EVS26
Los Angeles, California, May 6-9, 2012

Development of Metal Plate Fuel Cell Stack System as a Range Extender of Tourist LEV

Fangbor Weng*, Jion-You Chen, Ay Su and S.-H. Chan
Fuel Cell Center & Department of Mechanical Engineering, Yuan Ze University,
135 Yuan Tong Rd., Chungli, Taoyuan, 32003 Taiwan, R.O.C.
* fangbor@saturn.yzu.edu.tw

Abstract

A metal plate fuel cell stack is developed and integrated with balance-of-plant (B.O.P) and metal hydride tank as mobile power extender of tourist LEV. The metal plate stack is made by 20 cells with 100 cm^2 MEAs and 3 mm Au-coated aluminium alloy plates. The stack has best performance of 1200 W. The sensitivity of operational conditions is studied on this metal plate stack. The relative humidity has more effect on membrane conductivity and changed stack performance. The fuel cell stack is integrated with B.O.P. and power condition, and operated at a less gas stoichimotry and low relative humidity environment. Then, the fuel cell power system has maximum net power of 600W. Finally, the metal plate fuel cell system is integrated with metal hydride tank, storied 1500 litters H2 (~3kWh electricity), and hybrid with 500Wh LiFePO4 batteries. This hybrid power module is demonstrated in a three wheels tourist LEV to validate the technology and commercial feasibility. The hybrid power of tourist light vehicle has advantage of attracting tourist and providing environmental education.

Keywords: metal plate, fuel cell stack, Li battery, hybrid power system, tourist LEV.

1 Introduction

Proton exchange membrane fuel cells (PEMFC) have already commercial applications (e.g. telecom, material handling vehicle, home power and heating system) [1]. However, for automobile applications the lifetime of fuel cells remain an issue, specifically in case of cyclic operation and low humidity conditions. In addition, the cost of PEMFC systems continues to be high and hydrogen infrastructure is limited. Recent advances in batteries and/or ultra capacitors help to tackle these obstacles. The hybrid power system can reduce size and cost of fuel cells, also the fuel cell is less cyclic operation and increases its lifetime. The fuel cells could used to extend the driving distance and without recharge time of battery electric vehicle.

The development of metal plate fuel cell stack is important to automobile application to reduce the size and cost of fuel cells. The metal plate has advantage of mechanical and thermal properties, comparing with graphite plate. The disadvantage of metal plate is metal corrosion and material durability for fuel cell application. Cho et al.[2] used graphite, TiN/ss316 as bipolar plate. The TiN/ss316 plate has 90% performance of graphite. The metal plate has made of kw stack and 1028 hours test for 11% performance degradation.
Yi et al.[3] tested ss304 alloy metal coated with graphite film as bipolar plate of fuel cell stack. The cell contact resistance is 5.4 $m\Omega/cm^2$, its cell

performance is 923.9mW/cm$^{2.}$ The stack is operated for 200 hours, only 3.9% degradation, comparing 28.7% degradation without graphite film on ss304. Yun et al. [4] investigated ss316 coated with AuTi, AuNi metal film as bipolar plates. The AuNi metal film has accepted contact resistance and low cost material.

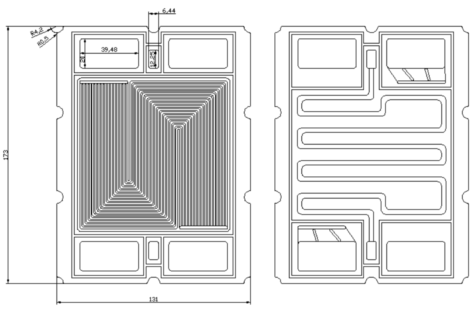
In this study, a metal plate PEM fuel cell stack is developed and integrated with balance-of-plant (B.O.P) as mobile power extender of tourist LEV. The metal plate fuel cell system is integrated with metal hydride tank and hybrid with LiFePO4 batteries. This hybrid power module is demonstrated in a three wheels tourist LEV to validate the technology and commercial feasibility.

2 Experimental

The fuel cell bipolar plates had gases flow and water channels on the plate surface as seen in Fig.1(a). The flow field could uniformly distributed the inlet gases into the electrodes. The gases channels are 16 serpentine channels with S shape from upside inlet to downside outlet. The detailed design of flow field plates is referred to Weng el al.[5] published paper. There are only different designs of main flow channels for large cell number. The aluminium alloy metal bipolar plate is coated with gold. Before the chemical Au coated onto Al surface, the Al alloy surface first coated with Zinc and Nickel to oxidize and chemically stabilize the aluminium alloy metal. After that, the zinc and nickel were chemically replaced with gold. Finally, the metal surfaces were electrochemically coated with gold again to reduce the pine-holes on the coated surface.

