The Influence of Hybrid Power System on UAV Endurance

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Abstract. With the wide application of UAVs in various fields of society, some shortcomings of UAVs are gradually exposed, especially the shortcomings of power sources make the endurance range and time limits of UAVs, which seriously restricts the development of UAVs industry. Through careful comparative study, this paper proposes that the use of hybrid power system will bring greater application value to UAVS. It is mainly reflected in: (1) Compared with pure electric power, the use of high energy density and specific energy fuel will significantly improve the navigation distance; (2) Compared with pure oil-driven power, the introduction of electric motor can keep the engine always working in the optimal state, effectively reduce engine fuel consumption and increase fuel efficiency. The hybrid power system ensures the efficiency and feasibility of the power system as much as possible, and is an efficient and reliable power form applicable to the whole scene application field at present.

Keyword: Drones; Hybrid Power System; Endurance.

1 Introduction

In recent years, with the UAV gradually becoming a hot research direction, its related technologies in all aspects are becoming more mature. However, the endurance time of UAVs is always a very significant shortcoming, and it has not been filled up so far, which seriously restricts the use scenario and scope of UAVs. At present, most UAVs use batteries as a power source, and their endurance time is affected by a variety of factors, including mechanical efficiency, battery capacity, battery energy density, ambient temperature, and altitude. One of the most critical factors is the battery energy density. The flight duration of drones is usually concentrated in 20-60 minutes. Considering that the battery accounts for a relatively large proportion of the overall mass of the UAV, if the battery capacity is simply increased to improve the endurance of the UAV, the battery quality will also increase, and the power consumed by the UAV will also increase accordingly. In order to improve the endurance of the UAV, it is still necessary to improve the battery energy density. However, the improvement of battery energy density is facing a technical bottleneck. Oil-powered drones are powered by fuel, and the energy density of fuel is much higher than that of batteries, so oil-powered

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drones can have extremely long endurance. On the other hand, due to the shortcomings of slow start, low energy conversion efficiency, nonlinear relationship between speed and fuel consumption, complex engine structure, difficult heat dissipation, loud noise, and environmental pollution caused by fuel combustion, its application scope is also limited. Hybrid UAV can improve the endurance at the same time, can provide an effective solution to the above problems.

This paper mainly analyzes the hybrid power system to improve the endurance of UAVs, first introduces the basic principle of hybrid power system, analyzes its components, functions and working principles, and points out its application advantages in UAVs; Secondly, the difference between traditional power system and hybrid power system is compared, how hybrid power system can improve the endurance of UAV by optimizing energy management is analyzed, and the practical application of hybrid power system to extend flight time is illustrated. Then the effects of hybrid power system on other aspects of UAV performance are discussed. Finally, the technical difficulties and challenges in the application of hybrid power system in UAVS are pointed out, and the development trend is analyzed and suggestions for continuous improvement and optimization are put forward.

2 Basic Principle and Composition of Hybrid Power System

2.1 Basic Concept of Hybrid Power System

Hybrid power system refers to the traditional engine (piston engine, gas turbine engine) to drive the generator to generate electricity, together with the energy storage device (lithium battery, etc.) to provide power for the motor, and the motor drives the propeller, fan or rotor to provide most or all of the new form of propulsion [1]. The hybrid power system includes an engine that is easy to achieve long endurance cruise, as well as a motor with high thrust-to-weight ratio and good control performance, which combines their advantages and is an efficient, flexible and reliable propulsion method.

2.2 Components and Functions of Hybrid Power System

The power system can be the "heart" of the UAV, is the necessary prerequisite for the UAV to complete the takeoff and landing and cruise, which is mainly composed of three parts: power source, power motor and speed regulation system, and the power motor and speed regulation system are determined according to the performance parameters of the power source, so the most important component of the UAV power system is the power source [2]. The UAV hybrid power system consists of an engine power generation system, a power battery system and a hybrid power management system connected with the engine power generation system and the power battery system respectively. The hybrid power management system is connected to the generator generation system through an ECU module and the power battery system through a BMS module. The hybrid power management system manages the overall energy according to the flight condition of the UAV. First of all, the hybrid power management system stores the demand for electric energy under different working

conditions. According to the real-time collection of the electric energy state of the generator generation system and the power battery system, combined with the demand for electric energy under the working condition, the charging path is allocated [3].

