Structural Optimization Design of Solar UAV
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Abstract. According to the current status of solar energy the development of unmanned aerial vehicle (uav), the difficulties, the development of solar uav based on solar energy new materials research and application of the unmanned aerial vehicle (uav) structure scheme of structure optimization, optimization model is established, research and development to make a fixed wing flight available solar powered platform. This paper will analyze the overall scheme design of the system, the performance of the wing of the solar uav, the structure design and test results of the solar uav. Is obtained by the experimental data and theoretical data analysis, as the change of structure, the resistance of the aircraft fuselage become smaller, at the same time, the grid carbon rod piece structure also makes the body has the very high intensity, so in this paper, the design platform for the big wings flying wing structure and body strength fully meet the design requirements.

Design of System Overall Scheme
In this paper, a fixed wing flying platform (around 6m wingspan, about 4kg) is developed through the design of solar unmanned aerial vehicle (UAV) for new materials [1]. By adding an efficient power system and an intelligent power management system, it can carry uninterrupted flight in the sun under the load of a certain payload (above 2kg). In order to meet the above requirements of the solar powered UAV, the design scheme includes two aspects: A. Reasonable structural and aerodynamic design should be carried out in the use of new materials. B. design a power system that can match the performance of aircraft.

So this paper adopts a new composite hard shell structure and a wood structure full mask structure to improve the structural strength of aircraft. When the solar UAV is required to meet the design requirements, flight needs to get the relevant design parameters of the solar UAV from the theory, for example, the pitch stability is calculated by the theoretical calculation that the center of gravity of the aircraft should be controlled within the design center point of 5 millimeter [2].

Performance Analysis of Solar UAV Wing
The structural design of wings can be divided into two parts: the selection of aircraft airfoils and the design of aircraft internal structure.

The airfoil selection of the aircraft theoretically determines the basic performance of the aircraft. There are many factors to be taken into consideration, including: under the condition of the airfoil L, the induced drag factor E, the whole machine weight M₀, the thrust space velocity relation T(V), the selection of the airfoil, the design state angle of attack and the area of the wing will be considered. The remaining thrust is the largest. The airfoil used in this article is: NACA 97.

Airfoil and Lift Drag Ratio
Lift drag ratio, also known as lift resistance ratio, aerodynamic efficiency. The ratio of lift (L) and resistance (D) at a at the same angle of attack is also the ratio of lift coefficient (Cl) and drag coefficient (Cd). In the interval where the Reynolds number can be ignored, the arbitrary working state of any rectangular wing can be fully described with the four quantities: the airfoil L, the string
length \( d \), the equivalent attack angle of the airfoil (the local angle of attack of the airfoil, the aircraft angle of attack + installation angle + down wash).

For the same airfoil, the corollary of the above conclusion is that the attack angle should be the maximum attack angle of airfoil lift / drag ratio. At the design point, the lift - drag ratio of the airfoil is determined [3]. The selection of the airfoil should be the maximum lift resistance ratio of all known, and grasp the original model samples (such as those mentioned in the last part, such as the skin wrinkling problem). In order to minimize the wing area and improve the structural stiffness, the greatest lift coefficient should be chosen. The lift and drag relations of airfoils selected for airfoils and lift resistance are shown in Figure 2.

![Overall frame diagram of solar UAV.](image1)

![Performance characteristics of airfoil.](image2)

**Wing Area (Design Speed)**

In the aircraft design, the larger the airfoil area, the slower the aircraft speed, the greater the induced resistance, and the greater the propeller thrust. For the sake of discussion, it is assumed that the lift-drag ratio of the airfoil is a certain value, and the lift force is equal to gravity, which is also a fixed value [4]. So only the induced drag changes with the airfoil area. Due to the hose will be used in the actual test as load object, and take the way of plugins from the objects in the plane's center of gravity point, also in order to simplify the discussion process, assuming that the landing gear, hose, outer side wing joint resistance is set to the sum of \( F_0 \) (often called waste resistance), and the resistance and the speed of the aircraft flight satisfaction: \( F_0 = \gamma v^2 \) + Where \( \gamma \) is the fixed coefficient. Since the size of the airfoil area is uncertain, the airfoil area can be regarded as an independent variable at this time, and the constraint conditions are usually:

\[
mg = T(v) - \frac{Cd}{Cl} mg - \frac{2(mg)^2}{\lambda \pi \rho b^2} \frac{1}{v} = \gamma v^2
\]

(1)

\[
T_i = T(v) - mg.
\]

Then, it can be obtained near the extreme value;

\[
0 \approx \frac{dT_i}{dv} = T'(v) + \frac{4(mg)}{\pi \rho b^2} \frac{1}{v^3} - 2\gamma v.
\]

(3)

\( v \) can be obtained from the equation, which is the design speed. In the design, the maximum design speed of this design is: 7m/s considering other relevant parameters.

