM (finite element method) is proposed, and the effectiveness of the method is investigated.

I. Introduction

A polymer electrolyte fuel cell (PEFC) with a quick power generation is considered to be used for the power supply of an electric vehicle or home etc. In the development of the PEFC, it is important to measure the distribution of power generation current inside the fuel cell. Especially, the measurement of the power generation current in MEA (membrane electrode assembly) inside the PEFC is necessary [1]. The power generation current generates a static magnetic field around the fuel cell. Therefore, there is a possibility that the distribution of power generation current inside the MEA can be determined using the static magnetic field around the fuel cell.

In this paper, the non-contacting detection technique of the distribution of power generation current inside MEA using the distribution of the static magnetic field around the PEFC is examined. The distribution of static magnetic field around the PEFC is measured using the magnetic sensor. In this research, the static magnetic field calculated by the forward 3D FEM is used as the measured value in the proposed 3D heuristic search, then the current distribution in MEA is determined.

II. Model and method of analysis

Fig.1 shows the structure of the PEFC. This is composed of a pair of end plates (copper plate), a pair of separators (carbon), which is the passage of hydrogen and oxygen, and a sheet of MEA (membrane electrode assembly). Fig.2 shows the analyzed model of the fuel cell using the 3D FEM. The MEA is a sheet and its dimension is 50mmx50mmx1mm. The conductivities of the end plate and separator are 5.9×10^7 S/m and 8.1×10^4 S/m, respectively. The *x*-, *y*-, and *z*-components of static magnetic field, B_x, B_y and B_z along the line a-b-c-d-a shown in Fig.3, obtained by the forward analysis are used in

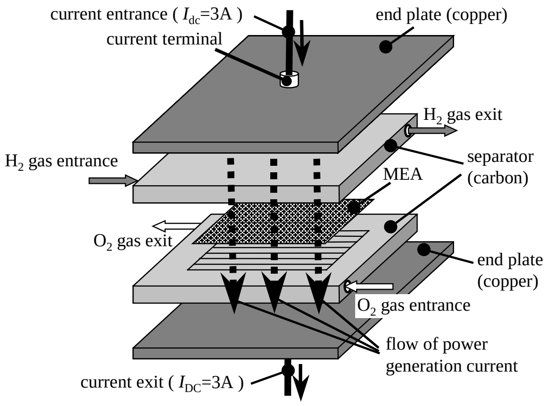


Fig.1. Polymer electrolyte fuel cell (PEFC).

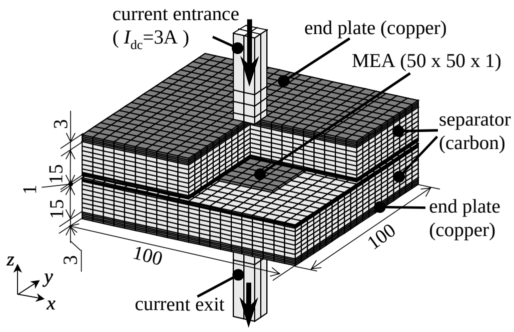


Fig.2. Model of the PEFC using 3D FEM.

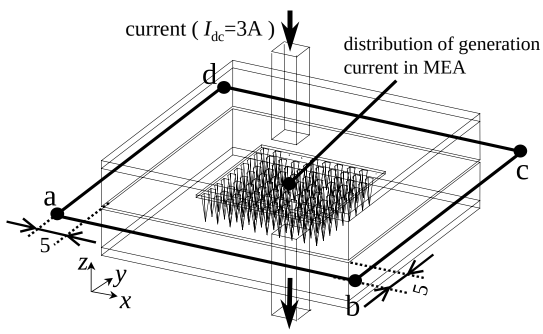


Fig.3. Position of four domains of static magnetic measurements.

3D inverse analysis. The total amount of power generation by the PEFC is 3A (dc). MEA is divided into 100 elements as shown in Fig.4, and its currents are treated as unknown variables.

There are various techniques in the inverse problem method. When the Evolution Strategy [2] using Tikhonov's method is used, the optimal solution was not obtained if the number of design variables is large. Then, the heuristic search which determines an "ON" or "OFF" region of the generation current in MEA which satisfies the specified flux distribution is introduced. The iteration process of calculation is shown in Fig.4 and the algorithm is as follows:

I) Process 1

"OFF"(no current) element is generated in MEA, and the following objective function W at the k-th iteration is calculated:

$$W^k=\sum_{i=1}^{n}\left\{\left(B_{ix}-B_{0x}\right)^2+\left(B_{iy}-B_{0y}\right)^2+\left(B_{iz}-B_{0z}\right)^2\right\} \quad (k=1, 2, 3\ldots\ldots) \quad (1)$$

