CHALLENGING THE POSSIBILITY OF SMALL AND LIGHTWEIGHT POWER SOURCES

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Abstract

Since a more comfortable and more computerized lifestyle is desired, the latest mobile electric devices and self-running robots continue to develop. The new small and light-weight power sources are required in order to improve the energy accessibility since the batteries used for those power sources at the present have small energy density. Then, in this paper, Utra Micro Gas Turbine (UMGT) and Micro Fuel Cell (MFC) that are noticed in the new small power sources are discussed. The fundamentals as well as challenges are introduced, and the problems to be realized and spread are shown. When UMGT and MFC are developed for a practical use, they will specially improve the energy accessibility in 3A of WEC's goals.

I study about a micro combustor for UMGT, so UMGT is shown on my knowledge. Although I do not study about MFC, MFC is shown based on some recent reports.

1. Introduction

Energy consumption by public welfare section and transportation section continue to increase year by year, because more comfortable lifestyles are required. Sustainability comes to be considered in energy for transportation and power station, and many counter-plans are tried to realize sustainable society. However, mobile electric devices we usually use are not considered energy-accessible and sustainable. For example, one often feels inconvenient when a cellular phone's battery is run out in the case of no battery charger. So new small power sources with large for mobile and wearable electric devices are needed.

Recently, technology rapidly progress in mobile and wearable electric devices or humanoid robots. With these progresses of those devices and their spread in the market, there are new needs for small and lightweight electric power sources, because batteries are the heaviest parts in today's electric devises; therefore, they are obstacles to miniaturize those devices and to develop them.

Development of small fuel cells and micro internal combustion engine generators are necessary to meet such needs. Those generators use fuels that usually have one or two order higher energy density than batteries. Compared to batteries, power sources that use chemical fuels have advantage of continuous utility just by adding fuels, and no toxic materials with them. If those small power sources are spread, most of today's electric devices will be released from electrical outlets and no one feels inconvenience to use those devices; that means no needs for charging the batteries many times or constructing new large infrastructures in any countries.

In this paper, two small power sources, which are the ultra micro gas turbine (UMGT) and the micro fuel cell (MFC), are introduced. Problems which are to spread UMGT or MFC are shown after this discussion. And the possibility of solving energy accessibility in developed or developing countries by UMGT and MFC is discussed.

2. Characteristics of new small power sources for mobile and wearable electric devices

Some kinds of small power sources are recently noticed. They have higher power density than batteries, and Micro-Electro-Mechanical-Systems (MEMS) makes them and mass production by MEMS will enable their manufacturing cost to be reduced. This is why new small power sources are good for mobile and wearable electric devices. In this session, the ultra micro gas turbine and the micro fuel cells are shown as typical new small power sources.

2.1.Ultra Micro Gas Turbine (UMGT)

It is generally said that gas turbines have large power density, with small vibration, and less maintenances. So the ultra micro gas turbine (UMGT) its diameter is about 20 mm is noticed and some research institutes have been studying. UMGT require hydrogen as fuel because of its high burning velocity and high chemical reaction rate.

The most famous UMGT has been studied by MIT in U.S. The concept of MIT's UMGT is shown in Fig.1 and the specification is shown in Table.1.This UMGT less than 1 gram in weight produces about 16W of power by consuming 7 g/hr of fuel, and rotor speed is about 2.4 × 10^6rpm. The smallest micro gas turbine sold now is 3kW of outputs, and rotor speed is about 100000 rpm. Since the rotor speed of UMGT is about 10 times as much as today's micro gas turbine, it is difficult to realize UMGT.

In Japan, it was planned to establish basic technologies for practicing ultra micro gas turbine that would be used for portable and reusable electric power or heat sources. Final target is to contribute the product development of the button size gas as large as MIT's. The goal of this UMGT is that power output is 10 to 100 W.

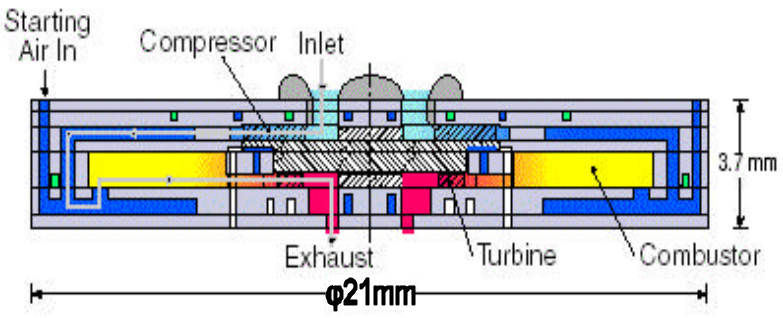

Fig.1 Concept of UMGT by MIT[1]

