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Saving energy resources of autonomous power sources of unbeiled flying apparatuses

The possibility of saving the energy resource of an autonomous power supply source of an electric motor for an unmanned aerial vehicle (UAV) is considered. Theoretically, this possibility is shown in the case of constant traction and rotor speed of the motor.

Introduction. Recently, small unmanned aerial vehicles (UAVs) have developed significantly, in which electric cars with propellers are most often used as engines. The lack of autonomous power-consuming and small-sized power supplies with fast charging does not prevent the rapid development of a UAV using electricity. But even the presence of energy-intensive power supplies does not exclude the consideration of the problem of economical use of electricity in the operation of an electrical machine with propellers.

At present, the UAV uses mainly only a battery, it can be an inverter, an electric motor with an air screw. Can be used solar cells located on the wings, body and tail to recharge the battery in order to increase the flight life of the UAV. A block diagram of such a UAV is shown in Fig.1.

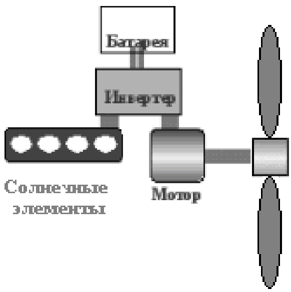
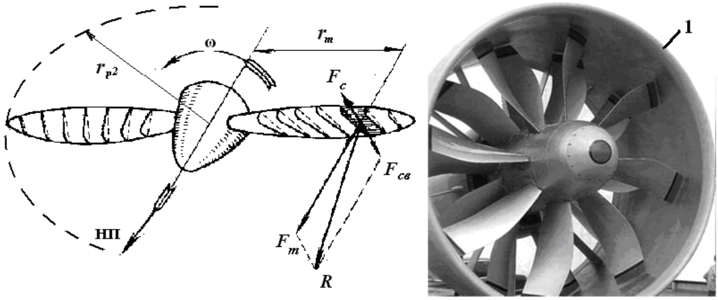


Fig.1.

The purpose of the work is to increase the flight life of UAVs as a result of energy saving of batteries and due to the modernization of its electric motor.

Wave distribution. Consider how the UAV's flight resource will change if the rotor radius of the motor is changed. Various forces acting on the aircraft propeller or UAV are shown in Fig. 2, where it is indicated: a - diagram of the aerodynamic forces acting on the propeller blade in flight; $F_{св}$ is the resultant force of the screw resistance at angular velocity of rotation ω; R is the resultant aerodynamic force; F_m - resultant traction force; F_c is the rotational force of the screw from the motor to compensate the force $F_{св}$; НП is the direction of the flight; r_m is the radius to the point of traction force application; r_{p2} is the radius of the propeller; б-engine НК-93.



a b

Fig.2.

The resulting resistance to rotation $F_{св}$ is directed against the direction of rotation of the screw [1]. In order for the screw to rotate at angular velocity ω, it is necessary to compensate the resulting resistance to rotation by force F_c, which is developed by the electric motor. As a result of the rotation of the screw, the resultant aerodynamic force R and the resultant tractive force F_m arise. From Fig. 2*a* and calculations it follows that the resultant aerodynamic force R is applied inside the propeller blade.

If we consider an electric motor with a power P and a UAV screw, which must develop a tractive force Fm with the resultant force of rotation resistance $Fсв$ at the rotational speed of the rotor ω. Then it is possible to obtain an expression for compensation of the resultant resistance to rotation $Fc= Fсв$.

$$F_c = \frac{F_м \cdot r_p}{r_m} \quad . \qquad (1)$$

where $F_м$ is the total mechanical force on the rotor produced by the electromagnetic force, r_p is the radius of the rotor on which the electromagnetic force acts, r_m is the radius at which the necessary tractive force is provided. From this expression it is seen that the tractive force with a constant electromagnetic force and the same angular velocity of rotation will depend on the ratios of the radius of the rotor of the engine and the radius to the point of application of the tractive force. Moreover, if the radius of the rotor is greater than the radius of the point of tractive force, then in this case it is possible to obtain a gain in tractive power with the same applied electromagnetic force.

