Application and design of a new high power and multi propeller hybrid aircraft

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Abstract. This paper describes and explained a new hybrid system that could be used in the multi propeller aircraft. This new hybrid system solved the problems of fuel cost and environmental protection of traditional fuel aircraft, as well as the endurance and load of pure electric aircraft.

1. Background Introduction

So far, global pollution and energy problems have gradually affected our daily life. All walks of life are actively adjusting the future development direction. In particular, the transportation and transportation industries put forward higher requirements in this regard. Nowadays, major brands in the automotive field have launched more mature products, such as the more representative works such as the Nissan Sentra and other hybrid vehicles. With the introduction of more mature products, more hybrid modes have also been proposed. For example, oil power generation and hydrogen power generation are used in some mainstream products. In the future, electric energy will become an irreplaceable energy and will be used in more fields. However, in recent years, the aviation industry has not made such mature new energy products in this regard. Because the aircraft needs high reliability and other requirements only exist in the experimental and theoretical stage. The earliest application of hydrogen energy in aircraft was in january1989. Tu-155 was equipped with a low-temperature LNG engine. The results of the first flight showed that the fuel consumption was about 15% lower than that of kerosene, and the fuel economy of the airliner was significantly improved. The aircraft was later tested using liquid hydrogen as power. Five successful flights have proved the feasibility of using hydrogen energy on aircraft. Although this technology could not be popularized at that time, in modern times, more people and companies saw the potential of this technology and continued to develop. For example, Boeing manufactured and tested the first modern small hydrogen powered aircraft in 2008. The aircraft has been improved on the original technology and its stability and reliability have been further verified. However, this technology is more used in small aircraft. This type of aircraft has a very limited load and ceiling, and it cannot be used as a mainstream commercial aircraft in the future. Therefore, this essay will combine the advantage of hydrogen energy extended range system on the existing new energy vehicles, transform and finally adapt to the multi propeller aircraft. Today, there are relatively mature extended range systems for vehicles in the market. The hydrogen energy hybrid system can simultaneously have the advantages of low emission, low noise and high torque of the pure electric system. And solved the problems of high cost, high weight and low endurance of the pure electric system. It is the best transition product from the fuel age to the pure electric age. So far, the system has achieved good results in the vehicle market. This paper will focus on the application and scheme of a complete set of hydrogen energy extended range system in multi propeller aircraft.

2. Operation

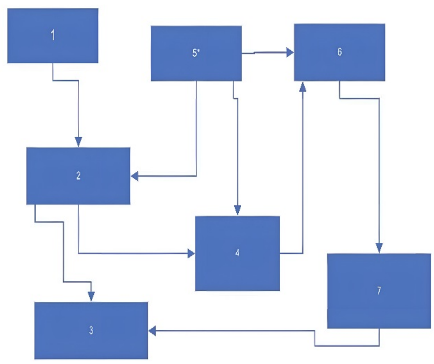

Fig.1. The operation of the hybrid system
1. Compressed hydrogen 2. Hydrogen and oxygen reaction device 3. Power battery 4. Brine bin 5.oxygen generation system 6. Water circulation system 7. Stirling engine / thermoelectric generator

2.1. The hydrogen energy range extender will be the main power source on the aircraft

It consists of seven parts. When on the ground, inject compressed hydrogen and replace the oxygen generation system as required. After the aircraft is started, compressed hydrogen and oxygen will enter the

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hydrogen oxygen reaction device to generate electric energy. Due to the lack of oxygen content in the high altitude, after the aircraft reaches a certain altitude, sodium chlorate and iron will react chemically to produce oxygen and input it to the hydrogen oxygen reaction device to generate sufficient electric energy. The oxygen generation system will be controlled by computer to generate enough oxygen only under appropriate working conditions. The hydrogen oxygen reaction device reacts oxygen with hydrogen to generate electric energy and store it in the battery. The salt produced in the process of producing oxygen and the water produced in the hydrogen oxygen reaction device will converge to the brine bin. Part of the salt water will be used to cool the battery. The remaining salt water will enter the water circulation system and circulate inside the wing to absorb the cold air on the wing surface. After that, the cold water will be brought into the Stirling engine to generate electricity. The biggest difference between this extended range system and the existing extended range system is that an oxygen reacting system is added. Sufficient oxygen can make the aircraft using the extended range system have a larger practical ceiling and speed up the aircraft. The use of sodium chlorate and iron will meet the reliability requirements of aircraft. By using compressed hydrogen to generate electric energy, compared with using liquid hydrogen to directly input it to the turbojet engine for combustion, the extreme temperature requirement for storage of liquid hydrogen and the danger during combustion is avoided. By adding Stirling engines, the waste of energy can be reduced and converted into electrical energy for aircraft use.