Table.1 Specification of UMGT by MIT

Pressure Ratio[-]	4
Air Flow[g/s]	0.15
Turbine Inlet Temp[K]	1600
Rotor Speed[rpm]	2.4×10^6
Power output[W]	16
Weight[g]	1
Fuel Consumption[g/hr]	7

2.2.Micro Fuel Cell (MFC)

It is four micro fuel cell systems that have mainly studied: Direct Methanol Fuel Cell (DMFC), Polymer Electrolyte Fuel Cell (PEFC) with fuel reforming reactor, PEFC with metal-hydride, and PEFC with bolonhydride ($NaBH_4$). DMFC and PEFC with fuel reforming reactor are especially noticed to use as small power sources.

The system of DMFC or PEFC with fuel reforming reactor is shown in Fig.2 or Fig.3. DMFC directly uses methanol as fuel and carry air and fuel by pump. PEFC with fuel reforming reactor uses hydrogen that is

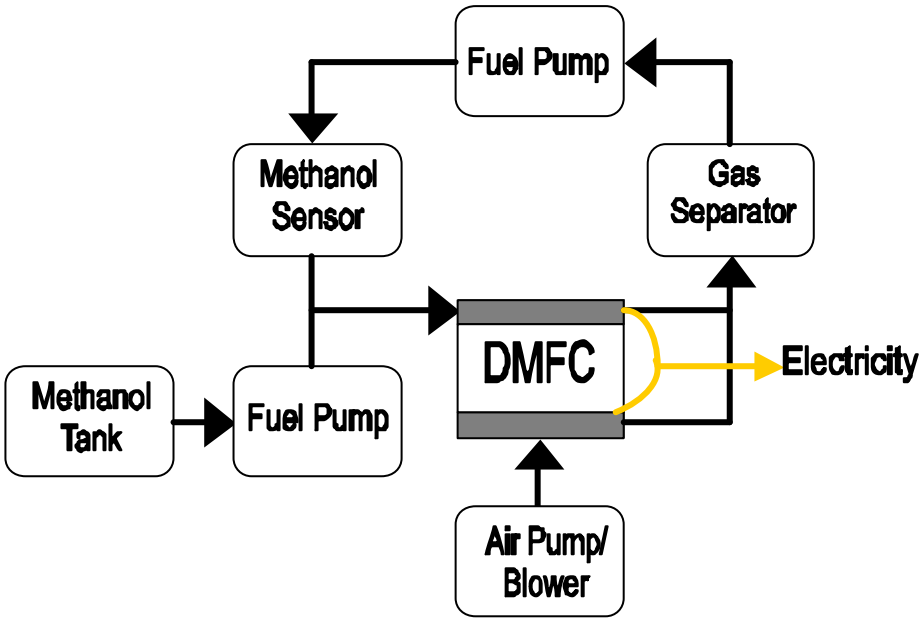

Fig.2 System of DMFC[2]