In fact, software analysis shows that the purple line deviates a lot from the red line at different frequencies. That is, if the airframe, external load, landing gear, tail, etc. are not considered or seriously underestimated in the design, the airfoil area will be smaller than the design. If these resistances are overestimated, the designed airfoil area will be larger, so the required airfoil area should be carefully considered in the design.
Design State Angle of Attack

Angle of attack (English: Attack Angle), also called angle of attack. For the wing shape, the angle of attack is defined as the angle between the chord and the velocity of the incoming flow. The angle of the head is positive and the head is negative. The lift depends on the angle between the airfoil and the relative airflow. Because the size of the attack directly affects the performance of the aircraft, the lift vector may not overlap with the longitudinal axis (horizontal line) of the aircraft. When athletes pull rods, they usually increase the attack angle of aircraft [5]. In the actual test, if the player reduces the power output thrust when the plane enters the flat flight state, then the aircraft will start to drop the height, which is usually said to fall, but usually to keep flat, the athletes will increase the power output and also increase the angle of attack at this time.

The lift characteristics of aircraft are often connected with attack angle and speed. When the aircraft is flying, the attack angle will increase continuously until the critical condition is increased, and the lift will also increase. If the angle of attack is constant, the lift of the aircraft will increase as the speed of the aircraft increases. However, when the attack angle and speed increase, the induced drag of the fuselage will also increase.

![Image](image_url)

Figure 3. Simulation and analysis of wing performance by xflr5.

When the attack angle increases to the maximum critical value, the airflow on the wing will be disturbed, thus lifting the lift of the aircraft. At this point the air flow is gradually separated from the left and right wings, causing the pressure difference between the upper and lower parts of the plane, causing sideslip and eventually causing the stall, that is, the frying machine we normally say. Through actual flight, it is concluded that the aircraft will be rotated around the fixed vertical axis of the devil's coat when it enters the stall (or out of control) state. If the athlete does not intervene artificially, the aircraft will crash. For the solar UAV, the main reason for this failure is the angle of attack. The design is not reasonable, and the aircraft wing production accuracy cannot reach the theoretical requirements [6]. This problem appears in the later test and in the actual competition, making the plane crash, the result of the competition is not ideal. In the actual flight summaries, there are many ways to make the aircraft from runaway to athletes regain control. Generally speaking, if it is not a simple aircraft wing workmanship that does not reach the design requirements, the aircraft is completely uncontrolled, reducing thrust, steering the reverse direction of the spiral, taking control and keeping in this position, until the plane is no longer spiraling and can be controlled. When the plane should be leveled, be careful not to screw the aircraft again.

In addition, in order to reduce the resistance of the aircraft, the solar power board in the solar UAV can be used more efficiently, and the wing is slightly smaller in the wing of the aircraft. In this paper, the structure of winglet and the winglet are analyzed theoretically in software Xflr5. The airfoil, plane shape, installation angle and twist angle can be adjusted manually. The main purpose of the adjustment is to ensure that the wing cannot stall before the main wing is stall.

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Performance Analysis of Solar UAV Wing

Application of Composite Materials

Based on the design requirements and other requirements, the most important new materials in this paper include carbon fiber.

Carbon fiber (CF) is a new type of fiber material with high strength and high modulus, which contains more than 95% carbon. It not only has the intrinsic characteristics of carbon materials, but also has the softness and workability of textile fibers. It is a new generation of reinforced fibers.

Design and Construction of Flight Platform

At present, in the aerospace, drone aircraft use light wood - more external skin structures, all flight platform, the structure of the conventional structure although made craft quality frivolous, satisfy the requirement of the relevant event competition, but completely contrary to the actual aircraft design. The construction of the entire flight platform through the lightweight timber-exterior skin structure has the following three fatal defects:

A. Flight platform structural strength is poor, it is absolutely not allowed for aircraft, due to the structural strength does not meet the design conditions, it is easy to cause the craft can't normal flight and even collapse in the air, causing some unexpected loss, this is often met in each big things, investigate its reason is that the designer didn't grasp the basic conception of aircraft design[7].

B. The aerodynamic performance of parliamentary air vehicle is poor. Designers in order to reduce the weight of the plane has wings mask area is insufficient, skin support area is small, cause serious skin collapse, cause the airfoil aerodynamic ceased to exist, for solar uav need high lift this affect is more serious; In addition, the stiffness of ailerons is insufficient and the deformation is serious under pneumatic load. At the same time, the torsional rigidity of the wing is not enough, and the wing has nearly 10 degrees of negative torsion under the action of bow torque [8]. Due to the usual use of water hose as a load, the aircraft's windward area increases and is close to the lower surface of the wing, which interferes with the wing and hinders the wake of the propeller. The center of gravity is usually fitted with 1/4 chord strength according to experience.