The fuel cells have fresh membrane-electrode-assemblies, made by Nanya PVC /Dupont company in Taiwan. The membrane is Nafion 211 and Gas diffusion layer is SGL 10BC, The platinum loading on electrodes are 0.2/0.4 mg/cm^2 on anode and cathode sides

(a).



(b).

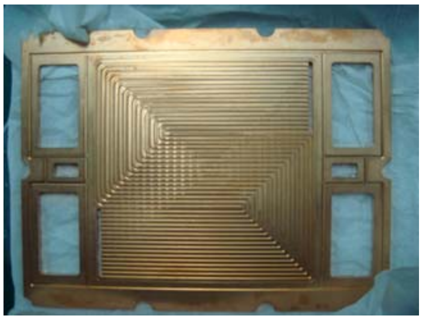


Fig.1(a). gas channels flow field and water cooling channels design on the bipolar plate, (b). picture of Au coated on aluminium alloy bipolar plate

The fuel cell stack is assembled with 20 cells and electrode area is 100cm^2 in each cell. The end plates has 10 bolts and three pair gases holes on the plates. The assembly and experimental test procedures and parameters of fuel cell stack are described in Weng et al.[5]. The parametric sensitivity study of fuel cell stack is based on SAE J2617 protocols [6]. Parameters are included the gases stoich. flow rates, stack temperature, humidified gases temperature, and cooling flow rate.

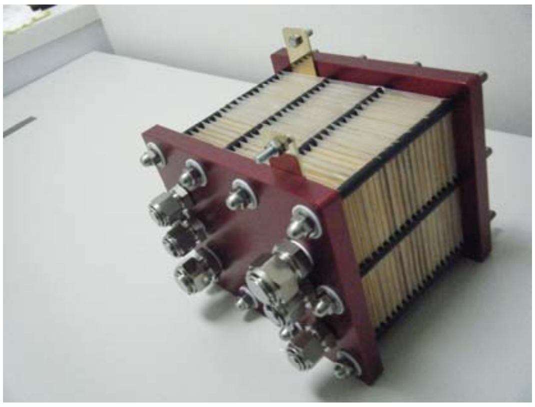


Fig. 2 Gold coated metal plate stack, 20 cells with 100cm^2 MEAs

Table 1 specification of metallic plate fuel cell stack	
MEAs	100cm^2 (Nan Ya), Nafion211, SGL 10BC, Electrode JM Pt 0.2/0.4 mg.cm^2
Metallic plates	173x 131x3 mm 16 serpentines, Aluminium with golden coated, Water cooling
Volume/weight	144x131x173 mm, ~3.5 L, /~10Kg
Power	700W~ 1200W, 20 cells
Operating conditions	60C, 1.2/4.0 A/C stoich., 50~100% RH,

After the fuel cell stack is assembled and performance test, the fuel cell stack is integrated with the B.O.P. The B.O.P included air pump, water tank, heat exchanger, humidify bottle, hydrogen relief valve, control unit, electronic power converter and start-up battery. The picture of the fuel cell power system is shown in figure 3. The hydrogen gas is dead-end design with switch valve. The hydrogen gas is release 2 second, every 25 seconds period. The heat exchanger has two air fans to cool the stack temperature below 60℃.

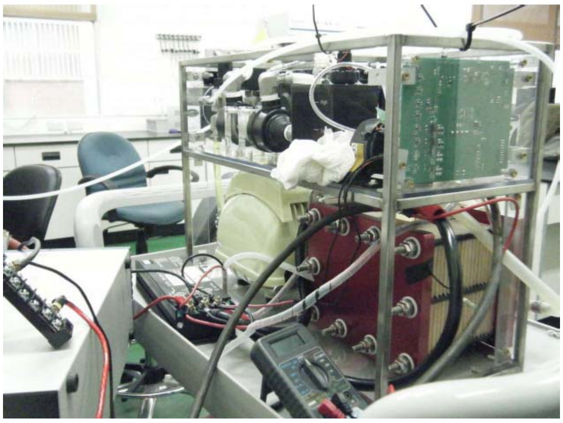


Fig. 3 Metallic plate stack with balance-of-plant as fuel cell power module.