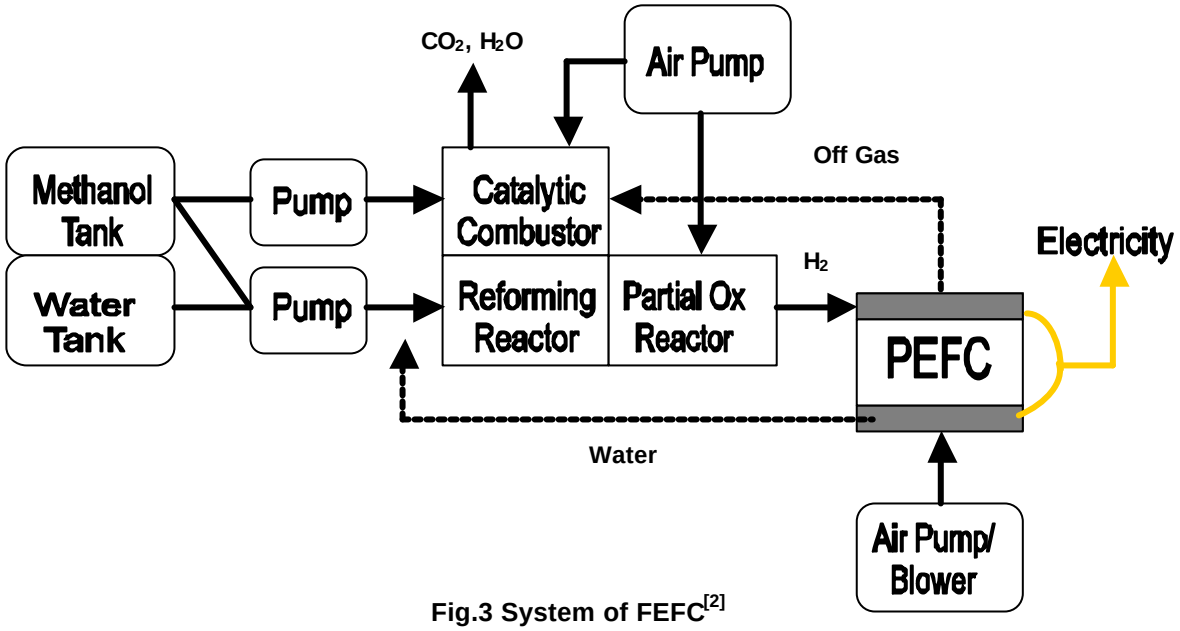

Fig.3 System of FEFC[2]

reformed from methanol and water in fuel reforming reactor. PEFC is more complex system than DMFC because PEFC needs fuel reformer and catalytic combustor, but PEFC has ten times as high power density as DMFC.

3. Challenges for developing small power sources

New small power sources introduced in section2 are not realized, because they have many problems with miniaturizing power systems. In this section, the problems of developing UMGT or MFC are shown and some counter-measures to solve are shown.

3.1.Problems to be solved UMGT

UMGT is so small gas turbine that thermal efficiency is lower than conventional gas turbine. Thermal efficiency of simple cycle UMGT is shown in Table.4. UMGT needs high rotor speed and heat-resisting materials to make UMGT highly efficient. UMGT's compressor is so small that rotor speed is about two million rpm to achieve requisite pressure ratio. High turbine inlet temperature, about 1600K, is required to achieve high thermal efficiency, so UMGT requires materials that endure high temperature. Further more, the combustor for UMGT has some problems, too. The four essential problems, which are practically ignored in conventional gas turbine combustors, must be solved in order to miniaturize a combustor. Those problems are relative increase of quenching region, high relative heat losses due to the high surface-to-volume ratio, and shortage of residence time by high combustion load, and flow laminarization that causes reduction of mixing rate.

Some studies have been tried in some institutes to overcome those problems. For enduring high rotor speed, the distance of

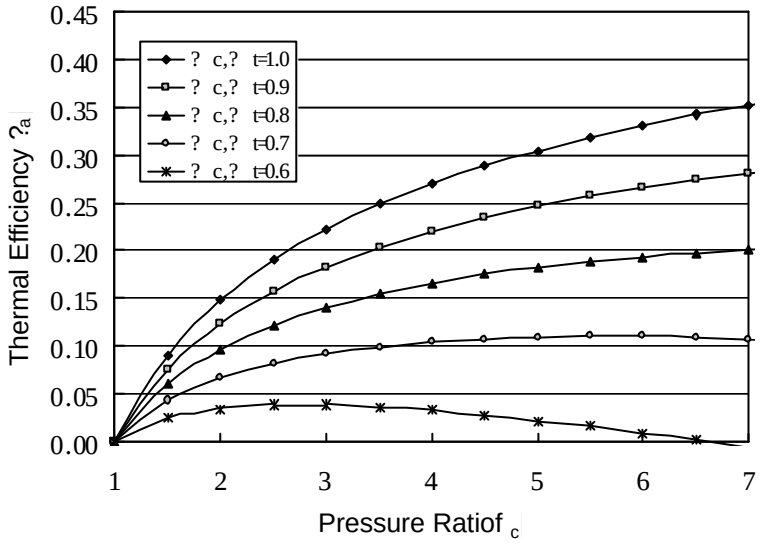

Table.4 Thermal Efficiency of UMGT

compressor and turbine is shortened, and air journal bearing has been developed. And UMGT made from SiC or Si_3N_4 have been studied, those materials can endure high temperature, about 1800K. And some kinds of combustors that are flat-flame combustor or high swirl combustor have been studied.

Thus, UMGT is at the stage where the component technologies are studied in any institutions. Rotor speed is 100,000 rpm in practically used micro gas turbine of about 3kW of outputs. Even if it takes only the rotor speed of UMGT into consideration, it is expected that it is difficult to realize it.

