Chapter 14
Possibilities of Using Fuel Cells in Transport Aircraft

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14.1 Introduction

Nowadays, it brings many global problems that humanity must address urgently. One of the most serious problems is the global warming of the atmosphere due to its pollution by human activities. The aviation also contributes to the pollution of the atmosphere. Their share will continue to increase with the emerging air traffic. By 2050, the share of aviation emissions is expected to reach 3%.

The issue of environmental protection in the activities of transport aviation is addressed at the global level, but also in the European Union. The ICAO International Civil Aviation Organization, at its General Assembly, accepted responsibility for the environmental impact of aviation and adopted three basic objectives in this area:

Reduction or reduction of air pollution on local scales;
Limiting or reducing the number of people affected by sound pressure;
Limiting or reducing the impact of greenhouse gas emissions on the global climate.

The International Air Transport Association (IATA) has adopted a four-step strategy to reduce emissions from aviation to improve the quality of the environment. Table 14.1.

Within Europe, research and technological development framework programs (until 2013) and the European Union's research and innovation framework programs have been key in Europe. These multi-annual programs, launched in 1984,

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Table 14.1 Four-step emission reduction strategy

Technology	Operations	Infrastructure	Biofuels and economic measures
New aircraft and engine kite technologies	Improved operating procedures	More efficient air traffic management	Global offset mechanisms
Modernization	More efficient flight procedures	More efficient airports	Positive economic incentives
Sustainable aviation fuels	Weight reduction		Public-private initiatives

included specific programs covering areas such as information and communication technologies, the environment, energy, biotechnology, transport, and researcher mobility. For aviation research, the total funding under the seven framework programs 960 million EUR and another 800 million EUR were allocated to the Clean Sky Joint Technology Initiative in the field of environmental protection. This program is one of the largest and most important European aviation research programs, which was launched in 2008. Since 2014, this program has been referred to as Clean Sky 2. Under the European Horizon 2020 program in the field of aviation, one of the main objectives is accelerate aviation innovation and strengthen its leading role in shaping the future of aviation. Horizon 2020 provides funding for, inter alia, Joint Technology Initiative partnerships with industry, including the member Sky second program and the Fuel Cells and Hydrogen second program.

14.2 Fuel Cell Development

The concept of the first fuel cell was developed in 1839 by William Judge, a British judge, scientist, and inventor of the forces, who discovered that it was possible to generate electricity by an inverse process for electrolyzing water. Its fuel cell had platinum electrodes placed in glass tubes, the lower end of which was immersed in an electrolyte (sulfuric acid) solution. The closed top was filled with oxygen and hydrogen. The voltage of such a cell was approximately 1 V. The vessel in which the electrolysis of water took place served as an indicator of the generated electrical voltage and current. The whole facility did not produce enough electricity to be suitable for industrial use.

The title “fuel cell” was first used by Ludwig Mond and Charles Langer in 1889, who tried to create a functional air and light-cell cell.

In 1932, he developed the first successful fuel cell device. The oxygen-hydrogen cell used cheaper nickel electrodes (Renewable resources 2003). The acid electrolyte was replaced by an alkaline electrolyte, which had no corrosive effect on the electrodes. A fuel cell with an output of 5 kW was created during the year.

Fuel cells were first used in the 1960s. At the time, NASA used fuel cells manufactured by Pratt & Whitney as a source of electricity for the Apollo spacecraft. This has become the impetus for the intensive development of fuel cells [5] (Fig. 14.1).

