Design and fabrication of a composite wing

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Abstract: with the rapid development and wide application of composite materials, the amount of advanced composite materials used in aircraft has become one of the important indicators to measure the advancement of aircraft structure. Based on the use of composite materials, an integrated wing is designed in this paper. After continuous three-dimensional model and aerodynamic optimization, the actual production of the wing and aerodynamic parameter analysis are carried out to testify the feasibility and good efficiency of the design scheme.

Key words: composite materials;Wing fabrication;Aerodynamic analysis

Introduction

Carbon fiber composite is a kind of material with stable properties, high temperature resistance, low density, high strength and other characteristics, which can make the wing have smaller density and excellent tensile strength. In addition to being widely used in large aircraft on the trunk line, composite materials are also widely used in UAVs. At the same time, by 2019, the consumption of composite materials for international advanced civil aircraft has exceeded 50%, and the fuel efficiency has increased by more than 20%.

This project aims to design a composite wing. Taking the half beam wing as the research object, taking the size of wing skin, beam and rib as the design variable , and replacing its skin with carbon fiber composite material, it not only has the inherent characteristics of carbon material, but also has the soft processability of textile fiber, and the wing rib is converted into carbon fiber sandwich structure (as shown in Figure 1). The skin made of carbon fiber composite material can avoid the changes of wing structure caused by the sunken mask and tight skin. At the same time, the wing skin made of carbon fiber has the characteristics of high load-bearing, high torsional resistance and high toughness. The carbon fiber skin can make the aircraft have high specific strength, high specific modulus, good fatigue resistance and cushioning performance, and reduce the weight by 25-30% compared with the conventional metal structure. At the same time, both the increase in the use of composite materials and the expansion of the scope of use have greatly changed the traditional aircraft design and manufacturing mode. In the actual production of the wing in this project, the wing model will use the sandwich structure of carbon fiber light wood carbon fiber as the wing rib, so as to further strengthen the strength of the wing.

1 manufacturing process of carbon fiber wing

1.1 production equipment and materials

Equipment: Wing mold (designed by CATIA and other 3D software and delivered to manufacturers), bending scissors, brushes, locating pins, shovels.

Materials: demoulding wax, nitrile gloves, industrial alcohol, industrial paper, epoxy resin, 3K carbon fiber cloth, isolation film, breathable felt, vacuum bag, demoulding cloth, sealing strip, light powder, cotton powder, light wood (2mm\3mm), plastic cup, linear optical axis, ice cream stick.

1.2 preparations:

1.2.1 shear material:

Cut 3K carbon fiber cloth, isolation film, breathable felt, vacuum bag and demoulding cloth to the required size.

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1.2.2 preparation of epoxy resin

Preparation method: the proportion of epoxy resin is 10:2:1（Resin: curing agent: catalyst), and the amount of resin needs to be adjusted based on the weight of carbon fiber cloth compared with the weight of resin adhesive. The ratio used in this project is 1:1.5 (carbon fiber cloth: resin).

Preparation: pour the resin into the plastic cup according to the required amount and stir evenly. When mixing the glue, hold it on the top of the cup to prevent the temperature from accelerating the curing of the glue. When making the wing, it is necessary to pour out a part and add light powder in the proportion of 1:1 to stir evenly. When closing the mold, it is necessary to pour out 60% resin and add light powder and cotton powder to prepare a mixture (resin: light powder: Cotton powder volume ratio 1:1:1).

1.2.3 clean the mold and workbench surface

Before making, wipe the mold and table surface. After soaking the industrial paper with alcohol, wipe the mold and table surface clean. Then remove the glue on the table surface with a shovel and wipe the table surface clean again with a shovel and alcohol.

1.2.4 waxing

Wrap the wax in the industrial paper and apply a certain amount of force to evenly smear the wax on the mold (continuously spiral forward, and the front spiral coil should cover 50% of the rear) in the shape of fish scale, so as to ensure that the wax can be applied everywhere on the mold. Pay attention to whether the front and rear edges of the wing mold are evenly coated and wait for 20 minutes. If the wooden mold needs to be waxed 24h in advance, the first use needs to be waxed three times on the production surface. After each waxing, wipe it off at an interval of 3min, and then wax it at an interval of 15min.

1.3 fabrication of wing skin

1. Brush the prepared resin glue evenly over the entire mold surface with a brush. (pour a strip of glue in the middle, and then apply it left and right with a brush). Pour a part of the glue onto the table and spread it with carbon fiber cloth, spreading it from one side to the other.

