2003.12.02

Fuel Cell System for Motorcycles

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Abstract

Expectations are mounting with regard to the use of fuel cells as a clean-running, efficient power source for automobiles, and now research has also begun into the use of fuel cells to power small motorcycles as personal-use vehicles. The biggest problem involved in the development of a fuel cell system for motorcycles is how to fit the entire system into the limited space available on a motorcycle. In order to avoid sacrificing running performance, it is also necessary to keep weight increase to a minimum. In this report we will describe the structure of our newly developed direct methanol fuel cell system for motorcycles and our concept model mounting this system.

1 INTRODUCTION

The fuel cell is considered one of the ultimate energy conversion devices, due to the fact that it emits no toxic gases and achieves a high level of conversion efficiency. However, there are still many issues that must be worked out before it can be applied practically to vehicles. The commonly known fuel cell systems for automobiles are mostly ones that use hydrogen as fuel[1,2]. The biggest problem with these systems at present is the establishment of an infrastructure to supply this fuel to the public. In the case of Japan, in order to achieve the Ministry of Economy, Trade and Industry goal of "5 million fuel cell vehicles on the road by 2020," it will be necessary to have at least 2,000 hydrogen fueling stations at an estimated investment cost of 400 billion yen[3]. In the USA, General Motors estimates that the necessary infrastructure investment will total about $12 billion[4].

There is also the issue of the technology to produce and supply as efficiently as possible the necessary hydrogen, an element which does not exist independently in the natural state. Since hydrogen is generally produced from fossil fuels like natural gas, there is a resulting release of the greenhouse gas CO_2. This means that unless the total energy conversion efficiency (overall efficiency) involved in the production of the hydrogen and its use in the fuel cell vehicles is not superior to that of a conventional gasoline engine vehicle, the introduction of fuel cell vehicles will not be an effective measure for reducing greenhouse gas emissions. Although present fuel cell automobiles using compressed hydrogen gas as fuel are said to have a high overall efficiency rate of 29%, when you consider the fact that the latest gasoline hybrid automobiles have reached overall efficiency rates ranging between 28% and 33%, the hydrogen fuel cell cars cannot really be said to have a clear advantage at this point[5,6].

2 TYPES AND USES OF FUEL CELLS

Fuel cells can be divided into the types shown in **Fig. 1** depending on the material used for the electrolyte, and the different types are used for different purposes based on their inherent characteristics. The PEMFC (Proton Exchange Membrane Fuel Cell) can be further divided into the types shown in **Fig. 2** based on the type of fuel used.

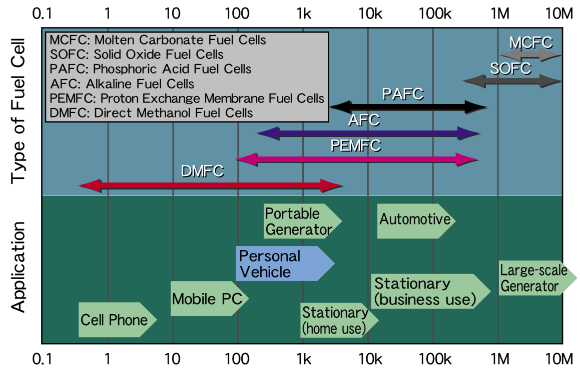


Fig. 1 Types and Uses of Fuel Cells

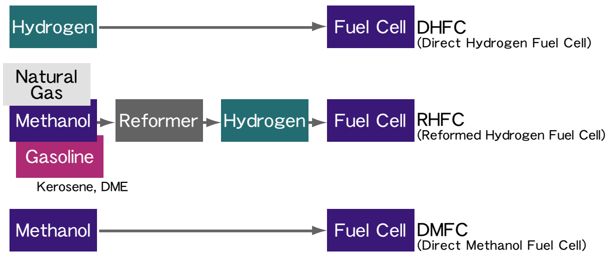


Fig. 2 Examples of PEMFC Systems by Fuel Type

3 CHOICE OF A FUEL CELL TYPE FOR MOTORCYCLES

When attempting to apply a fuel cell as a power source for a small motorcycle, the main issues become how to fit the system into the extremely limited space available and how to limit the weight of the system. When a desired running distance per fueling is set, the weight of the overall system, including the fuel system, generating system, peripheral components and control systems, increases in accordance with the amount of electrical power output performance required by the vehicle. This relationship is shown in **Fig. 3** in a comparison of a PEMFC of the compressed hydrogen type (CHFC: Compressed Hydrogen Fuel Cell) and a PEMFC of the direct methanol type (DMFC: Direct Methanol Fuel Cell). Here we see that for an electrical power output of 1kW or less, a DMFC system becomes the lighter system. For a system using compressed hydrogen gas, there is a tendency for the fuel system to take up a larger proportion of the total weight when a comparatively long running distance is required and the amount of electrical output