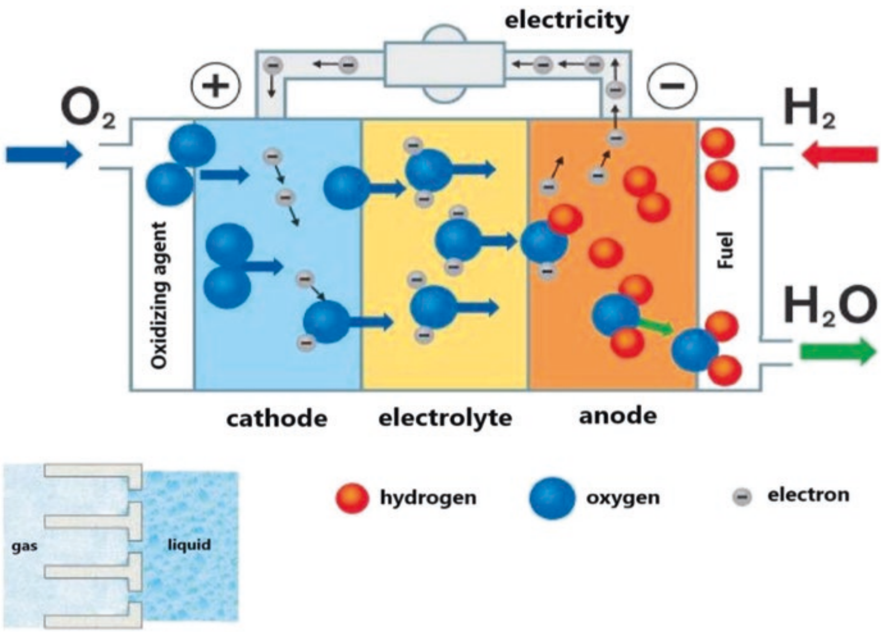

Fig. 14.1 Fuel cell operation principle

A fuel cell is an electrochemical device that converts the chemical energy in the fuel directly into electrical energy, much like a battery. This direct energy conversion makes it possible to achieve higher electrical efficiency (up to 60%) compared to conventional energy sources.

14.3 Possibilities of Using Hydrogen in Aviation

Many years ago, hydrogen was identified as an energy source that represented a sustainable, safe, cost-effective, environmentally friendly energy system. Hydrogen is one of the three basic options for green transport, which include, in addition to the use of hydrogen, the use of biofuels and electric propulsion. Unlike other options, hydrogen does not require high arable land, as is the case with biofuels, nor heavy batteries, which require a long charging time.

Hydrogen is considered a preferred source of energy. It can be used for the ecological production of electricity in fuel cells or directly burned in internal combustion engines, which significantly reduce harmful emissions. The direct combustion of liquefied hydrogen in the modified combustion chamber of the NK-88 twin-jet aircraft turbocharger engine was practically tested on 15 April 1988 on the Soviet Tu-155 aircraft (Fig. 14.2).

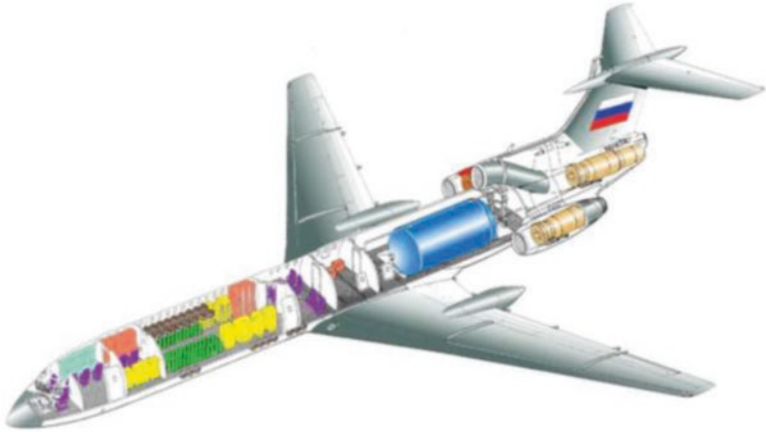

Fig. 14.2 Tu-155 aircraft with one NK-88 engine, in which hydrogen was burned

The climatic benefits of hydrogen burned in the combustion chambers of aircraft turbochargers are questionable. Compared to conventional turbocharged engines, which burn kerosene, they produce twice as much water vapour, which contributes significantly to the greenhouse effect and contributes to global warming. This effect is even more unfavorable because water vapor is produced at high altitudes, where water vapour in the form of ice crystals is maintained for a much longer time. It is assumed that there will be no direct combustion of hydrogen in the aircraft turbocharger engines of commercial aircraft by 2050.