2. Place one end of the cut carbon fiber 3K woven cloth on the wing mold and press the leading edge of the mold, and then press it along the mold to the other end and press the other edge. After the 3K woven cloth is fully compressed, the place not soaked by the glue is brushed with glue again to make the woven cloth completely wet. Then cut the woven cloth outside the front and rear edges of the mold with scissors, and pay attention to compacting the front and rear edges with a brush.

3. Lay the film stripping cloth, isolation film, breathable felt and vacuum bag on the mold in turn, and stick a circle of sealant strips around the mold. Note that the sealant strips at the four corners are closely bonded together to prevent air leakage.

4. Adhere the sealing strip to the vacuum bag, pull up a bulge at both ends of the four corners of the mold to leave a safety margin to prevent the vacuum bag from being broken during vacuum pumping.

5. Connect the vacuum membrane to the air pump, vacuum to 0.9-0.8 and keep it for two days (according to different resin time, generally 12-24 hours). Vacuum (vacuum coefficient 0.8-0.9) for die pressing. The minimum guarantee is 0.8.

1.4 fabrication of light wood wing rib with carbon fiber clip

1. Pour a part of the glue on the table, and spread the carbon fiber cloth on one side first, and then slowly spread it to the other side.

2. Press the carbon cloth with a brush to wet the carbon cloth with glue. Put on the wooden board and press it to make it closely connected with the carbon cloth. Each wooden board needs to be placed with a gap. Press the middle gap when brushing glue to make it have creases. Brush the glue on the board and put the other half of the carbon fiber on the board to press the glue.

3. Lay the release cloth to prevent bubbles when laying the release cloth, then lay the isolation film, and finally lay the breathable felt.

4. When laying the vacuum bag, wipe the adhesive around with alcohol, and then stick the sealing strip around, leaving a safety margin at the four corners of the vacuum bag.

5. Connect the vacuum membrane to the air pump, vacuum to 0.9-0.8 and keep it for two days.

1.5 wing clamping operation

1. Use a small shovel to gently separate the formed wing skin from the mold, and then use a shovel to shovel off the excess part. Cut the aileron at the trailing edge of the skin.

2. Measure the position where the ribs are to be installed, draw a line and then polish the scribed part with sandpaper. Roughly polish the positions of the wing ribs and leading edge strips with sandpaper. Wipe the polished part with industrial paper soaked with alcohol.

3. Coat the prepared resin with resin of clear resin and hydrogenated powder and cotton powder on the grinding place and the contact surface between the rib and the skin. Scrape off the excess glue with a wooden strip to make the glue and the rib surface arc. The leading and trailing edges of the skin.

4. Close the molds of the upper and lower wing surfaces together and insert positioning pins for fixation.

2 pneumatic analysis

Profili software provides airfoil shape data and aerodynamic performance data, which shortens the airfoil design cycle.

The airfoil selected in the design is Clark W: the maximum camber is 11.22% at the chord of 30.0%; The maximum surface is 3.76% at 40.0% chord. The governing equation in numerical simulation is the unsteady Navier Stokes equation with constant density and viscosity.

According to this figure, the minimum drag angle of attack of this airfoil is 4alpha.

Airborne equipment: two Lanyu 32212 700kv motors, two haoying 50A electric regulators, 3s2p21700 battery pack, Lei Xun pixhawkv4 flight control, steering pan tilt, and binocular image recognition system. Aircraft takeoff weight: WTO is the sum of model aircraft structural weight WS, airborne equipment weight wfeq and loading weight WPL. Namely:

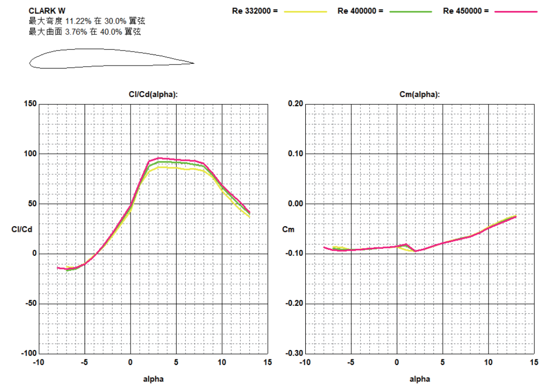

Figure 1 airfoil analysis

Wto=ws+wfeq+wpl (1)

Where ws=1770g; Wfeq=458g; Wpl=300g is calculated as wto=2528g.