2.2 The oxygon reaction device

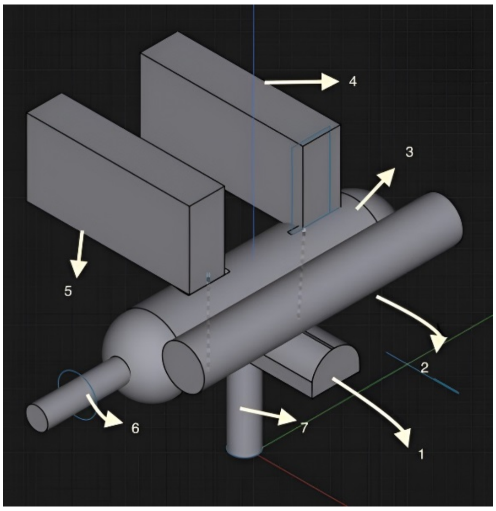

Fig.2. Design of the oxygon reaction device
1.Reusable detonator 2.Copper pipe 3.Combustion chamber 4. Iron powder 5. Sodium chlorate 6. Oxygen 7. Salt

Due to the scarcity of oxygen in the air, in order to absorb as much electrical energy as possible, oxygen production equipment is very important. Its existence determines the efficiency of the extended range system, and allows the aircraft to fly to higher airspace to obtain better aerodynamics. [8]The system solves the problem of raising limit of small hydrogen powered aircraft and improves its practicability. In this oxygen production system, iron powder and sodium chlorate will be used as oxygen production materials. When the aircraft reaches to the place where the oxygen content is much lower than usual, such as plateau or stratosphere. The flight computer will operate the valve as needed to release a certain amount of iron powder and sodium chlorate and start the reusable detonator to ignite the raw materials in the combustion chamber.

According to $2Fe_2O_3$+$NaClO_3$-(heating)-$3O_2$ +NaCl

This method of oxygen production is called oxygen candle. Theoretically, its stored oxygen density is as high as 45%, and 1L oxygen candle contains 798[1]oxygen.therefore, it is now widely used in the field of emergency oxygen production. This method can produce a large amount of oxygen in a short time. According to the experiment, about 2600 liters of oxygen can be produced in about 60-90 minutes. By controlling the input of raw materials into the combustion chamber, a large amount of oxygen can be provided to the hydrogen oxygen reaction device when needed to generate enough electric energy to drive the aircraft. Once the chemical reaction is started, the combustion chamber will produce a high temperature of about 600 degrees Celsius. By connecting copper tubes around the combustion chamber, this heat energy is transferred to the Stirling engine and electricity is generated again. After the reaction, salt will be produced in addition to the required oxygen. In this hydrogen energy hybrid system, the salt branch is combined with the water produced by the hydrogen oxygen reactor and used in the water circulation system. To make this chemical reaction controllable, the biggest problem relies on the dose of raw material input. The burning amount is too small, and the oxygen candle cannot burn continuously. The burning amount is too much, which will cause side reactions and lead to oxygen pollution. [2]. Pure oxygen is the prerequisite for the hydrogen oxygen reaction device to generate electric energy, so the intervention of flight computer will be very important. The involvement of more computer works can also make aircraft more intelligent and more convenient to manage, which is another goal pursued by the aviation industry at present.

2.3 The Battery

As an energy storage method of new energy vehicles, energy storage batteries have always had various technical problems. So far, the main problems are energy storage density, battery material, battery stability and battery weight. According to the the graph of the article that compares each batteries, it shows that due to different battery materials and technologies, each battery has its own advantages in these problems.[3]

However, due to the requirements and limitations of stability and weight on aircraft, only a few batteries can be successfully used on aircraft. For example, solar drones is a relatively mature field in which such batteries are widely used.[3]

According to the energy density and power density model, lithium batteries stand out among many batteries and become the most suitable battery for new hybrid aircraft. These problems are also reflected in this multi propeller hybrid aircraft. For large aircraft, the power consumption will be much greater than that of ordinary small aircraft. Therefore, lithium battery can be used as the most suitable way of energy storage.

