Conceptual functional design of hybrid energy source of unmanned convertiplane

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Abstract. Convertiplane is explored in this article as an unmanned aerial vehicle incorporating hybrid power sources and hybrid propulsion systems. Based on the use of an electric generator in conjunction with a battery, fuel element and internal combustion engine as a source of energy in the non-manifold electrical engine convertiplanes, hybrid power sources and hybrid propulsion systems manufacturing specifications, as well as providing convertiplane with a long-term flight issues are considered hereby. In order to provide selection of the optimal design, hybrid energy source models from connection designs of different types of energy sources have been analyzed. Structural schemes of power systems with different configurations consisting of “sequential”, “parallel” and “mixed” connections of hybrid energy sources and hybrid propulsion systems have been analyzed and optimal connection schemes have been determined on their basis. It has been shown that when using four hybrid winged-motor group, the lifting system becomes complicated, the weight of the convertiplane is becoming relatively heavy. For an airplane weighing 15-20 kg, it is recommended to use four electric motors as a lifting engine, an internal combustion engine as a driving motor and an electric generator to charge the battery during the flight in order to ensure vertical flight, endurance or hovering at the height. A conceptual block diagram of a convertiplane type unmanned aerial vehicle is developed.

1. Introduction

The production of small-sized airplanes, helicopters, multicopters and unmanned aerial vehicles (UAV) of the convertiplane type, using storage accumulator batteries (AB) as an energy source, brushless electric motors (EM) as power plants has been rapidly developing in recent years [1-3].

The production and operational cost of such aircraft is lower than that of medium-sized and large-sized UAVs, and hybrid energy sources (HES) made on the basis of two or more different types of energy sources are used to ensure their long-term flight. HES are environmentally friendly compared to standard internal combustion engines (ICE), they have such advantages as low noise, thermal radiation et.c., and when they are used, the amount of toxic substances released into the air decreases, the efficiency of energy consumption is exclusively increased.

Although the small-size UAVs have high maneuvering and intelligence features, their flight time is short, so for example, the duration of a flight using a lithium-polymer accumulator battery (LPAB) with a specific energy density of 100 watts*hours/kg is 20-25 minutes. By connecting an additional AB, it is possible to increase the flight duration by 40 minutes; however, the payload weight is reduced [4, 5].
Currently, there are disadvantages, such as the insignificant flight time and the low payload weight of the low-propeller UAVs in operation, the low flight speed and the complexity of the flight control system. [14, 15].

An important task facing researchers is to create new energy sources or energy supply schemes for which the technical indicators for UAVs are comparatively superior to those of existing energy sources. Along with ensuring a long flight, the possession of an UAV of high speed and reliability is also an important task. An analysis of the scientific and technical literature shows that although a number of research projects have been carried out in the direction of designing HES, there are no ready-made projects working with hybrid energy sources for mini UAVs [6-13, 16, 17].

2. The aim of the work
The aim of the work is to develop the optimal scheme of a powerful system represented by a HES and a propulsion system to ensure a comparatively long flight of an UAV such as a convertiplane.

One of the two types of internal combustion engines (ICE 1) in the HES system works with gasoline or diesel-based fuel; ICE 2 in the HES system works with carbon-hydrogen based fuel such as hydrogen, propane, methanol, etc. It is also recommended to use lithium-ion, lithium-polymer and other type accumulator battery - AB, the generator (G) that generates electricity to fill it and the hydrogen - based fuel cell-HFC.

3. Analysis of HES systems
In a "series" connection of the type (ICE1+G)-AB, the engine is supplied with power at a predetermined time by the AB charging system (ICE1+G) from only one source by means of a voltage converter operating with electrical energy generated by a generator. The speed controller, in which power is supplied by the AB, controls the power transmitted to the brushless EM, which propel the propellers of the UAV. The advantage of “series” connection is the simplification of the design, its use of a complex mechanism to carry out the process of transferring shortcomings between energy sources [4, 5, 7].

The implementation of power supply of the EM with a "parallel" connection type (ICE1+G)-AB simultaneously from two sources is possible (figure 1). In this case, the main power supply of the EM is carried out using a “parallel” connection to the AB system, if this is not enough in hard loads by means of (ICE1+G) [13]. The disadvantage of the circuit is the lack of a function for charging the battery from the generator. In the "parallel connection" type (ICE1+G)-AB it is possible to eliminate their inherent disadvantages, while retaining the advantages of the circuit of the two previous connections. In this case, a "mixed" connection is applied and the tension force for a long flight is mainly created by (ICE1+G), while the AB is being charged. In hard loads, the EM starts and provides additional draft power. At this time, the power supply of the EM from both the generator and the AB becomes possible, which allows even more efficient loading of the AB and the electric generator, regardless of draft power [4, 5].

