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Research on the Influence of Airfoil on the Flying Performance of Glider

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Abstract. Gliders are heavier-than-air fixed-wing aircraft that do not rely on power plants to fly, and are now widely used in scientific observation, daily entertainment, and other fields. After taking off, it only relies on the reaction force of air acting on its lifting surface for free flight. Different gliders can stay in the air for different amounts of time in different environments, which is mainly determined by the airfoil. Therefore, through literature reading, this paper understands its flight principle, and studies and analyzes the advantages and disadvantages of existing airfoils by comparing the influence of different airfoils on flight performance. In view of the problems existing in the airfoil, rationality calculations and improvements are put forward, hoping to promote the development of the aviation industry. After research, the concave wing is by far the most suitable gliding airfoil, which can provide relatively large lift and stability, but there is still the problem of insufficient load. In order to improve these deficiencies, the airfoil is optimized by increasing the contact area between the airflow and the wing. For example, the defect can be improved by lengthening the length of the entire wing, reducing lateral airflow, and increasing the upward curvature of the wingtip.

Keywords: glider, airfoil, Glide stability, aerodynamics, Bernoulli's Principle.

1. Introduction

Bionics has always been an important tool for human scientific research and invention, just like a glider. The glider was inspired by the gliding flight of various birds and others. Typical of such creatures are large land and sea birds, flying squirrels, flying fish, and flying squid. Flying seeds also disperse in this manner. In gliding flight, the gravity force and the aerodynamic force are major factors [1]. The same goes for gliders. It can stay in the air for a long time without a power device, but because it needs a special flight form, the airfoil has a great impact on its flight performance. In light of human expectations of flight and the importance of flight for practical observation and research, it is necessary to conduct in-depth research on the influence of airfoils on the flight performance of gliders.

A key part of aircraft design is the wing. The cross section of the wing is called the airfoil, and a modern aircraft usually also has part of the wing move to help control the aircraft, making the wing a fairly sophisticated robotic device [2]. In this paper, the comparative analysis method and the event study method are used to evaluate the impact of the airfoil on the flight performance of the glider through a literature review and the analysis of various examples, and to analyze the advantages and disadvantages of the existing airfoil.

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Through the research in this paper, the existing different types of airfoils will be compared and analyzed, and the existing problems, such as small load, cost, and so on, are proposed to be solved. After improving the airfoil, the engineering construction cost can be reduced as far as possible, the flight distance of the glider can be extended, the load of the glider can be improved, and the landing safety can be improved.

2. Introduction to relevant theories

When an aircraft is in flight, the airflow through the wing is divided into two parts because, according to Bernoulli principle, the two parts of the flow rate are different will form the upper and lower pressure difference, plus the effect of the angle of attack between the wing and the fluid, which will make the aircraft lift, and rise [3].

2.1. Reynolds number

It is a dimensionless number that determines the fluidity of a fluid in a given device.

$$\mathrm{Re} = \frac{\rho v d}{\mu} \tag{1}$$

According to formula (1), v, ρ and μ are the velocity, density and viscosity coefficient of the fluid respectively, and d is a characteristic length.

2.2. Bernoulli's principle

The mechanical energy of the fluid is conserved. That is to say: kinetic energy+gravitational potential energy+pressure potential energy=constant.

$$p + \frac{1}{2}\rho v^2 + \rho g h = C \tag{2}$$

2.3. Angle of attack

There will be an included angle between the forward direction of the wing and the chord. Within a certain range, the greater the angle of attack, the greater the lift and drag coefficients.

3. Comparison between glider airfoil and conventional aircraft airfoil

3.1. Comparative Analysis of Flight Principles and Performances of Gliders with Different Airfoils

Figure 1. Göttingen airfoil.

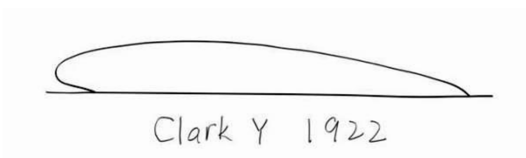

Figure 2. Clark Y Airfoil.

3.1.1. Clark Y Airfoils. As shown in Figure 1, the Clark Y airfoil was an improvement on another very unsuccessful airfoil, the Göttingen airfoil, which is shown in Figure 2. Because the camber of the airfoil is conducive to improving the maximum output of the airfoil, the thickness of the airfoil can increase its adjustable range and increase the stall angle of attack. Two characteristics fully reflected by the Göttingen airfoil. A thick Göttingen wing with variable arrangement of small circular vortex chambers also with fixed distributed suction from the surface of the central body [4]. But the overall performance of this airfoil is poor. So American engineer Clark modified it. The bottom surface of the Clark Y airfoil was almost completely flat, which reduced the wing thickness. Although this simplified the manufacture and installation of Göttingen airfoil, their aerodynamic capability such as turbulent flow was still not ideal. Cavitation may occur when the local pressure in a turbulent flow drops below the saturated vapor pressure due to fluctuations and vortices [4]. This greatly affects the stability of the aircraft.