Currently, in UAV propellers, the radius of the rotor of the electric motor is less than the radius of the applied traction force on the propeller blade. If the rotor of the electric motor is made in the form of a ring connecting the upper ends of the propeller along the radius r_{p2}, that is, the rotor is located along the dotted line (Fig. 2a), then for the UAV there is the possibility of saving the energy source of the autonomous power source with the chosen tractive force. Therefore it is proposed in accordance with Fig. 2*b* to place the stator windings in the casing 1 of the fairing of the fan. As in the HK-93 engine, two stators can be placed to allow the fans to rotate in different directions and at different speeds to reduce the locking effect. In this case, there is no need to use complex gearbox systems that are used in the HK-93 engine. If you use an asynchronous motor, the rotor can be made in the form of a "squirrel cage" with an annular magnetic core connecting the ends of the fan. It is also possible to use other motors, but the design must be such that the radius of the rotor is greater than the radius of application of the tractive force [2]. As air propulsors, except for propellers and fans, impellers can be used. For asynchronous motors, the fan speed can be controlled using a frequency converter. Using such a design of electric motors will increase the efficiency of the propeller and the flight time of the UAV, that is, it will save electric power of autonomous power supplies.

Let's consider, how many times will the operating time of an asynchronous electric motor, stator of which is located in the fairing (Fig. 2*b*), and the rotor is made in the form of a "squirrel cage" with a magnetic circuit.

The theory of electric motors [3] makes it possible to determine the values of the rotor currents with small r_{p1} and large r_{p2} radii. Considering that with the same tractive force and angular velocity of rotation of the propeller, the moments of the rotors with small and large radii must be equal, that is, $M_1 = M_2$, we get the current consumed by the engine with a large radius

$$I_2 = \frac{I_1 \cdot r_{p1}}{r_{p2}}. \tag{2}$$

It can be seen from expression (2) that the larger the rotor radius of the motor, the less current is needed to create the necessary tractive force.

It is known that the capacity of autonomous power sources - *C*, for example, of accumulators, is determined in ampere hours. Consequently, it can be found how many times the running time of the motor *H* with a large rotor radius will last longer than the smaller rotor radius

$$H = \frac{C}{I_2} = \frac{C \cdot r_{p2}}{I_1 \cdot r_{p1}}, \tag{3}$$

where I_1, and I_2 are the values of the rotor currents with small r_{p1} and large r_{p2} radii, respectively

Thus, a motor with a large rotor will work longer in r_{p2}/r_{p1}.

In the event of a change in the design of the motor, it is necessary that its working properties correspond to the previous motor, i.e., that both engines have the same mechanical characteristics, namely electromagnetic moments. One of the conditions for the appearance of a magnetic moment in an asynchronous machine is the presence of an active resistance of the rotor R_2, which determines the dependence of the moment on sliding, that is, determines the working properties of the asynchronous machine. Analysis of the dependence of the electromagnetic moment on the electrical parameters of the engine showed that if the parameters such as the number of phases, the number of pairs of poles, the voltage, frequency, and slip applied to the motor are maintained, the torque in small slip will depend mainly on the active resistance of the rotor. On the other hand, for small slip, the cosine of psi can be approximately equal to unity.

Obviously, with increasing rotor size, the parameters of the motor will change, and to maintain the mechanical characteristics of the changed motor, the rotor resistances must be the same, then we determine how the cross section of the rotor conductors should change. Assuming that the specific resistance of conductors from the same material varies little from its cross-section, we obtain an expression for increasing the cross section of the conductors of a large rotor with respect to a small rotor

$$S_{сеч2} = \frac{k_{об21} \cdot w_{21} \cdot l_2 \cdot r_{p1}}{k_{об22} \cdot w_{22} \cdot l_1 \cdot r_{p2}} \cdot S_{сеч1}, \qquad (4)$$

where $S_{сеч1}$, $S_{сеч2}$ are sections of small and large size rotor conductors, l_1, l_2 is the length of the rotor conductors in the phase of small and large size.

Similarly, inductive rotor resistance is calculated.

Thus, if the requirements for the equality of the active and reactive resistances of the rotor windings are satisfied, then after changing the motor design, the mechanical characteristics of the motor can be maintained.

Conclusions. As a result of the modernization of the design of the UAV motors, it is shown that in saving energy and increasing the flying resource at the selected tractive force and the angular speed of rotation of the rotor of the electric motor or screw. It is shown that the consumption of electric power is reduced if the radius of the rotor of the electric motor exceeds the radius of the propulsion unit. And when using battery batteries, the duration of the operation of power supplies will increase in proportion to the ratio of their radii to the engine.

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