The fuel cell power module is tested the power rate with electronic load to analyze the fuel cell stack performance as integrated with B.O.P. Finally, the fuel cell power module is test in a light vehicle platform, which integrated with metal hydride hydrogen tank and charged the LiFePO4 battery as seen in figure 4. The metal hydride is 6 bottle tanks with 250L hydrogen in each. The Li battery is 500Wh, assembled by local company. The three-wheel light vehicle is designed and based on the size and weight of the hybrid power module.

Fig. 4 LEV platform with hybrid PEM fuel cell/LiFePO4 battery power system.

3 Results and Discussion

The fuel cell stack is tested its performance on different air stoich. flow rates as shown in figure 5. The other optimal operating conditions are stack and humidified temperatures, 60℃ and anode stoich. flow rate 1.4. The cell current density is 1000mA/cm2 at 12V. It's maximum power is 1200W. The results show that air stoich. flow rates are little effect on stack performance as the value is larger than 3. After that, the anode stoich. flow rate, stack temperature, and humidified temperature are studied aa SAE J2617 protocols. The results show the humidified temperature is more sensitivity on stack performance as temperature is less than 50℃.

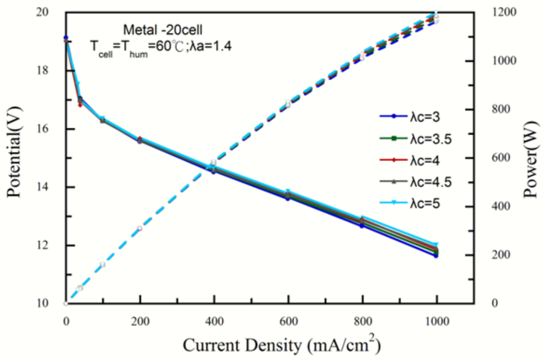


Fig. 5 Fuel cell stack performance at variable cathode stoich. Flow rate, stack temperature 60C, 100% humidified gases and anode stoich. flow rates 1.2

The stack performance is tested on low humidified and less gases stoich. flow rates conditions to simulate B.O.P. environment. The stack power is about 700W.

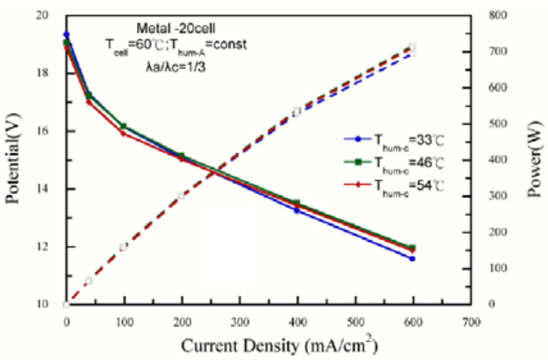


Fig.6 Stack performance at low stoich. flow rate and low relative humidity conditions.

The stack also operated at steady output current of 60A for 8 hours to test its stability. The stack design and operation without water flooding in the stack. The results demonstrate steady stack performance for long periodic time in figure 7.

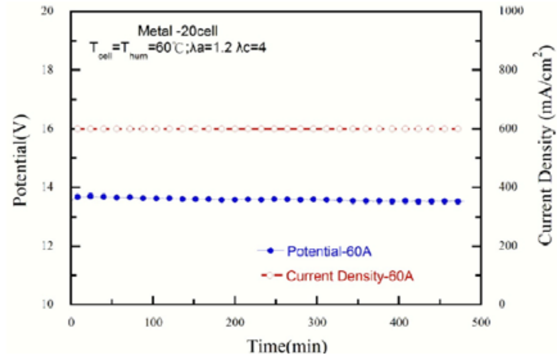


Fig. 7 Fuel cell stack total potential operating at steady current load operation for 8 hours

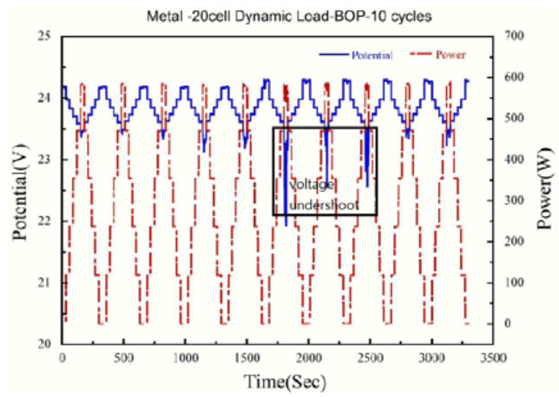


Fig. 8 stack integrated with balance-of-plant as power module for dynamic load operation.