3 Introduction to the background of energy recovery

For large new energy powered aircraft, the use of energy will be very important. So far, in addition to hydrogen powered aircraft, solar powered aircraft have formed relatively more mature technologies. In the solar aircraft, Airbus zephyr s and sunglider of HAPS mobile have completed a series of long-term stratospheric flight experiments. Among them, Airbus zephyr s completed a total of 6 test missions in 2021, with an average of about 18 days per flight [5]. This experiment confirmed the possibility and reliability of solar powered aircraft.

Beside that, there are a lot more solar powed drones been developed around the world.[6]Therefore, it is a good choice to use solar energy as part of the energy recovery system of the aircraft in order to solve the endurance short board of the multi propeller hydrogen powered aircraft.

3.1 application of solar energy collection system

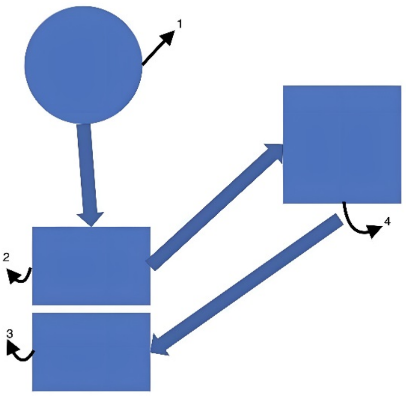

Fig.3. Explanation of the solar energy system
1. sun light 2. Front of solar panel (n-type semiconductor)
3.Rear of solar panel (p-type semiconductor) 4.energy storage[4]

Installing solar panels on aircraft to generate electricity is the mainstream method of solar energy generation so far. The efficiency of the starting point will vary according to the flight altitude and speed. The faster the aircraft flies, the higher the altitude, and the greater the efficiency of solar power generation. [7] Matching with a suitable solar battery can increase its efficiency. Lithium battery has long service life, no memory effect, convenient maintenance and no pollution, so it can be used as the preferred material for power battery. [7] Therefore, solar power generation can be adapted to multi propeller hydrogen powered aircraft. Taking C-130 as an example, its wingspan area is 162.12 square meters. If the power of each solar panel is 150 watts and the efficiency is assumed to be 20%, the power generation efficiency per square meter can be obtained when the illumination time in a day is 7 hours (750w*0.2=150w) (0.15w*7h=1.05) and on C-130 aircraft (1.05*162.12= 170.226). Under different weather conditions, the efficiency of solar power generation may be different from the ideal state.

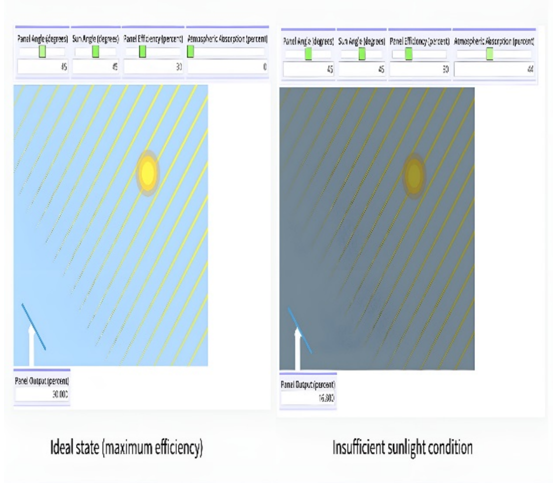

Fig.4. Simulation of the solar energy system

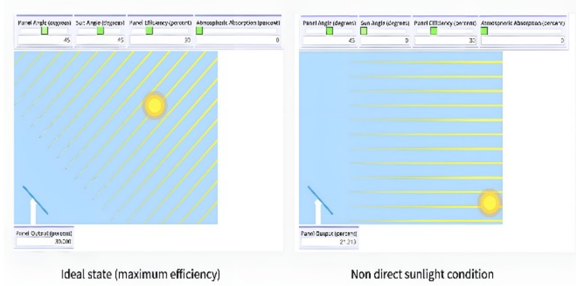

Fig.5. Simulation of the solar energy system

The efficiency of solar energy is also related to the area of solar panels, so solar energy harvesting on aircraft with larger wingspan will more reflect its advantages. Although the solar energy collection method does not have high environmental requirements, its energy conversion efficiency is only about 20%. In contrast, the energy conversion efficiency of the propeller can be greater than or equal to 70%. [7]