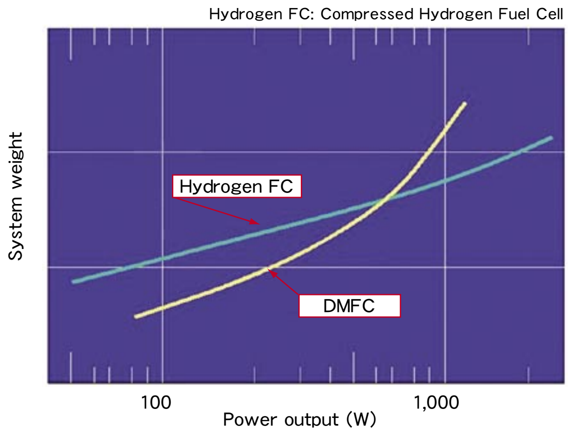


Fig. 3 Weight Comparison for Fuel Cell Systems (Calculations based on a set amount of stored energy)

required is relatively small. There are also systems that use a metal hydride actuator tank or ones that use hydride cartridges instead of compressed hydrogen gas, but these systems do not offer much of an advantage in terms of system weight reduction[7]. Furthermore, when factors like the amount of time required for refueling the system with hydrogen or the effort involved in the storage and maintenance of the exchange cartridges, at the present point, these systems do not necessarily offer significant advantages in terms of convenience compared to a conventional electric vehicle using a rechargeable battery.

As evidenced by the fact that DMFC systems are being developed for use in mobile phones and mobile PCs, they are systems that are well suited for use in small devices. In terms of conversion efficiency, the DMFC is inferior to a compressed hydrogen gas type fuel cell, but it has many other practical advantages, such as the fact that it can use liquefied fuel, the fact that no cooling passage is required for the cell stack and the fact that it does not freeze easily in cold conditions. In particular, the fact that the DMFC systems use liquid fuel is a strong advantage for use in small motorcycles, not only because of the reduced space and weight they require but also in terms of safety. Although the methanol that serves as the fuel is a flammable liquid, it can be distributed as a non-hazardous substance when diluted in water below a certain concentration, which means it is easier to use than gasoline or kerosene. While there are expected to be some issues involved in attaining a sufficient distribution of this form of methanol as a fuel throughout the market, the fact that there would be no need to wait for the completion of a new large-scale distribution infrastructure surely makes this a practical form of fuel that presents fewer hurdles than other types.

4 EXAMPLE OF A FUEL CELL SYSTEM STRUCTURE FOR MOTORCYCLES

Fig. 4 is a photo of the exterior of a prototype DMFC system we have developed for powering a motorcycle. **Fig. 5** illustrates the structure of this system and names of its different components, the electricity generating principle and the structure of the cell stack. This system has a rated wattage output of 500W, a rated voltage of 24V and a weight of 20 kg. The exterior dimensions are a roughly 400 × 400 × 400mm cube. The

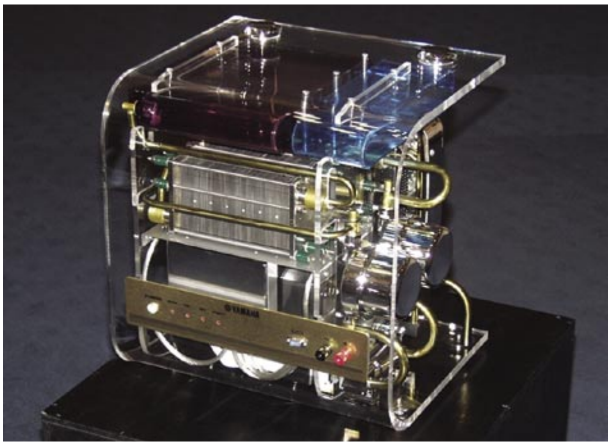
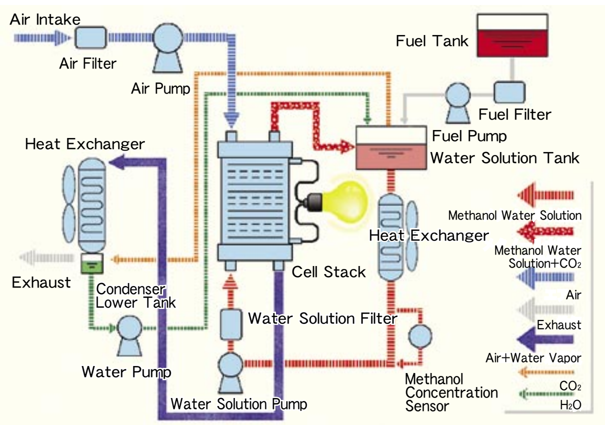
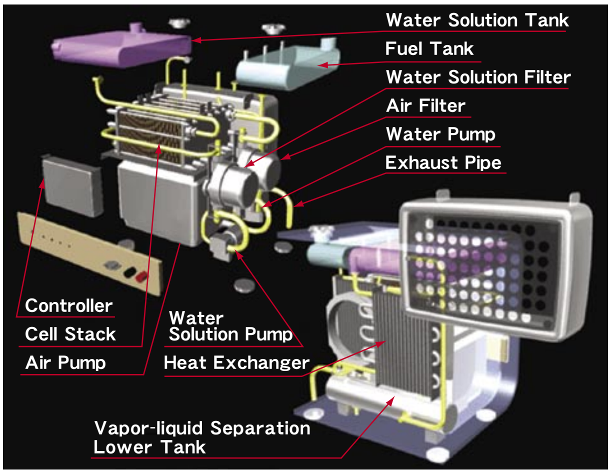