![Figure 1. HES "parallel" connection scheme.](image)

When using AB charging by means of a (ICE+G) system in a “mixed” connection, it is possible to increase the technical parameters of the system by replacing the ICE and generator with a HFC and a voltage converter, respectively. In this case, it should be noted that the oxidation reduction reaction is carried out at high temperatures (60 .. 1000)°C using hydrogen as a fuel, the use of a catalyst made of expensive and rare metals to lower the temperature to (60 .. 100)°C, including the consumption of part
of the energy received for cooling the system, and also because of the high probability of explosion of composite tanks filled with hydrocarbon gases under high pressure, the use of a AB - a HFC with a hydrogen base is not appropriate as an energy source in UAVs micro and mini type thorough HES.

4. Analysis of hybrid propulsion systems

The Schemes of "serial" and "parallel" connection of hybrid moving systems of an UAV are mainly characterized by the structural arrangement of the axes of the ICE and the electric engine. In a "series" connection scheme, the propellers are directly attached to the bearing axis and the torque of the internal combustion engine is transmitted to the bearing axis through a mechanical coupling [15].

In this case, the axes of the ICE and the EM are located in one straight line, the supporting propeller is directly attached to the EM axis, and the EM is supplied with power through the AB. The EM is connected to the system to provide the required power during hard loads [5-9]. The axes of the ICE and the EM in the "parallel" connection system of the hybrid propulsion system of the UAV are not located in one straight line (figure 2). In this case, the rotational moments formed by the ICE and the EM are transmitted to the bearing axis by means of clutch gears.

In both connections, it is possible to obtain a configuration (ICE1+G) and provide charging of the AB during the flight by adding a generator to the ICE. The circuits analyzed above serve as a group of a single-propeller motor. If a group of four four-propeller lifting motors is used in an UAV such as a tiltrotor, this can lead to a complication of the system for using these schemes and an increase in the weight of the UAV. By using four EMs for vertical flight and one ICE for horizontal flight, it is possible to reduce the weight of an UAV and increase the duration of horizontal flight [6-9].

In order to ensure a long flight, you may be chosen the energy consumption of the AB, powering the EMs in UAVs, which use an ICE, so that in any case, for example, during a failure of the thrust engine providing horizontal flight, the landing system will ensure safe landing UAV. It is possible to reduce the weight of the UAV by optimizing the weight of the AB selected with the condition of full satisfaction of the delivery and landing of the UAV in a safe place. Intensive charging of the AB during flight may be required to ensure prolonged freezing in the air. In this case, the AB is charged using a generator. The image of an UAV such as a convertiplane with a hybrid propulsion system designed to ensure vertical and horizontal flights is given in figure 3. Here, the EM supplying vertical flight of the UAV is powered by a LPAB; its horizontal flight is secured by the pushing force generated by the ICE.

Depending on the configuration (DYM + G) selected from the HES, it is possible to continue the horizontal flight of the hybrid aircraft by means of an EM in quadrocopter mode [5-9].

As can be seen from the block diagram, the command (speed, direction, etc.) specified by the pilot operator is received in real time by the air-information terminal of the UAV and transmitted to the central flight computer (figure 3). At the same time, the data collected hereinafter on the coordinates of the UAV from the GPS (the Global Positioning System), the speed from the accelerometer and gyroscope (inertial navigation system), as well as the flight speed from the applications (Pitot tubes), about flight altitude from barometers are processed in the central flight computer.
Figure 3. Conceptual block diagram of the designed convertible type hybrid UAV.

The vertical take-off and landing of an UAV and its transition to horizontal flight mode is controlled by a central flight computer. To ensure vertical flight, four brushless EMs are used, powered by a LPAB, and the speed of which is regulated by a speed controller. Speed controllers regulate the lifting power of the EM according to the command given by the central flight computer.

Depending on the HES and the selected configuration of the propulsion system, the central flight computer controls the thrust power of the ICE, the operation of the generator, as well as the operating modes of the EMs.

5. Conclusions
To provide vertical and horizontal flight of a hybrid unmanned aerial vehicle weighing up to 20 kg, four lifting and a one driving electric motor powered by a lithium-polymer battery. To provide vertical and horizontal flight of a hybrid unmanned aerial vehicle weighing up to 20 kg, four power lifting and one electric motor powered by a lithium-polymer battery. To provide a vertical flight of this type of unmanned aerial vehicle weighing more than 15 kg, the battery powered four electric motors with a lithium-polymer battery and an internal combustion engine for horizontal flight. An internal combustion engine are increase the horizontal flight time of the aircraft and perform battery charging during the flight. Connecting a charged battery to the electric circuit in the event of failure of the internal combustion engine during horizontal flight ensures that the unmanned aerial vehicle landing in a safe area.

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Naucny vestnik MSTU, Aeromechanics and Strength 125 145-50