2.3 The Principle of Hybrid Power System and Its Advantages In UAV

The power management system of the UAV is essentially the same as the power management system of the electric vehicle and the management system of other power supply systems. The difference is that the selection of device parameters, the way of processing and the setting of working mode need to be adjusted according to different electrical equipment. Power management systems can also be seen as power management systems. The application of power management system is to improve the power utilization efficiency more effectively, rationally allocate and optimize the power consumption of electrical equipment system; Excellent power management control technology can greatly extend the power consumption time of the system according to the power utilization of the power load, and at the same time can prevent the damage of the power system and the power supply battery, and maintain the stability and safety of the system operation [4].

Under the current technical level, hybrid power system is an excellent scheme that combines high efficiency and performance, can truly realize the personalized design of UAV, and has obvious advantages in the application of UAV. On the one hand, the use of hybrid power system greatly expands the freedom of aircraft design and brings the possibility of greatly improving the overall performance of aircraft. The "scale independence" feature of electric propulsion can change the current centralized power form (single, double, four) into distributed propulsion according to needs, and realize the overall improvement of aerodynamic, noise and propulsion efficiency through the optimal integration of aerodynamic, structural, and dynamic forces. On the other hand, the hybrid power system realizes the integrated design of the power and the aircraft, and realizes the synergistic value-added benefits. Although the hybrid power system may be heavier, more complex and less efficient than the traditional power system, the performance improvement brought by the hybrid power system is very significant when considering the overall aircraft [1].

3 Hybrid Power System to Enhance the Endurance of UAV

3.1 Difference Between Traditional and Hybrid Power System

The power system of traditional UAVs mostly uses a single power source, such as internal combustion engines such as gasoline engines and heavy oil engines, or chemical batteries such as lithium batteries and nickel-chromium batteries. When chemical batteries are used as a single power source, there are shortcomings in battery life, system energy density, and infrastructure requirements. When the internal combustion engine is used as the propulsion form of a single power source, there are still shortcomings in terms of noise, vibration and emissions. The hybrid power system using fuel and battery dual power sources can effectively make up for the shortage of

single power source by adjusting the output of the dual power sources when facing the complex operating environment. Therefore, petrol-electric hybrid power systems are becoming one of the best solutions for UAV power systems [5].

3.2 Improve Endurance of UAV by Energy Management Optimization

Since there are two or more power sources with different power output characteristics in the hybrid power system, it is necessary to coordinate and distribute power output through energy management strategies and methods under different working conditions and tasks to reduce power system energy consumption and improve the endurance of the UAV. Energy management strategy and Power Control Unit (PCU) can be used. To achieve efficient operation and low carbon emissions of hybrid power systems. Traditional energy management strategies are generally divided into rule-based energy management strategies and optimism-based energy management strategies, such as rule-based energy management strategies such as finite state machine, which have simple and clear design logic, and have been widely used in various hybrid power systems. Rule control generally sets the corresponding control threshold, compares the actual state of the system with the threshold value as the system input, and determines the energy management according to the state, which has high real-time and operational reliability. Equivalent Consumption Minimum Strategy (ECMS), The energy management strategy based on optimization is to realize the optimal control of the system by modeling and analyzing the internal operation law of the power system and solving the optimal output and control of the system under different conditions with mathematical calculation. Therefore, the energy management strategy based on optimization has higher control precision and better effect. Considering the complexity and safety of the relevant power plant operation, simulation test platform should be built for the relevant system to conduct simulation tests in the process of energy management strategy research to verify the reliability and effectiveness of the strategy [5].

3.3 Measures to Extend the Flight Time of UAV

At present, the main factor restricting the flight time of UAVs is the power system, the use of battery as a power of UAVs, the operation task is limited by the energy density of lithium batteries, and the influence of low temperature environment to accelerate the discharge, making the sailing time is very short. Battery technology is difficult to have a qualitative breakthrough for a long time in the future, and the battery life caused by the use of battery power is difficult to solve. The energy density of fuel is more than ten times higher than that of lithium batteries, and fuel engines are theoretically a better solution than batteries in driving. However, the linear throttle of the engine is very complicated, and the speed regulation procedure is cumbersome, resulting in a slow response speed of the UAV. The speed of the engine under the optimal output power is very narrow, and the gearbox needs to change the gear ratio to adapt to different speeds, which will increase the design size and weight of the UAV. Therefore, the practical oil-driven UAV drive scheme is extremely difficult. In terms of technical difficulty and work efficiency, the hybrid technology driven UAV is one of the most promising

breakthroughs for industry users at present. Hybrid technology not only has the stability and ease of handling of electric drones, but also has the sustainability of oil mobility, which can be applied to long endurance and large load operations [6].

