

Fuel Cell Technologies In China

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Abstract: Fuel cells are a kind of electrical generators, which are highly efficient and environment-friendly. So many countries have paid a great many attentions to this clear energy. As the second biggest consuming nation, China are studying and developing these technologies actively. This paper first briefly presented the developing history of fuel cell in China, then fuel cell technologies in China are discussed in detail, including proton exchange membrane fuel cell (PEMFC), solid oxygen fuel cell (SOFC), melt carbonate fuel cell (MCFC) and alkaline fuel cell (AFC). At last, this paper gives a prospect of fuel cell technologies in China.

Keywords: China; fuel cell; new energy; research and develop

1. INTRODUCTION

In 1970s, energy crisis and the pollution caused by fossil fuel becoming more and more serious, these made many nations to pay more attention to the research of clear energy and sustainable energy. As one great population nation, with the economic rapid development in recent years, China has been the world's second largest energy consuming country behind the USA. To meet the demand, Chinese organizations are making research on clear and sustainable energy technologies actively.

2. THE DEVELOPMENT HISTORY OF CHINA'S FUEL CELL TECHNOLOGIES

In 1958, China starting the research on fuel cells^[1], former Tianjin Energy Institute belonging to electron industry office was the first organization to develop MCFC. In 1970s, promoted by spaceflight project, the research on fuel cells in China appeared the first high tide. Then in 1990s, Chinese Science and Technology Ministry and Chinese Academy of Sciences placed fuel cell technology as the ninth five years plan's tackle key problem, which brought the second fuel cells high tide in China. Furthermore Chinese governments attached big importance to the development of fuel cells. In 1996 and 1998, Xiangshan meeting ever made special topic discussion for two times, and emphasized the importance and essentiality to develop fuel cell technologies independently. Especially with the rapid development of economy and the improvement of people's living standard, China strengthens the research on fuel cells. In the seventh five year plan, the eight five year plan, the ninth five year plan and the tenth five year plan, hydrogen energy project was included. Moreover in state's important technology-dynamolectric vehicle special project which government invests 800 million RMB, 300 millions is used to develop fuel cell technologies.

In recent years, China has made progress about fuel cell technologies in different aspects. Gradually it formed one specialty team, which is mainly consisted of universities' and colleges' researchers and Chinese Academy of Sciences and petrochemical industry sections etc to develop and research fuel cell technologies. Supported by National Natural Science Foundation of China, Administration of Science and Technology of China, Chinese Academy of Sciences and China National Petroleum Corporation, this team is responsible for many projects including the research program of National natural science foundation, high tech project of national '863' program, national key scientific and technological project and important project of Chinese Academy of Sciences. Chinese scientific researchers have done much trailblazing works such as hydrogen production, storage and utilization, and some intellectual property in hydrogen energy is attained. Some of research may well be said to have reached international advanced levels. Chinese present research in fuel cell fields is focus on PEMFC, SOFC and MCFC, especially PEMFC with the heaviest investment.

3. RESEARCHES AND DEVELOPMENT OF FUEL CELL TECHNOLOGIES IN CHINA

3.1 Research and Development of PEMFC

Changchun Institute of Applied Chemistry of China is the first organization to develop PEMFC. In the past few years, China enhanced the study of PEMFC. At present, there are many organizations in China which are developing PEMFC, and according to undercount, these organizations include Dalian institute of chemical physics, Changchun institute of applied chemistry, Shanghai institute of organic chemistry, Shanxi institute of coal chemistry, Tsinghua university, China University of Petroleum, Beijing institute of technology, Tianjin University, Shanghai Jiaotong University, Fudan University, Shanghai University and so on.^[2]

In 1990, Changchun Institute of Applied chemistry

took up the task to study PEMFC that belonged to China Academy of Sciences. The concentration was preparation of catalyst and electrode, development of methanol reforming equipment. Now prototype of 100W PEMFC has been made. And in 1994, research of direct-methanol PEMFC also carried out. This institute also built long-term corporation relationship with Case Western Reserve University of America and Hydrogen energy and Plasma Institute of Russia.

Beginning in mid-1990's, as the initiator, Dalian institute of chemical physics was engaged in research on fuel cell materials and fuel cell system and did many work about electrode and fuel cell structure. And now this institute has developed the fuel cell unit with 140cm^2 operating areas and with power density of $0.35\text{W}/\text{cm}^2$. Also different fuel cells and fuel cell systems has been carried out by this institute.

In 1993, the designing institute of nuclear energy technology of Tsinghua University began to develop PEMFC. The fuel cell unit made by it can supply $100\text{mA}/\text{cm}^2$ current density when output voltage is 0.7V. This institute also did research to improve the fabricating technique for asbestos current collector and brought forward the calendar PEMFC.

In 1994, with the support of Nation Natural Science Foundation of China, Tianjin University begin to develop PEMFC, mainly developing catalyst and electrode.

In early 1990's, Fudan University carried out the research about methanol-directed PEMFC, which mainly developed polybenzimidazole membrane and electrode.