Although the principle of operation of hydrogen fuel cells has been known for a long time, the development of their applications for the needs of industry, automotive and aviation is slow. Only recently, due to strong environmental pressure, has their development accelerated. The reasons for this development are the high costs of implementing this new technology, the problems with hydrogen storage, the lack of infrastructure, as well as the use of precious metals. An important factor that, in addition to price, will have an impact on the expansion of fuel cell technology is functional reliability.

14.3.1 Aviation Fuel Cells

The environmental goals for sustainable aviation infrastructure set by the European Commission in the "Flight Path 2050" vision are forcing the largest aircraft manufacturers to seriously address the issue of reducing carbon dioxide emissions by 75% and nitrogen oxides by 90%. One possible solution to this problem is to focus on the use of hydrogen.

The development of any device intended for use in air traffic is a very demanding process that goes through a testing phase to meet strict aviation regulations. The use

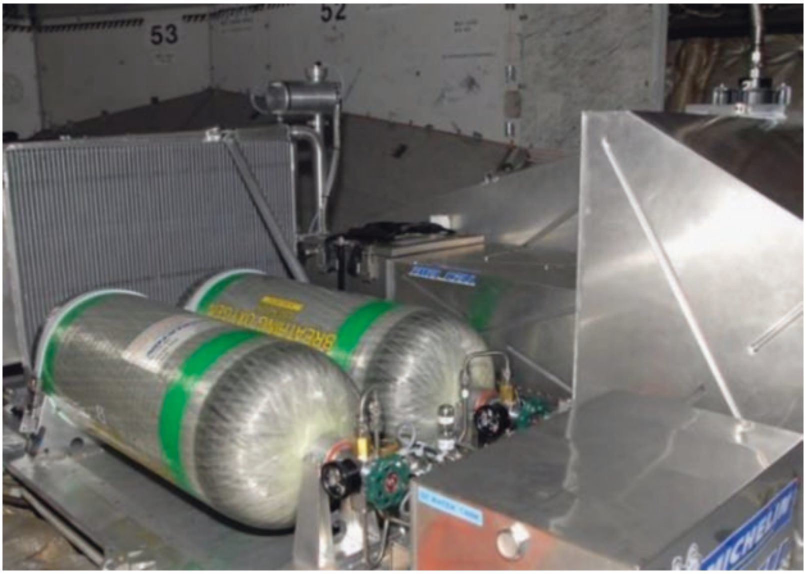

Fig. 14.3 Test installation of a test fuel cell in an Airbus A320

of a fuel cell on board a transport aircraft is currently being tested on several different projects. An example is the project of using a fuel cell on board an Airbus A 320 ATRAC. The final state of the project envisages the complete replacement of the turbine auxiliary power unit of the aircraft with an electrical output of 100 kW for the needs of the aircraft with a fuel cell (Fig. 14.3).

This testing was successful in 2008. A low temperature Michelin Polymer Electrolyte Fuel Cell (PEFC) fuel cell was used in collaboration with the Institute for Technical Thermodynamics of the German Aerospace Centre.

During testing, the fuel cell was installed in the cargo hold of the aircraft. In this phase of testing, hydrogen and oxygen were stored in separate composite pressure tanks. The fuel cell was designed for an electrical output of 25 kW. The fuel cell powered the electric pump of the backup hydraulic circuit to control the rudders of the aircraft.

14.4 Conclusion

The further development of transport aviation will be largely limited by the emissions produced by aircraft engines. The requirements, which are defined for the amount of these emissions as defined in ICAO Annex 16, Volume 2, will be constantly tightened in the future. The solution to this problem is the use of new technologies, including the use of hydrogen and fuel cells.

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