Table 1 motor model parameters

power P	voltage	Current I	Thrust wt	Efficiency eff
23.61	24.79	0.95	289	12.24
50.93	24.68	2.06	428	8.4
104.61	24.41	4.29	661	6.32
168.55	24.13	6.98	879	5.21
236.16	23.8	9.92	1087	4.6
316.73	23.48	13.49	1290	4.07
406.85	23.09	17.62	1497	3.68
515.98	22.65	22.78	1688	3.27

It is found that fstatic tension =2×1290=2580g.

Thrust weight ratio: fstatic tension /wto=1.02.

Reynolds number is a dimensionless number representing the relationship between inertial force and viscous force, which is calculated by re=332060 of the following wing model.

Re=pvl/μ(2)

From the following formula

Bav= (b0+b1) /2 (3)

Determine that the chord length BAV of the aircraft is equal to 1.4m

From the following formula

λ=I/b=i2/s (4)

Determine that the aspect ratio of the aircraft is equal to 4.36.

It can be seen from this figure that the pressure on the wing, wing box, flat tail and leading edge of the aircraft head is relatively large, and the maximum pressure is 3.153×ten^{2}PA.

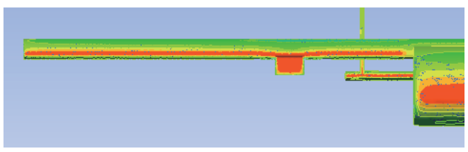

Figure 2 front pressure nephogram of aircraft

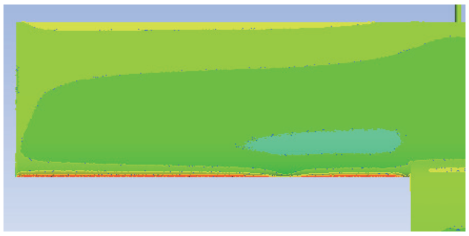

Figure 3 cloud chart of aircraft back pressure

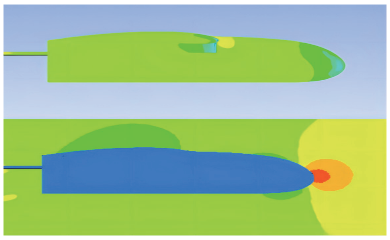

Figure 4 pressure nephogram of aircraft side and cross section

For aircraft mesh generation, the denser the mesh, the more accurate the solution. Therefore, local mesh refinement is usually performed on the wing part that has an impact on the results.

It can be seen from this figure that the pressure distribution on the upper wing surface and the upper part of the flat tail of the aircraft is relatively uniform, and due to the existence of the wing box, there is a local low pressure near the wing box on the upper wing surface, with a minimum pressure of -110.83pa.

Pressure fluctuation can be calculated by eddy current surface method or by solving Navier Stokes equation (CFD). It can be seen from this figure that the pressure on the side of the aircraft is relatively uniform, and the pressure on the side of the aircraft head presents a gradient distribution, and the maximum pressure point appears at the leading edge of the aircraft head, of which the maximum pressure is 3.153×ten²PA.

It can be seen from this figure that the speed difference between the upper and lower wing surfaces of the aircraft airfoil shape and pressure distribution is large, and the positive suction provided by the upper wing surface is large, which makes the lift coefficient of the aircraft wing larger, and the maximum speed difference is 6.09m/s.

It can be seen from Figure 7 that the air flow around the wing tip and the bottom surface of the aircraft head will form a low-pressure area.

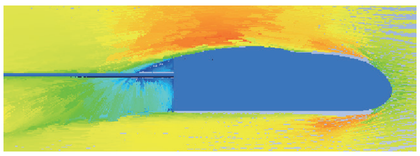

Fig. 5 velocity variation diagram of aircraft cross section

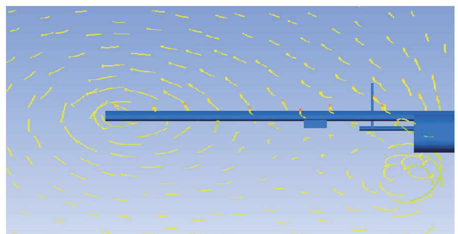

Figure 6 front vortex diagram of aircraft

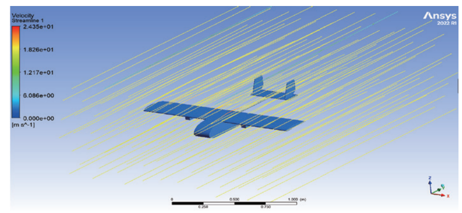

Figure 7 Overall streamline diagram

3 Summary

In this paper, an integrated wing based on composite materials is designed and fabricated. The manufacturing process of composite materials is introduced in detail and the aerodynamic performance of the wing is analyzed. The rationality and feasibility of this design can be verified through a series of verification in this paper.

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