3.2. Problems to be solved MFC

In order to miniaturize fuel cells, the essential problems to be solved are as follows; keeping square of membrane and electrode large in downsized volume, fluid control for equal provision of hydrogen and oxygen, fluid control for provision of humid hydrogen in anode and dehumidifying cathode, and thermal control.

Many companies are challenging development of MFC now. The companies that proceed in technical

development or utilization are Toshiba, CASIO, Hitachi, Battelle, and Motorola. Especially Toshiba announced that they developed the smallest fuel cell system with direct methanol on June 24, 2004. Since MFC is trade secrets, neither a development situation nor its specification can be known in detail. However, this announcement from Toshiba makes ones expect that MFC is practically used in near future.

3.3.Problems of fuel portability

UMGT and MFC directly use hydrogen or use hydrogen reformed from methanol or hydrocarbon. Table.2 shows energy density of each fuel. Hydrogen has about 200 times as high energy density as lithium ion battery, and methanol has 30 times, butane has 80 times. However hydrogen needs high-pressure cases that are heavy without developing materials that effectively occlude hydrogen: metal-hydride, carbon-nanotube. Considering the weight of high-pressure cases, UMGT and MFC lose the advantage of higher energy density. So new materials are required for putting UMGT or MFC in practical use.

Table.2 Energy Density[3]

	Energy Density[kWh/kg]
Hydrogen	33.2
Methanol	5.4
n-Butane	13.3
Li-ion battery	0.17

4. The possibility of small power sources

New small power sources have many problems and many steps to be developed as shown in section3. This section shows that UMGT and MFC contribute to energy-accessibility in the sustainable society under the assumption of those realizations. It is assumed that the container using the metal-hydride and the carbon-nanotube for carrying hydrogen and methanol is also realized.

4.1. The possibility in developed countries

Technology rapidly progress in mobile and wearable electric devices or humanoid robots. Mobile and wearable electric devices are specially developing and their functions are increasing now. However, the battery used as those power sources now has small energy density, and it is unsuitable as power sources of those electric devices that need higher performance.

When UMGT and MFC are standard equipped as a power source of Note PC and a cellular phone, those electric devices were released from restrictions of energy density, and were highly computerized with high performance rather than present. Now, a Note PC needs to charge once in a couple of hours, and a cellular phone needs to charge once a day. However, carrying electric devices becomes possible in one refueling for a long time by equipment of UMGT or MFC, and their mobility is improved. Moreover, electric devices can be used in the area to which system electric power is not supplied only by carrying the fuel for supply.

Moreover, self-running robots, which are represented by ASHIMO of Honda, are considered to be used in the future for assistance at home or in dangerous works that people cannot do. Those robots have large power consumption and a power source with high energy density is needed. If a robot's technology progresses increasingly and UMGT and MFC come to be used as those power supplies, the time which a

robot cares for an old man or does civil work will come.

If small power supplies, such as UMGT and MFC, are put in practical use as this section has described, mobile electric devices will develop increasingly, and a robot will spread as an object for assistance of a human life. This is because the energy accessibility is improved by UMGT and MFC.

4.2. The possibility in developing countries

There are many areas round which infrastructures are not fully fixed and commercial energies, which are such as system electric power, have not spread in developing countries. In those areas, the further increase in population will be expected, and those who cannot access commercial energy are expected to increase. Those people cannot use light at night not to speak of electric devices.

It is assumed that UMGT and MFC come to be produced in large quantities at a low price and they come to be used as power sources of electric devices, such as a PC or a cellular phone. Electric devices can be used at any time without large-scale infrastructures just by adding fuel. The spread of small power sources will give exact information to people who cannot access commercial energy. Moreover, those power sources will give a chance to use electric devices to people who are not be settled like the nomad. Although this does not solve the energy accessibility fundamentally, comparative small electric devices can be used anywhere. Therefore, it is thought that UMGT and MFC become one solution that improves the energy accessibility of people who cannot use commercial energy.

5. Conclusion

The energy accessibility of comparative small electric products, such as a note PC, becomes good, and it comes to be possible to use them anywhere by spreading UMGT and MFC. However, UMGT and MFC have many problems that must be overcome and they are still the small power sources of research stages by the time they realize. Many subjects are left behind: it is necessary to solve the way for carrying fuel though UMGT and MFC are realized by the time they are generally used.

In order to realize and to spread the mobile small power sources that can be used anywhere at an early stage, the research organizations of each country have to tackle development. The government of each country should summarize those researches systematically, should squeeze out a budget, and should tackle for realization and spread of those power sources.

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