3.1.2. Concave wing. A concave wing is a type of airfoil with the lower wing facing upward, as shown in Figure 3. This type of airfoil allows eddy currents to flow away from the wing end and towards the center of the wing surface. Since the lower arc of the concave wing is on the wing string line, the aircraft using this type of airfoil has a greater lift, which is suitable for gliders without power system support. The concave shape of the lower surface reduces the transverse flow of the airflow through the lower surface without additional loss of lift pressure, which increases the pressure difference between the lower surface of the wing and the leading edge of the wing formed when the angle of attack increases, so that the aircraft can stay in the air for a long time, improving the air time and stability of the aircraft[5]. From the aspect of heat conduction, the heat transfer rate under the heat shield also decreases due to the reduction of local velocity[6].The increase in lift can also increase the load of the aircraft to some extent, but because there is no power system, its load is still limited.

Figure 3. Concave wing.

3.2. Airfoil of a conventional aircraft
The airfoil of a conventional aircraft (take the A380 as an example): The Airbus A320 is the world's largest and most powerful passenger jet in production. Its wings are huge. It is 36.6 meters from the wing root to the wing tip, and 17.7 meters from the root chord. Because of the large wing area, there is a huge amount of lift. To improve takeoff performance, the Airbus A320 uses a leading edge flap device. Vortex breaks the stability of air flow, and the instability of air flow affects the stability of aircraft flight, and also causes buffeting. Leading edge flaps are particularly attractive tools because all of the vorticity of a leading edge vortex comes from the separation point along the leading edge, so the leading edge flap structure increases overall stability [7]. At the same time, the wing of the A380 changes the angle of wing torsion and bending along the direction of the station, which reduces airflow resistance to flight and engine interference resistance to the wing.

4. Airfoil optimization

4.1. Theoretical basis of optimization
Mainly from the aerodynamic analysis process, the relative air velocity will change with the shape of the contact object, and the local characteristics of still air, flow field, etc., will also have an impact on it. Relative air velocity may also be determined by wall roughness, catalytic capacity, chemical composition, temperature, pyrolysis and other characteristics [8]. So the airfoil is optimized by measuring the performance of different relative air velocities under different conditions, including pressure difference, vortex size, etc. Finally try wind tunnel tests. The test carried out by aircraft in a wind tunnel is the most popular test in aerodynamics and hydrodynamics [11].

4.2. Optimization process
By comparing the general characteristics of glide airfoil models in history, it can be found that the stability, load and endurance of the aircraft are still lacking. The bending thickness of the airfoil is changed to optimize the airfoil. Change airfoil upper and lower surface camber, material friction coefficient, and wing thickness,as shown in Figure 4. The prediction and evaluation of the lift-drag ratio of the optimized rear wing body fusion glider and the calculation of static stability under pitch

and yaw conditions [10]. The difference between the optimized airfoil and the existing airfoil is compared to observe whether its performance is improved.

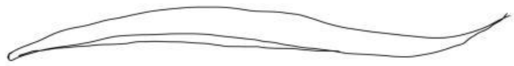

Figure 4. Optimized airfoil.

4.3. Optimization result

By comparing the flight performance of various airfoil types, it can be found that the concave wing has most of the flight capabilities required by gliders, so it is optimized on that basis. It aims to reduce the impact of laminar flow separation, improve start-up response, and meet the acceptable structural integrity level of a low Reynolds number aircraft [11]. Therefore, to reduce the diffusion of vortices around, the curvature of the wing tip can be increased to make vortices gather in the center part and improve its flight stability. Simultaneously, the larger the air contact area, the greater the air velocity difference, and the increase in the lower pressure difference on the wing surface, the better the load and endurance.

5. Conclusion

In this paper, the characteristics of low Reynolds number gliders are studied, different types of airfoils are compared, and the advantages and disadvantages of flight performance are analyzed. Through the comparative study of the upper and lower laminar flow of the aircraft and the observation of the separation point, it is concluded that the more feasible airfoil is the concave wing. On the basis of the concave wing, the load, stability, and other problems are optimized and improved.

Only theoretical speculation and calculations can be carried out in this study: field tests cannot be carried out. At the same time, the comparison type is not comprehensive enough to take into account existing problems in various aspects, and comprehensive analysis and improvement of an airfoil cannot be carried out. It is hoped that in the future, a model aircraft can be built and tested in wind tunnels. In a wind tunnel test, all aspects of the actual situation of the airfoil can be seen more accurately to determine its accurate flight performance.

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