In final test, the fuel cell stack is integrated with the B.O.P. and power condition of 24V with dynamic load change. The 10 cycles of load changes show in figure 8. The 6-8 cycles show a little voltage undershoot effect after power conditions. The estimated power consumer of B.O.P is 100W. The net maximum output power is 600W in this fuel cell power module.

After the fuel cell power module is finished performance test, the power module is integrated as hybrid power system. A high efficiency electric power converter is developed to convert voltage from 24V to 52V to charge the LiFePO4 battery. The S.O.C of battery is set a range of 85% to 25%. In addition, 1500L hydrogen gas (~3KWh electric power) is stored in metal hydride tank. The LiFePO4 battery has ~500Wh max. power capacity (48V, 10Ah). The hybrid power module is integrated into a three wheels tourist electric vehicle as shown in figure 9.

Fig.9 Tourist LEV of hybrid power system with fuel cells as range extender

The tourist LEV demonstrates in road test in restore hotel area in Taiwan. The estimated specification of the LEV is described as blelw,

Table 2 Specification of the tourist LEV

Hybrid power module	♦ 600W fuel cell max.power, Set battery charged rate 300W, ♦ 500Wh(48V) Li battery set S.O.C 85%~25% ♦ 1500L H2 (~3KWh electricity) Metal hydride tanks ♦ 24V→52 Power converter 95~98% eff,
Motor	3kW
Vehicle weight	~150KG
Vehicle speed	15 ~ 30 km/h
Drive range	60~80 km per hydrogen tank

4 Conclusions

A metal plate fuel cell stack is developed and integrated with balance-of-plant (B.O.P) and metal hydride tank as mobile power extender of tourist LEV.

- The metal plate stack is made by 20 cells with 100 cm^2 MEAs and 3 mm Au-coated aluminum alloy plates**.**
- The stack is operated at optimal conditions, with 1.2/ 4.0 stoich. of H_2/air, and maintained at 60 C fuel cell temperature, 100% relative humidity. The stack has best performance of 1200 W.
- The fuel cell stack is integrated with B.O.P and power condition, and then operated at a less gas stoich. flow rate and low relative humidity environment. Then, the fuel cell power system has maximum net power of 600W.
- Finally, the metal plate fuel cell system is integrated with metal hydride tank, storied 1500 liters H2 (~3kWh electricity), and 1kWh LiFePO4 batteries. This hybrid power module is demonstrated in a three wheels tourist LEV

The tourist vehicle is daily used in a community area. It is easy to build the electric or hydrogen refilling station. The hybrid power of tourist vehicle has advantage of attracting tourist and providing environmental education. This hybrid power module could provide a platform of technology and commercial studies for EVs and hydrogen infrastructure.

Acknowledgments

This work was conducted under the “intelligent light vehicle program” of Engineering Division, National Science Council, Taiwan of R.O.C. The authors would like to thank industrial partner of Yueki Industrial Co. and Yuan Ze Fuel Center for financial support and technical assistance during the project.

References

[1] A. Elgowainy, L. Gaines, M. Wang, Int. J. Hydrogen Energy 34 (2009) 3557–3570.

[2] Cho, E.A., et al., Performance of a 1 kW-class PEMFC stack using TiN-coated 316 stainless steel bipolar plates. Journal of Power Sources, 2005. **142**(1-2): p. 177-183.

[3] Yi, P., et al., Performance of a proton exchange membrane fuel cell stack using conductive amorphous carbon-coated 304 stainless steel bipolar plates. Journal of Power Sources, 2010. **195**(20): p. 7061-7066.

[4] Yun, Y.-H., Deposition of gold-titanium and gold-nickel coatings on electropolished 316L stainless steel bipolar plates for proton exchange membrane fuel cells. International Journal of Hydrogen Energy, 2010. **35**(4): p. 1713-1718.

[5] Weng, F.-B el al., Design, fabrication and performance analysis of a 200 W PEM fuel cell short stack Journal of Power Sources, (2007) **171** (1), pp. 179-185.

[6] SAE J2617, Recommended practice for testing performance of PEM fuel cell stack sub-system for automobile application.

Authors

S.H Chan is University Professor & Far-Eastern Energy Distinguished Professor Yuan Ze University. He received his Ph.D. from Mechanical Engineering, University of California-Berkeley in 1969. His research areas include fuel cell, combustion and thermofluid.

Fangbor Weng is a faculty member in the Department of Mechanical Engineering at Yuan Ze University in Taiwan. He is active in PEM fuel cell research of modelling, diagnostic tools in fuel cell durability, and stack development.