Fig. 4 DMFC System Prototype for Motorcycles

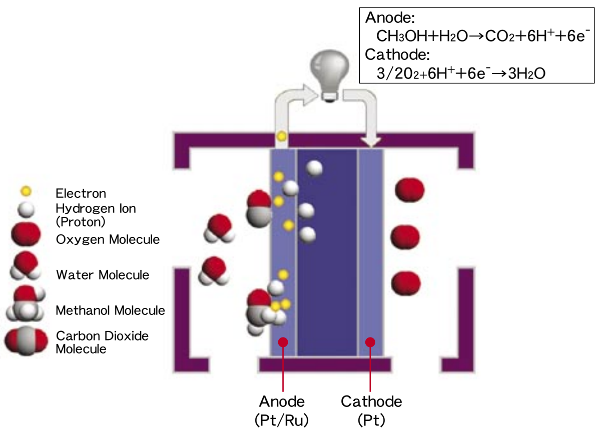
system comprises a fuel tank (primary tank) that holds a 50% concentration methanol-water solution and another water-solution tank (secondary tank) that supplies the cell stack with a constant supply of methanol-water solution maintained at a concentration of 1M/L (3.2% by mass). From the cell stack, water solution containing bubbles of CO_2 gas produced by the chemical reaction in the cell stack is circulated back to the secondary tank, where the gas component is separated out. The device for monitoring the methanol concentration comprises a Yamaha-developed concentration sensor and a control algorithm. The system is designed in such a way that when the methanol concentration in the circulating water solution falls below the designated level, a controller signal is generated that causes high-concentration methanol solution to be sent from the primary



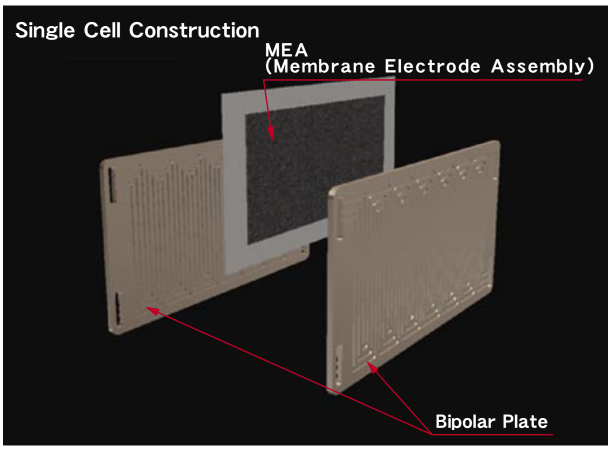
① System Flow Diagram



② Layout and Part Names



③ Principle



④ Cell Stack Construction

Fig. 5 DMFC System for Motorcycles

tank to raise the concentration. Air is supplied to the cell stack cathode by means of a Yamaha-developed high-efficiency air pump after passing through an air filter. The exhaust, with its steam component, passes through the heat exchanger where the water component is condensed out, after which it is collected and circulated out of the system. At the condenser lower tank the water level of the recovered water is controlled and the excess water is removed from the system here.

5 EXAMPLE OF A MOTORCYCLE MOUNTING A DMFC SYSTEM

In order to integrate the system described above into a small electric motorcycle, the layout would have to be changed in accordance with the structure of the motorcycle in order to achieve a viable weight balance. **Fig. 6** shows an example of a concept model mounting a DMFC system. This concept model has been designed to satisfy the needs of a light business-use model for the near future with a compact, lightweight body and sufficient running distance per refueling to be practical. Adopting an in-series hybrid system with a Li-Ion battery gives this model easy starting, acceleration and cruising performance. With a 100V, 3A AC outlet, it can also serve as a "running electric generator" providing an electricity source for outdoor leisure or emergency use.

Fig. 6 Concept model "FC06" mounting a DMFC system

6 CONCLUSION

If such a vehicle can be developed in the near future, the need for the charging time necessary with existing electric motorcycles would be eliminated and it should be possible to achieve a running distance on one refueling equivalent to that of a motorcycle powered by an internal combustion engine. It is exciting to imagine what uses customers would find possible with a personal vehicle like this in their lives that emits no toxic exhaust substances or unpleasant noise. On the other hand, efforts will be necessary to achieve a further weight reduction and more compact size for the major components of the system like the cell stack, to ensure adequate reliability and durability in the full range of use conditions and to establish the technologies necessary for mass production and eventual reduction of the production costs. At the same time, concerted efforts will also be necessary in developing a market and establishing a sufficient fuel distribution network.

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