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Composite sandwich endplates with a compliant pressure distributor for a PEM fuel cell

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ABSTRACT

Two endplates are used to fasten a proton exchange membrane fuel cell (PEMFC) stack composed of gaskets, gas diffusion layers (GDLs), membrane electrode assemblies (MEAs) and bipolar plates. The endplates should provide uniform and adequate compaction pressure to the stack components to decrease the electrical resistance of stacks and to prevent fuel leakage. It is also important to provide good thermal insulation for low heat loss and good cold-start characteristics. Therefore, an optimum endplate design is necessary to improve both the energy efficiency and reliability of the PEMFC.

In this work, an insulating foam–core composite sandwich structure and a pre-curved compliant pressure distributor for the design of endplates are employed for both good insulation performance and uniform pressure distribution on the PEMFC stack. The thermal insulation, flexural rigidity, structural safety, weight and cost of the endplates were considered in the design of the composite sandwich structure. Finally, the composite sandwich endplate was developed based on the optimum design, and the uniformity of pressure distribution on the stack surface was tested using pressure sensitive films.

1. Introduction

A proton exchange membrane fuel cell (PEMFC) is a clean electrochemical energy converter that transforms the chemical energy of hydrogen fuel into electrical energy. PEM fuel cells provide a solution not only for next-generation clean automotive applications but also for stationary and portable power generation applications [1–5]. A diagram of a fuel cell stack composed of membrane electrode assemblies (MEAs), a gas diffusion layer (GDL), bipolar plates, a current collector, a gasket and endplates is shown in Fig. 1. The endplates are placed at both ends of the stack and serve to fasten the other stack components.

One of the functional requirements (FRs) of the endplate is to provide adequate and uniform pressure to the other components in the fuel cell stack because an adequate pressure on the stack is very important to prevent the leakage of reactant fuels such as hydrogen and oxygen and to minimize the electrical contact resistance between components in the stack [6–8]. Too excessive pressure could squeeze the gas diffusion layer and change its porosity ratio, which could choke the fuel cell by making the flow of gases and migration of water difficult [9,10]. Too little pressure could result in a high electrical contact resistance between the gas diffusion layer and the bipolar plates, which would reduce the fuel cell efficiency [9,10]. Therefore, an adequate and uniform pressure distribution on the endplate is essential for the safety and efficiency of the PEMFC.

The other functional requirement of the endplate is to have a high thermal resistance. During the cold start of a fuel cell lower than the freezing temperature of water, the auxiliary battery in the PEMFC should heat stack as rapidly as possible because electro-chemical reactions such as oxidation and reduction are activated only when moisture exists. Also the PEMFC operates efficiently when the stack reaches the proper operating temperature from 60 to 220 °C [11]. Therefore, to improve the cold start characteristics of the PEMFC when it begins operation and prevent heat loss during operation, a high thermal resistance is another essential requirement of the endplate.

Many researches have been performed to improve these two functional requirements of PEMFC endplates. Xinting et al. developed a hydraulic piston [12] and Yu et al. developed a pre-curved hybrid composite endplate to achieve a uniform pressure distribution [10]. Ahn et al. [13] and Yu et al. [11] suggested using a foam–core sandwich structure for the endplate to achieve a high thermal resistance. However, a hydraulic piston might not be easy to apply

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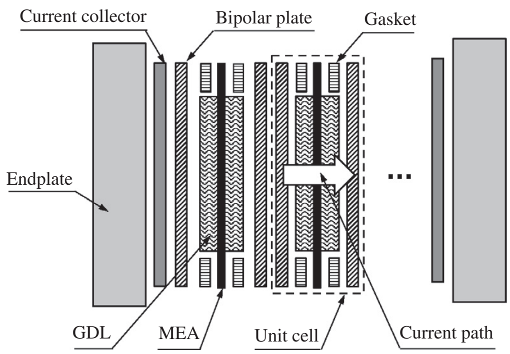

Fig. 1. Schematic diagram of PEMFC stack.