Recent years, Xiamen University cooperated with the university of Hong Kong and Case Western Reserve University of America to develop methanol-directed PEMFC.

In 1994, work with Shanghai University, Beijing Petroleum University mainly developed catalyst, electrode and electrode membrane.

Funded by china arm industry ministry, in 1995 Beijing Institute of Technology began to develop PEMFC, which has worked out fuel cell unit with current density of $150\text{mA}/\text{cm}^2$.

In 1994, Institute of Engineering Thermophysics started to study PEMFC, with an emphasis on comparing various plans by the way of Numerical Heat Transfer and Computational Fluid Dynamics, which includes supplying gas, humidification, cooling and drainage. Then put forward its proposal for improvement of heat and mass transfer.

In 1997, supported by Fusan Foundation of Guangdong Province, South China University of Technology began the study of PEMFC, cooperating with National Science Committee. the technology that catalyst natural gas to carbon monoxide and hydrogen has been a patent.

Recently, Institute of Electric Engineering carried out the research on PEMFC system and running mode for vehicle. Furthermore this institute will cooperate with Research Institute for nonferrous metal to develop hybrid PEMFC-solar system.

In 1995, cooperating with New Energy Company of Canada, Beijing Century Fuyuan Fuel Cell Power Co.Ltd began to develop PEMFC, and prototype with various output power has accepted the order.^[3]

In 863 program of the Tenth Five Year, China set up a special program for electric vehicle, and will mainly develop new generation electric vehicle technology. The program is to develop the whole system individually for fuel cell car, fuel cell bus, hybrid electric car, hybrid electric passenger car and electric car. And power installation of fuel cell vehicle is PEMFC. A bus with 19 seats was made by Dongfeng Motor Corporation, running on the power set which consists of six 5kW fuel cell stacks generated by Dalian institute of chemical physics and the electric installation generated by. This bus has passed vehicle riding experiment. In 2000, Dalian Institute of Chemical Physics and Institute of Electric Engineering has gotten all fuel cell for vehicle experiments completed. Besides, with the support of UNDP Chinese Science and Technology Ministry executed feasibility study for fuel cell application in China. China will do extensive researches on Proton Exchange Membrane fuel cell cars.

3.2 Research and development of SOFC

Because of working under high temperature, SOFC faces one problem that was how to choose engineering materials. Nowadays in China, a lot of organizations began to develop SOFC, such as Dalian Institute of Chemical Physics, Shanghai Institute of Ceramics Chinese Academy of Sciences, Beijing Institute of Physics, Tsinghua University, Jilin University. But on the whole, research and develop level is lower. Many of these organizations just carried out substantial research. In the ninth five year plan, Chinese Science and Technology Ministry set develop of SOFC as one of tackle key problems.

As the first organization to develop SOFC in China, Shanghai Institute of Ceramics started study on SOFC in 1971, which emphasized on the research on electrodes and electrolyte materials of SOFC. In 1980s, under the auspicious of National Natural Science Foundation, this institute made systematic study on zirconium oxide membrane, electrodes materials, the structure of SOFC unit and it has primarily grasped the technologies to prepare stable zirconium oxide nanometer membrane and to make densification ceramics.

In 1989 supported by Jilin Young Scientist Foundation, Jilin University began to study about electrolyte and electrode materials. Also fuel cell unit was packaged and passed the appraisal of Jilin Science and Technology Commission. Since 1995, electrode, electrolyte, seal and connection material were developed successively. Radio and recorder could run properly on four fuel cell units, each unit with 1.18V open-circuit voltage and $400\text{mA}/\text{cm}^2$ current density.

Supported by Chinese Academy of Sciences, in 1991 Institute of Chemical Metallurgy (now called Institute of Process Engineering) started developing SOFC. Material was first studied and then tube and plate fuel cell units were made with $0.09\text{W}/\text{cm}^2 \sim 0.12\text{W}/\text{cm}^2$ power density, with $150\text{mA}/\text{cm}^2 \sim 180\text{mA}/\text{cm}^2$ current density and with 0.60V $\sim$ 0.65V voltage. In 1994, fuel cell stack with output from 20W to 30W was bought from Ural division of Russian Academy of Sciences, of which the life was 20 years.

After analyzing superincumbent bed structure SOFC of Russia, tube structure SOFC of American Westinghouse and plate structure SOFC of Germany, this institute designed new cube structure, which absorbed the merits of tube structure and was with metal felt connection and can be made by traditional ceramics.