C. The power to match, mainly due to the above two reasons make flying platform operability is poor, also makes the relative experience in dynamic matching can only by hard is tie-in, not only cannot meet the initial design goals of flight platform, also makes the flying platform risk coefficient increases,

But for a lightweight aircraft program (such as a glider program), the proper design and structure of light wood can meet the requirements of the competition. In this paper, the special requirements for aircraft and the application of new materials, the fuselage and wings will be introduced separately.

Structure Design of Wing

In order to make the flight platform with a wingspan of 6 meters meet the above design requirements, special structural design needs to be carried out within the specified airfoil shape.

The wings are mainly divided into: wing beam, wing rib, solar panel bracket, wing cover and outer cover.

Wing leung is the most important part of bearing, so the strength of the wing beam quality determines the flying platform foundation, this paper discusses the design of the weight of the whole aircraft specific limits, under normal circumstances, the heaviest part in the whole wing SPAR quality, but in this paper, the design of the strength is not affected or even enhance the strength of the situation puts forward new design on the wing beam. The wing girder is a sandwich - hollow structure.

The wing girder is a rectangular structure. The upper and lower part of the wing girder is carbon sheet with a width of 5mm and a thickness of 1mm. In the production process, the use of white latex, quick drying glue and other materials so that the carbon sheet and light wood form a relatively stable type of stress structure [9].
The role of wing rib in aircraft wing construction is indispensable. Between the ribs and the combination of ribs and wing beam will greatly improve the overall stress level of airplane wings, in the spare area is formed between the ribs not only improve the adhesion of skin area, a complete aerodynamic shape of the wing, is also the framework of the solar panel set up, in the heart of the solar power in the late is the energy of the flying platform support base. This puts forward higher requirements for the wing rib, which is also the part of the main girder in the construction of the flight platform described in this paper.

Through analyzing the stress of the single ribs, unmanned aerial vehicle (UAV) when flying in the air for the ribs of the part with a pressure inside, at the same time for the lower part of the ribs has a pull outward, as shown, at the same time, through laser engraving machine, considering the light wood cut into existing ribs shape, its texture structure for mechanical strength is almost zero. So in the ribs and other parts of the complete right of joint, joint with ribs on ribs of the same width, thickness of 0.2 mm carbon plate, through such structure makes the ribs - ribs - wing beam forming is very strong and stable structure, combined with the surface adhesion of rectifier skin, the whole wing theory can achieve very good strength. At this time, the weight of the entire wing without electric power distribution is 0.9kg.

**The Structural Design of the Fuselage**

The use of new materials is an essential basis for the design of the aircraft platform in this paper, and a large amount of carbon materials are also used in the design of the aircraft fuselage. Based on the design requirement of flight, this paper choose the extensive use of carbon materials from two aspects: first, to ensure the materials used in the aircraft platform building is no more than the target weight 4 kg, secondly to ensure that the airframe strength. In actual flight training and to participate in the relevant game, frequent occurred due to the airframe strength is not enough by the disintegration of the air, so in this paper the fuselage is emphasized in the design of airframe structures of carbon structure. Through the analysis of the force on the fuselage of the flight platform, it can be seen that the main force in the fuselage is the connection between the wing and the fuselage to the tail of the aircraft. Fuselage main conduction the tail of the vertical tail in the air and tailplane balancing force to the wings, so here is used to estimate the balancing force calculated first, and then will come the strength multiplied by the safety factor of 3 as ultimate bearing standard of the fuselage.

A function of the fuselage is connect aircraft parts as a whole, you first need to consider with the connecting way of the wing, this article USES carbon plate and shell fragments the combination by means of screws [10]. Because of the need to pay attention to the above the paper talked about flying platform induced drag, counter-offensive Angle and external negative side wing Angle adjustment, on the fitting by cut carbon plate into ribs shape, at the same time in the fuselage determine position (center of gravity of flight platform), using carbon plate structures, structure and the connection of a square grid, and then design a hole next to take half arc design, makes the wing during installation according to the installation of the weather changes to adjust the wing Angle, made under the illumination intensity of fixed solar unmanned aerial vehicle (UAV) flight to reach the highest efficiency. The overall weight of the fuselage is only 0.3kg.
Test Program Results

As shown in the figure, the relationship between the Angle of attack of the wing and the mass of the load is shown.

![Graph showing the relationship between aircraft attack angle and load.]

Figure 5. The relationship between aircraft attack angle and load.

Summary

From the figure, as the load quality content increasing, the overall Angle of attack of the wing is also on the rise, is obtained by the experimental data and theoretical data analysis, this article design platform for the big wings flying wing structure completely meet the design requirements. At the same time, the fuselage design needs to meet certain streamlined, so the whole body structure as shown in figure, such as the change of the structure makes the aircraft fuselage resistance become smaller, at the same time, the grid carbon rod piece structure also makes the body with high strength.

The above analysis shows that the fuselage strength fully meets the design requirements.

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References