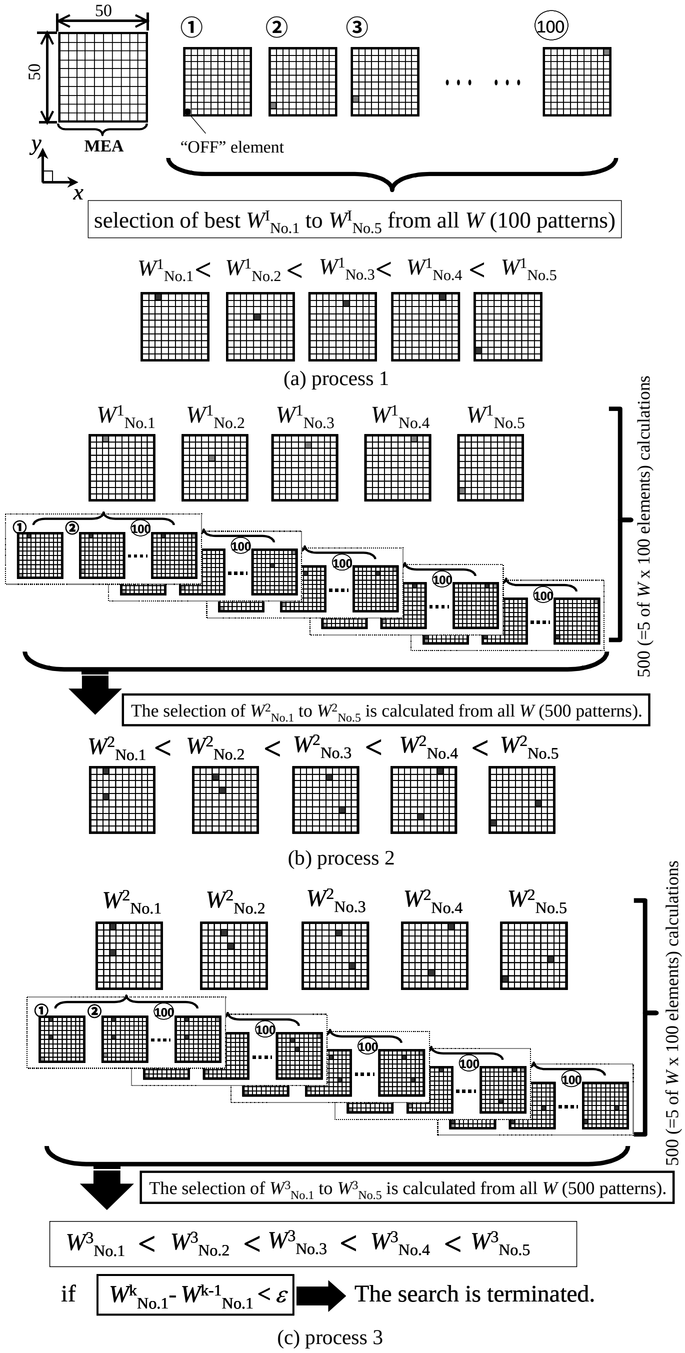
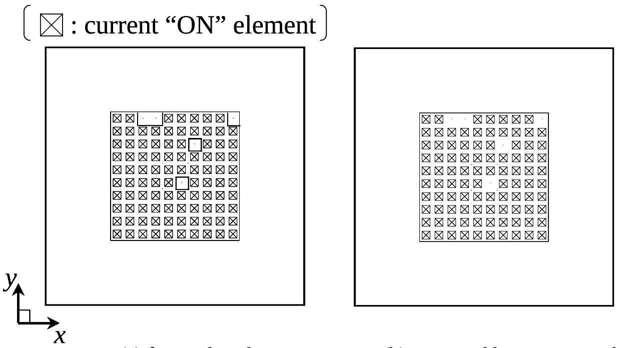


Fig.4. Iteration process using proposed heuristic search.



(a) forward analysis (b) proposed heuristic search

Fig.5 Distribution of current density in MEA.

where n is the number of elements along the line a-b-c-d-a around the fuel cell shown in Fig.3. B_{ix}, B_{iy} and B_{iz} are the x-, y-, and z-components of the flux density calculated using 3D FEM. B_{0x}, B_{0y} and B_{0z} are the x-, y-, and z-components of flux density calculated by forward analysis (corresponding to a measured value). One hundred kinds of calculations of W are carried out for each "OFF" element in MEA. The smallest five Ws are chosen from all W^1. These five W^1s are defined as $W^1_{\text{No.1}}$ to $W^1_{\text{No.5}}$. Fig.4 (a) shows the example of distribution of ON/OFF current in MEA of $W^1_{\text{No.1}}$ to $W^1_{\text{No.5}}$. The grey or black element denotes an "OFF" element.

II) Process 2

One hundred calculations are carried out by generating additional one "OFF" element for each W^1 as shown in Fig.4(b). Then, new current distributions of $W^2_{\text{No.1}}$ to $W^2_{\text{No.5}}$ are selected among 5x100=500 patterns.

III) The calculation of process 2 is iterated as shown in Fig. 4 (c), and new current distributions of $W^k_{\text{No.1}}$ to $W^k_{\text{No.5}}$ at the process k are obtained.

If $W^k_{\text{No.1}}$-$W^{k-1}_{\text{No.1}}$ is less than ε (ε is chosen as 1.0×10^{-20}), the search is terminated.

III. Results and Discussion

Fig.5 shows the comparison between the current distribution in MEA by the forward analysis and that by the heuristic search. The figure shows that the current distribution in MEA of the fuel cell can be obtained by the proposed heuristic search using the flux distribution around the fuel cell.

In the full paper, the equivalent experimental verification will be illustrated.

V. References

[1]G. Bender, M. S. Wison, and T. Zawodzinski, "Further refinements in the segmented cell approach to diagnosing performance in polymer electrolyte fuel cells", Journal of Power Sources, vol.123, pp.163-171, 2003.

[2] M.Horii, N.Takahashi, T.Narita:"Investigation of evolution strategy and optimization of induction heating model", *IEEE* Trans. on Magnetics, vol.36, no.4, pp.1085-1088, 2000.