Muli-fuel Technologies of PEFC System for Various Applications

KATSUKI YAGI*1
SHIGERU NOJIMA*1
SETSUO OMOTO*1
KEIICHI HORI*2

1. Introduction

Commercializing fuel cells is expected to provide low-pollution and high-efficiency distributed power that may help lower the damage of accidents by providing an emergency power source and prevent global warming. Polymer electrolyte fuel cells (PEFC) capable of short starts and stops are especially promising in the field of civilian use, where daily power demand varies widely and distributed power operates below 100°C. Early adoption and spread of PEFC is eagerly sought for.

Given the instability of global supply of fossil fuels, e.g., the wars in the Middle East and the rapid economic growth of China, Japan must free itself of its dependence on imported supplies of fossil fuels. PEFC offers a solution because it uses different energy by way of hydrogen.

Mitsubishi Heavy Industries, Ltd. (MHI) is developing catalysts and reforming systems of fuels such as city gas, LPG, naphtha, kerosene, methanol, and dimethyl ether to develop multi-fuel technologies(1). This paper introduces key technologies for multi-fuel use and PEFC systems for various applications.

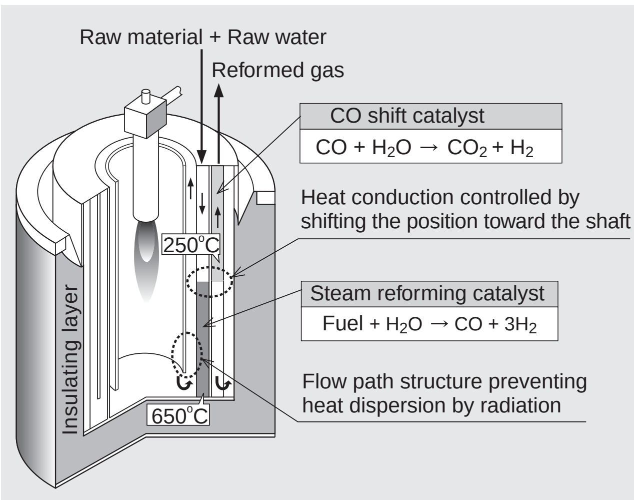

Fig. 1 Design of reformer temperature distribution
Radiation and heat conduction are not proportional to load, making cooling and heating unproportional to the load and deteriorating efficiency and catalyst life.

2. Key technologies for multi-fuel use

2.1 Thermal fluid design technology for fuel reformers

The fuel reformer produces reformed gas including hydrogen from fuel using three types of catalysts to promote three continuous reactions: steam reforming, CO shift, and CO preferential oxidation. The fuel reformer design requires that the optimum temperature be maintained for each catalyst regardless of the operating load. Since the catalyst and required temperature differ with the fuel type, the fuel reformer is designed independently for each fuel.

When catalysts with different temperature zones lie side by side, various kinds of heat transfer take place between catalysts, heat transfer caused by conduction and radiation is determined solely by temperature regardless of the load. This makes it necessary at design to allow for maintaining equivalent temperature distribution for all loads. We developed a reformer that maintains high efficiency for a wide range of loads by controlling thermal conductive heat transfer through geometrical structural design and radiative transfer by optimizing flame positioning and radiation shielding. The conceptive diagram of the technology is shown in **Fig. 1**.

MHI has developed a 1 kW-class fuel reformer using city gas and LPG. The reformer, which has a cylindrical manifold structure without a heat exchanger, evaporates raw water and controls catalyst temperature by one burner. The reformer has realized a high reforming efficiency of over 72% (LHV) at a wide range of loads from 30% to 100%.

Reforming petroleum fuels with a high carbon number involves fuel-related technical problems and difficulty in reforming technology determined by the carbon number in the molecule, the inclusions of olefin, aromatic series, and sulfur compounds, etc.

MHI has amassed multi-fuel technologies such as (1) catalyst temperature design and start-stop technology to prevent unconverted fuel slip causing after-stage catalyst deterioration, (2) thermal flux design technology to prevent carbon precipitation, and (3) homogeneous mixing of raw material composed of fuel and water for stable hydrogen generation, and evaporation technology controlling vibration. MHI is promoting development targeting improved efficiency and durability.

*1 Hiroshima Research & Development Center, Technical Headquarters
*2 Hiroshima Machinery Works

2.2 Long-life catalyst technology

Daily start and stop (DSS) that shuts down generators at night when little demand exists for power consumption and starts them up early in the morning when demand increases helps maximize economy in power generation. Conventional inert gas purging in reformers required for safety was eliminated by deregulation. MHI uses purging method that effectively uses burner exhaust gas to prevent deterioration of Cu-type CO shift catalysts. This technology is applied regardless of the fuel type, making it important for multi-fuel systems.

3. PEFC systems for various applications

3.1 1 kW-class system for home use

MHI developed a compact package system of the smallest size in the world (180 L) as a 1 kW-class PEFC using city gas and LPG and is conducting demonstration testing in the home[(2)]. To prevent excessive supply of electric power and hot water, the PEFC must be operated based on the load by maximizing efficiency over a wide range of load. MHI achieved power generation of over 32% LHV (36% LHV at rated load) at a wide load region ranging from 30% to 100% by improving a fuel reformer whose efficiency deteriorated at low load region.

3.2 10 kW-class system for commercial use

PEFC for commercial use is anticipated. In a joint project with Nippon Oil Corporation, MHI developed a 10 kW-class PEFC using kerosene as fuel. It is a government subsidy project, and part of "Experimental Studies for Stationary Fuel Cells by New Energy Foundation." We commenced testing on the system at a convenience store in Tokyo this year. The appearance of the system is shown in **Fig. 2**.

Compared to city gas and LPG, it is difficult to control the reforming conditions or to carry out desulphurization in the case of kerosene. However, kerosene offers the advantages of low cost and no need for DSS or load-following operation. Currently, a joint project with Nippon Oil Corporation is under way to obtain various operation data on basic characteristics such as durability targeting commercialization.

3.3 Use at housing complex

Reducing cost is a central issue with PEFCs. In housing complexes with buildings becoming taller and taller and space being limited, the introduction of PEFC system is supposedly difficult.

MHI proposes a low-cost system that reduces initial cost in half and dramatically reduces maintenance cost by simplifying and downsizing the system by centralizing of the fuel reformer. The system is made applicable to different types of fuels by changing the reformer and should be useful as an emergency power source at the time of disaster.

This research was conducted in a joint project with industrial, academic, and public circles including Hiroshima Gas Company, Ltd., etc., subsidized by the Regional New Consortium Research and Development Program for fiscal years 2003 and 2004 under the jurisdiction of the Chugoku Bureau of Economy, Trade and Industry.

4. Conclusion

This paper discusses technologies for multi-fuel systems and their applications. We plan to continue field verification and cost reduction targeting the early commercialization of PEFCs.

Given current technical trends in energy-saving electrical appliances and improved power plant efficiency, we will decide product specifications after making estimation of the project feasibility at the time of launching the project into the market.

We are also making study on a system for pure hydrogen or for transportation (ships and aircraft).

References

(1) Yoshida et al., Advanced Technologies for High Performance Stationary PEFC, Mitsubishi Heavy Industries Technical Review Vol.41 No.2 (2004)

(2) Yoshida et al., Activity Towards Practical Application of Stationary PEFC, Mitsubishi Juko Giho Vol.40 No.4 (2003)

Fig. 2 10 kW commercial PEFC (PEFC using kerosene)


Katsuki Yagi


Shigeru Nojima


Setsuo Omoto


Keiichi Hori