3.2 Propeller energy recovery system

In order to improve the efficiency of aircraft energy collection and take advantage of the high efficiency of propeller energy conversion, the other part of the energy collection system is propeller energy collection. So far, the most popular mechanical propeller energy collection system on the market is ram air turbine system, which is a foldable small propeller. In case of emergency when the aircraft loses power, it will be automatically released, and the propeller will be driven by the air flow to generate power for the aircraft instruments, so that the pilot can make an emergency landing. This principle can be applied in the multi propeller hydrogen power system and the kinetic energy of the aircraft can be recovered.Ram Air Turbine,By improving the system and applying it to a higher power energy recovery system, more electric energy can be recovered.

Use a 4-propeller aircraft as an example.

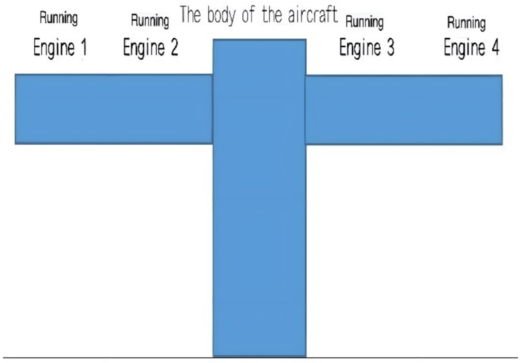

Fig.6. Propeller energy recovery system (Take off)

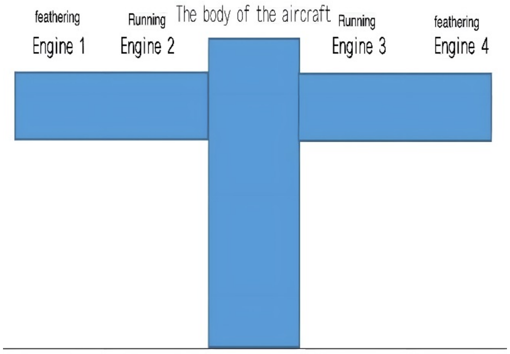

Fig.7. All engines generate power (Cruising)

1 and 4 engines will be feathered, and 2 and 3 engines will work normally.

According to the working conditions (load, wind direction, etc.), the thrust of 1 and 4 engines should be appropriately increased in case of upwind or high load.

According to the working conditions (load, wind direction, etc.), when it is necessary to slow down, start 1 and 4 engines and reverse the propeller to obtain resistance and additional energy.

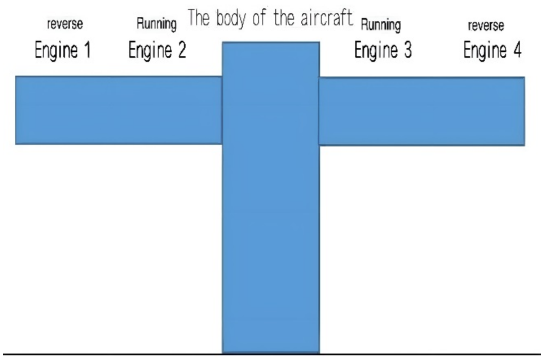

Fig.8. Propeller energy recovery system(Descending)

1 and 4 engines reverse to generate resistance and start energy recovery. Engines 2 and 3 work normally.

Through this design, the aircraft can recover as much energy as possible during the flight and convert it into electrical energy for use by the aircraft. Especially in the descent stage, the system can ensure that the aircraft can generate electric energy while obtaining resistance deceleration. Compared with traditional aircraft, this power system can better utilize and recover energy under more working conditions

4. Conclusion

This power system solves most of the problems in the current civil aviation industry by using compressed hydrogen and generating electric energy to promote the operation of aircraft. It combines the advantages of current fuel aircraft and pure electric aircraft, so it can put forward an ideal model for civil aircraft in the next 20 years. In the future, when human battery technology is upgraded to a new level, pure electric or hydrogen hybrid power systems will provide power for mainstream aircraft. The hybrid system proposed in this paper can be regarded as the best transition product from now to the future.

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