4 Other Effects of Hybrid Systems on UAV Performance

4.1 Effects of Environmental Conditions on Hybrid Power System of UAV

Environmental conditions have an important impact on the flight process of UAVs. For VTOL mode, environmental wind will increase the power required for UAVs to keep hovering, while gust will affect the flight attitude of UAVs. In fixed-wing flight mode, UAVs' power fluctuation will increase significantly. Wind and wind direction also have a significant impact on the power output of the drone. Therefore, the UAV conducts flight tests in a high wind speed environment, and the hybrid power system can meet the power requirements of each flight state of the UAV. However, compared with low wind speed, the fuel cell load increases and the system efficiency decreases [7].

4.2 Impact on Maintenance Cost and Environmental Performance of UAV

The use of hybrid technology can greatly improve the endurance time of the UAV, not only retains the high energy density of gasoline fuel, but also has the characteristics of flexible operation, simple structure and strong reliability of the electric UAV. A wide range of applicable environments, can be used in the environment of minus 20 degrees to 40 degrees above zero can be normal application; It can bring more power to the on-board equipment; It is no longer necessary to frequently replace the UAV battery, simplify the procedure of using the UAV, and greatly reduce the use cost and maintenance cost of the UAV [6]. At the same time, this power system can greatly reduce fuel consumption and harmful substances emissions, and because of the reduced use of batteries, as far as possible to reduce the impact on the environment, to achieve environmental protection purposes.

5 Discussion

5.1 Overview of Global Hybrid Power System Research

Europe and the United States and other countries attach great importance to the research and development of hybrid power systems, especially distributed propulsion systems, and have given a lot of support through various projects and plans, and have accumulated a lot of theoretical technology and engineering experience, and have high expectations for its application prospects. The European Union has continued to advance multiple hybrid projects, and the United States has continued to carry out efficient and reconfigurable hybrid power management/small unmanned systems and large unmanned aircraft hybrid distributed propulsion system research work since 2016, the United States Air Force Research Laboratory (AFRL). This paper mainly analyzes the hybrid power system to improve the endurance of UAVs, first introduces the basic

principle of hybrid power system, analyzes its components, functions and working principles, and points out its application advantages in UAVs; Secondly, the difference between traditional power system and hybrid power system is compared, how hybrid power system can improve the endurance of UAV by optimizing energy management is analyzed, and the practical application of hybrid power system to extend flight time is illustrated [1].

5.2 The Challenges of Hybrid Power System in UAV Application

During the flight of UAV, there are many factors that affect the range and endurance of UAV, such as UAV geometry, UAV self-weight, payload, flight speed, flight form, meteorological conditions in the navigation area (air pressure, temperature, wind direction, wind speed, etc.), UAV control law, and UAV navigation mode (manual guidance, autonomous navigation) [8]. Since the UAV with hybrid power system has two power layout forms and two or more energy sources, its supporting power system needs to have the following two characteristics: First, stable and reliable multi-system coupling relationship, so that the UAV can cope with different task requirements. The second is the efficient working mode design to give full play to the advantages of multi-source hybrid propulsion UAV and improve the energy utilization rate of the whole machine [9]. In addition, the energy utilization efficiency of hybrid power system decreases due to the increase of system complexity and weight. Therefore, on the basis of technological development, continuously improving the power density and system efficiency of the hybrid power system has become the main line of continuous research and verification [1].

5.3 Future Development Trend of Hybrid Power System

1) Drones are truly personalized. Because the hybrid system, especially the tandem hybrid system, greatly expands the freedom of aircraft design, such as distributed propulsion design, integrated flight-push design, wing-body integration design, eliminating wing tip vortex/tail vortex design and efficient propeller/fan system design, the aircraft propulsion efficiency can be greatly improved, even 20% higher than that when installing advanced traditional engines. Therefore, future UAVs with hybrid power systems can truly achieve efficient propulsion, as well as demand-oriented and personalized design [1].