- In 1982 University of Science and Technology of China began to develop solid electrolyte and mixed conductor. In 1992 with the support of National Natural Science Foundation and the 863 program, this university carried out the research on medial temperature SO fuel cells. One of them the electrolyte was zirconium oxide nanometer with 450 °C operating temperature. Another's electrolyte was proton conductor with 200mA/cm² current density. Moreover a new generation of porous ceramics-based SOFC is under studying.
- In the early 1990s Tsinghua University started studying SOFC. Solid electrolyte and air electrode was made successfully and the technology of plate SOFC forming and sintering was developed well.
- Supported by National Natural Science foundation, Natural Science Foundation of Guangdong Province, Li Ka Shing Foundation and Fushan Foundation of Guangdong Province, in 1992 South China University of Technology began to develop SOFC. Tube fuel cell unit was resembled, which operated with methane as fuel, at the maximum of 4mW/cm² and the current density of 17mA/cm². Running continuously for 140 hours, the unit had not apparent tendency to attenuate.
- In 1994 Dalian Institute of Chemical Physics began to develop SOFC and made great advances about electrode and electrolyte.
- With the support of National Natural Science Foundation in 1995 Beijing Institute of Physics carried out the basic research about the new style of electrolyte and electrode materials.

To realize SOFC commercialized in China, a lot of problems are still to be resolved, for example the efficiency of fuel cell unit and power of stacks are low and starting time is too long etc. The study on SOFC in China is still in its infancy. To accelerate the development of SOFC, the financial assistance from government should be enhanced and there should be more research and development personnel to work on it.

3.3 Research and development of MCFC

Since 1990s, supported by Chinese Science and Technology Ministry, National Natural Science Foundation and China Academy of Sciences, Applications basic studies of MCFC were carried out in China. But the studying level is relatively lower. Not many organizations in China are developing MCFC and the following are main research organization.

- With the financial assistance from China Academy of Sciences, Dalian Institute of Chemical Physics began to study MCFC. Membrane for MCFC was made from self-made LiAlO₂ micro-powder through the method of cold rolling and strip casting. Fuel cell unit was resembled, the quality of which

has come to the international level in 1980s.

- In the early 1990s, Changchun Institute of Applied Chemistry began to develop MCFC and made great advances in the preparation for LiAlO₂ micro-powder and in the application of mental compounds as anode of MCFC.
- In the early 1990s, supported by National Natural Science foundation University of Science and Technology began to develop MCFC. Interaction between electrode and electrolyte was the emphasis of the research.
- During the period of the eighth five year, Institute of Electrical Engineering CAS investigated the international demonstrations about MCFC. Also the running situation of these power stations was studied. And now the key technologies about MCFC power station are being researched and studied.
- At present, Shanghai Jiao Tong University and Shanghai Electric Group are working together to accept one project of the 863 program during the tenth five year plan. MCFC, which the power is 50kW and the fuel is natural gas, will be researched and developed.^[4]

3.4 Research and development about AFC

In China, developments about AFC systems are carried out mainly in two fields. One is in aerial field and another is in ground field. The main organizations are Tianjin Institute of Electric, Dalian Institute of Chemical Physics, Wu Han University, Wu Han Institute of Electric Science.

- The capital organizations that studied AFC system for aerial application are Tianjin Institute of Electric and Dalian Institute of Chemical Physics CAS. From 1960s to 1970s Tianjin Institute of Electric has been studying fuel cell system for aerial application. In 1970s, two types (A type and B type) AFC for aerial applications were made successfully by Dalian Institute of Chemical Physics. Liquid hydrogen and oxygen are the fuel of A type fuel cell which are also with water reused cleaned system. The compound gases with nitrogen and liquid oxygen that are produced by decomposition of hydrazine are the fuel of B type fuel cell. All of the two types fuel cells are passed the simulation exam under the aerial environment.
- AFC systems for ground application are under developing. According to the difference of fuel, there are many kinds of AFC. They are ammonia-air fuel cell, hydrazine-air fuel cell, -air fuel cell. In 1972 cooperating with Wu Han University, Wu Han Institute of Electric Science began to research and to develop the AFC for microwave relay station application and in 1976 ammonia-air AFC system was made successfully which was with worthy metal as catalyst. From 1978 to 1981 ethylene glycol-air AFC stack was made by Tianjin Institute of Electric. With the voltage in range of from 5V to 8V and the power of 2W, the stack was consisted of ten fuel cell units and ever applied as the power source of navigation mark light.

Short start time, efficient, and low cost are the

merits of AFC, but it is so strict with fuel that only pure hydrogen and oxygen are its fuel. Therefore in some special fields such as aerial field, deep-sea field AFC has its advantages, but the applications on ground are limited. So in China the research and development about AFC is not active as that about PEMFC.

4.CONCLUSION

Comparing with some developed countries such as Canada, America, Japan, the development of fuel cell in China is relatively low. But in China the worth of the technologies of fuel cell has been realized and a plenty of funds have been invested in the study of fuel cell. In China many researchers especially researchers in universities and colleges have taken part in the development of fuel cell actively. Invests and researcher in China have reached certain level, especially the research about PEMFC, which has step up in commercialization stage. The research and study of foundational technologies is the key for the

development of fuel cell. Only after improving the efficiency, prolonging operating life and reducing cost, the extensive application of fuel cell can be realized. So in China more study should be made on the foundational technologies to promote fuel cell technologies and to spread the application of this new clean energy.

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