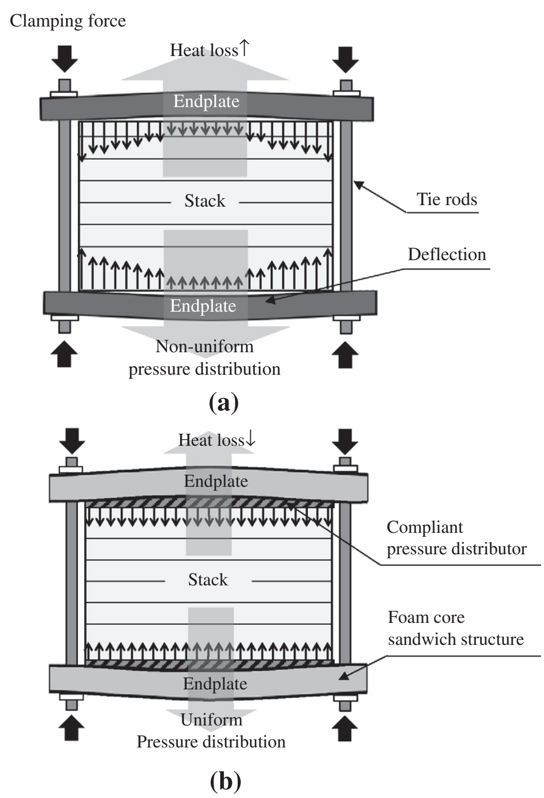

Fig. 2. Deflection and heat loss of (a) conventional endplate and (b) composite sandwich endplate with a curved compliant pressure distributor.

in portable applications, and a pre-curved composite endplate might not have a high thermal resistance [10]. Although the foam–core sandwich endplate has a high thermal resistance

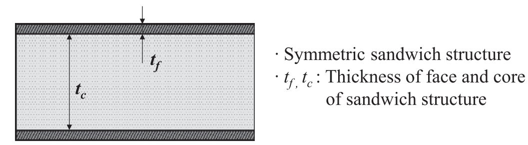

Fig. 4. Schematic drawing of the composite sandwich structure for the endplate design.

[14–19], a uniform pressure distribution might not be easily achieved because of the deflection at the endplate center despite the high flexural stiffness of the sandwich structure [20–23]. Additionally, there has been little research on endplate designs that could be applicable to the varying sizes and different environments such as high temperature PEMFCs (HT-PEMFCs).

Therefore, in this work, an advanced endplate structure composed of a foam–core sandwich structure and a compliant pressure distributor was designed to simultaneously achieve an adequate and uniform pressure distribution and a high thermal insulation property. Since flexural rigidity, thermal insulation, structural safety, weight and cost of the endplate are important parameters for endplates of PEMFC stacks of different sizes and environments, they were considered in the design of endplates in this work. Finally, the endplate was developed based on the design method developed, and clamping test on the endplate was performed using pressure sensitive films to verify the safety of the endplate structure and the applicability of a uniform pressure distributor on the stack surface.

2. Design of advanced composite endplate structure

The main concerns in the design of conventional endplates are to avoid a non-uniform pressure distribution due to the deflection of the endplate and excessive heat loss during the cold start of the PEMFC, as shown in Fig. 2(a). Therefore, in this work, an advanced endplate composed of insulating foam–core sandwich structure and a curved compliant pressure distributor was adopted for good thermal insulation and a uniform pressure distribution, respectively, as shown in Fig. 2(b). To design the advanced endplate structure, the sandwich structure was designed first, followed by the compliant pressure distributor (PD). The design methods were proposed based on the five basic design considerations and eleven material properties.

2.1. Design of composite sandwich endplate structure

To design the optimal composite sandwich structure for an advanced endplate, proper flexural rigidity, good thermal conductivity, sufficient structural safety margin, low weight and low cost should be considered. For these purposes, the material selection and the determination of the dimensions of the face and core in

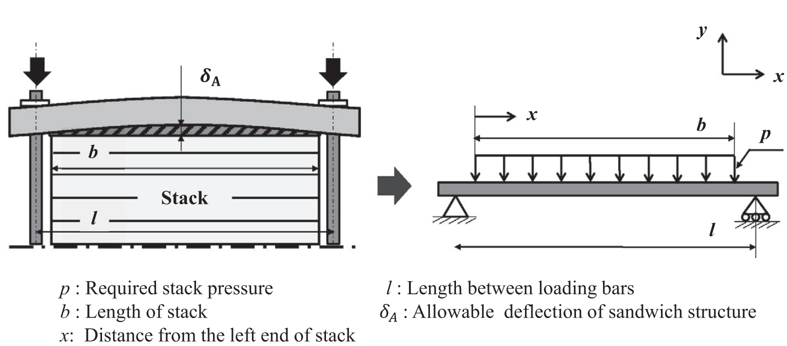

Fig. 3. Simple beam model of the composite sandwich structure of the endplate with design variables.