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Determination of the effective parameters on the fuel cell efficiency, based on sealing behavior of the system

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ABSTRACT

Distribution and its magnitude pressure on gas diffusion layer (GDL) have direct influence on efficiency of the fuel cell. There are various parameters which affect the pressure. The aim of this investigation is to provide predetermined uniform distribution over GDL by choosing appropriate parameters (e. g. clamping force, thickness of end plate and sealant groove depth). First of all, using an experimental sealing test, the minimum compression stress over washer for no leakage condition was achieved to be 2 MPa. Sealing of the fuel cell stack was considered as a criterion for analyzing proper pressure distribution. In other words, we sought for an operational condition in which the applied stress over the washer and the magnitude of uniform pressure over GDL reach to the predetermined value. Furthermore, the influence of effective parameters such as clamping force, sealant groove depth, and thickness of end plate on the uniform pressure distribution over GDL were examined and discussed. Finally, the optimum values were reported based on the minimum clamping force, complete sealing condition, and uniform pressure distribution over the GDL.

Introduction

Research and development efforts concerning replacing and supplying fuel, are considered as the main criteria for development of a country. Up to now, fossil fuels, as the oldest energy sources, are extensively used by human being. Their use, however, has been limited by two major drawbacks. The first problem is that the fossil fuels are seen to be finite and will be depleted sooner or later. The second problem arises from their negative impacts on the environment, such as pollution, global warming, and etc. However, along with the predominant tendency toward innovative solutions, fuel cells have been suggested for solving these two interconnected global obstacles. Among the various types of fuel cells, proton exchange membrane (PEM) fuel cells have triggered an enormous attention in recent years due to their high efficiency, high energy density, low temperature operation, and low or zero emission [1,2].

There are various literature which have investigated different parameters affecting the fuel cells efficiency. Among them, electrical resistivity between gas diffusion layers (GDLs) and bipolar plates (BPs) is of high importance. In fuel cell stack, electrical resistivity is related to the clamping pressure. The resistivity between BP and GDL is highly dependent to the compression stress [3]. High contact pressures decrease ohmic contact resistance. In the meantime, porosity of the GDL and the active area would also decrease, thereby reduce

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the cell performance [4]. Furthermore, it is crucial to apply uniform pressure on the contact surface between GDL and BP. Non-uniform pressure distribution may lead into different ohmic resistance between GDL and BP layers. In order to achieve uniform pressure distribution, small deformation is needed in the end plate [5].

Recently, increasing attention has been given to the effects of clamping on the contact resistivity of fuel cell plates. Lee et al. [6] studied the effect of compression pressure, resulting from different bolts torque, on the performance of a PEM fuel cell. They represented that the optimum bolt torque is depend on gasket thickness, GDL porosity and electrical contact resistance. Chang et al. [7] experimentally investigated electro-physical properties of a carbon paper GDL (such as contact resistance, porosity and etc.) as a function of clamping pressure. The results indicated that at lower clamping pressures, higher interfacial resistance and gas permeability between the BP and GDL are observed, while higher clamping pressures can significantly reduce the contact resistance and gas permeability. In another study, Yim et al. [8] evaluated cell performance of a 5-cell PEM fuel cell stack under different GDL compression and gas flow rate conditions. Their observations revealed that better performance can be achieved by increasing GDL compression at all current ranges. They also concluded that GDL compression is one of the important parameter for stable stack operation. Wang et al. [9] suggested a newly designed end plate with hydraulic fluid to uniformly apply pressure in fuel cells. The new designed end plate proved the benefit of uniform pressure distribution over the fuel cell active area.

Xing et al. [4] developed a three-dimensional model to comprehensively investigate the effect of clamping pressure on the performance of PEM fuel cells. They also determined the optimum clamping pressure under different operating voltages, using simultaneous perturbation stochastic algorithm. They reported that the optimum pressure varies for different GDL material. Furthermore, direct relationship between clamping pressure and operating voltage is also observed. Based on the experimental interfacial contact resistivity data, Lai et al. [10] developed a mechanical-electrical finite element model to predict the contact resistance between GDL and BP plates. They extracted a potential function to simultaneously define mechanical and electrical contact behaviors. Taking the simulation technique into consideration, investigation of the influence of round corner of the BP plate on the contact resistance revealed the existence of optimal round corner for minimizing the contact resistance. Bates et al. [11] engaged an efficient finite element method for simulating the clamping pressure in a single-cell and 16-cell stack assembly. Based on the simulation, they specified the distribution and magnitude of pressure across the GDL. Combining these theoretical results and experimental testing, they could recommend a solution for some clamping pressure concerns by use of a method involving preloading of fuel cell stack and etc. Effect of non-uniformity of contact pressure on the contact electrical resistivity in PEM was investigated by Zhou et al. [12]. The results showed that uniform pressure distribution can improve contact resistivity up to 30%. Liu et al. [13] implemented a multi-objective stepwise optimization to peruse geometrical parameters of the endplate. The optimized results not only gave small mass, but also provided uniform pressure distribution on the PEM fuel cell components. Alizadeh et al. [14] studied effects of thickness and material of endplates, sealant hardness and number of stack's cell on the contact pressure distribution over membrane electrode assembly by finite element method. Chang et al. [15] employed a stiffness-controlled endplate to improve the performance of a flexible fuel cell. From the obtained results, the authors suggested that the modified endplate may be a beneficial in some special applications.

The main goal of current study is to theoretically and experimentally investigate the influence of various parameters to achieve proper clamping pressure over the GDL, considering minimum clamping force, minimum deformation of the end plate, and complete sealant of the system. To evaluate the selected parameters, in this research, leakage between the layers is used as the criterion. As the primary step, the required stress on the washer is experimentally obtained, based on the condition that no leakage is happened. In the next step, the influence of sealant groove depth on bipolar plate is modeled utilizing finite element method. The effects of clamping pressure and thickness of end plate on the pressure distribution of GDL and end plate deformation are also investigated and discussed.

Simulation and experimental setup

As mentioned in section 1(Introduction), simulation and experimental approaches are carried out in the present study, to evaluate the pressure distribution on the GDL and deformation of end plate. The simulation and experimental procedures along with the performed leakage test are separately explained at the following.

Simulation

The finite element method using commercial code of ABAQUS has been used to simulate the assembly of single fuel cell. Due to the symmetry of the stack and to reduce computational effort, only half of the single fuel cell is employed in the analysis. Fig. 1 illustrates the single fuel cell stack used in our investigation.

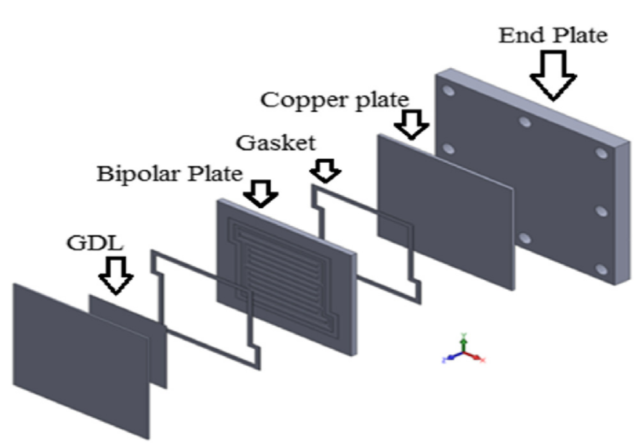

Fig. 1 – The employed single fuel cell stack.