2) High power density and high efficiency motor is the focus of development. As can be seen from the architecture of the hybrid system, the system weight is increased compared to a single conventional engine, and the energy conversion process is more complex. Therefore, according to the key technical analysis, in order to make up for the increase in system weight and reduce the cost of energy conversion efficiency, it is necessary to strengthen the design of high-density and efficient motors, including the matching design of motors and engines before and the design of motor control and power conversion devices, and even the use of superconducting technology to improve the power density, efficiency and energy supply quality of the entire system.

3) Comprehensive energy management technology is an important guarantee. Due to the increasing capacity of the UAV power grid brought by the expansion of the mission system, the load characteristics are becoming more and more complex, which brings huge technical challenges to the complex energy management system composed of energy storage system, energy conversion system, drive system and cooling system. In order to ensure the stable and efficient supply of energy system, it is necessary to optimize the configuration and operation control of engine and battery system. At the same time, the internal inefficient operation of the power system caused by load changes and the short-time rate discharge of lithium batteries will lead to a more serious power generation situation of the system equipment, which must rely on the integrated energy management technology of the system with efficient cooling capacity.

4) To achieve all-electric depends on the development of high energy density energy storage systems. At present, the energy density of liquid fuel cells is mostly higher than that of lithium batteries, but the power density is generally too low to provide the payload in the case of providing the power required for take-off. Therefore, in order to truly realize the practicality and marketization of all-electric aircraft, we must rely on the development of high energy density energy storage technology that meets the high power density. For a long time in the future, hybrid power system is still the best choice for electric propulsion UAVs that have certain requirements for range [1].

5.4 Recommendation for Continuous Improvement of Hybrid Power Systems

The current development of UAVs is restricted by energy sources, although the hybrid power system can greatly improve the endurance of uAVs to a certain extent, but from the long-term development of UAVs, especially small UAVs, it is necessary to seek lighter, higher energy density, more environmentally friendly and safer hybrid energy sources, which is now an important section to be solved. At present, the control technology of the UAV industry has been very advanced, and the UAV can be used to implement various tasks and save manpower and material resources, only by overcoming the bottleneck of battery energy density, or developing a new safe and reliable high energy density energy, can we fundamentally solve this problem [4].

To optimize the hybrid power system, key technologies such as hybrid power layout, power component selection, and propeller matching, especially the key power supply, can be used to improve the endurance of the UAV: vigorously promote the comprehensive efficiency optimization of the fuel cell system, and solve the problems of the fuel cell system in the middle and high altitude and low temperature environment, system design at high altitude and low pressure, and thermal management of the battery system. Break through the key technologies of fuel cell system with high energy density, low target characteristic signal, high safety and high hydrogen storage density, and meet the practical requirements. Although both lithium-ion batteries and fuel cells have certain shortcomings, the capabilities of the two can complement each other. Use the recharging ability of lithium-ion batteries to improve the endurance of drones; The fuel cell has the advantages of simple structure and high energy conversion rate to improve the emergency handling ability of UAV. The use of non-similar double

redundancy power supply, the use of their own advantages, so that the two complement each other, will promote the development of UAV long endurance technology [10].

6 Conclusion

UAV endurance has become a bottleneck technology restricting the development of the UAV industry. At present, there are three mainstream types of UAV power systems: fuel, pure electric and photodynamic systems, in addition to other self-powered power systems, but a single power source has obvious disadvantages. Man-machine hybrid propulsion system is a new type of propulsion between traditional engine and all-electric propulsion system. The research results show that: For the UAV power needs, under the existing technology level, hybrid power system is a combination of high efficiency and hybrid power system including easy to achieve long-term cruise engine, as well as high thrust-to-weight ratio, good control performance of the motor, integrated their advantages, is an efficient, flexible and reliable propulsion mode.

The hybrid power system has many advantages, which can truly realize the personalized design of the UAV, meet the requirements of high efficiency, long endurance and large thrust to weight ratio, and is the key direction of the future development of the UAV power system. At the same time, there are also key technical bottlenecks in the hybrid power system, such as overall system design, high efficiency and high power to weight ratio motor, integrated energy management, and high energy density energy storage, which need to be focused on and overcome. In short, the hybrid power system can improve the status quo of the original UAV power source, so it can greatly improve the endurance time of the UAV, and then meet the needs of long-term work in the actual work, which has important practical significance.

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