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The Scale Model Experiment and Aerodynamic Analysis of a UAV

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Abstract

This paper uses CATIA to 3D model a certain type of UAV and uses 3D printing to make a scaled model, and then uses the AF1300 low-speed wind tunnel to conduct wind tunnel experiments on it, and obtains its lift characteristics and resistance characteristics. The data was also collated by EXCEL and compared with the wind tunnel test data of the NACA0012 airfoil and the XFLR5 simulation data, which verified that the simulation analysis of the XFLR5 was suitable for aerodynamic analysis and design of the UAV. Then, using XFLR5, the aerodynamic characteristics of the different torsional angles of the main wings of the above-mentioned UAV were analyzed and compared, and the relationship between the rising resistance characteristics and the torsional angle of the wingtip was obtained.

Keywords

Wind Tunnel; XFLR5; Aerodynamic Characteristics; Wingtip Torsional Angle; Wingtip Vortex.

1. Introduction

Wind tunnel experiments are arguably the most commonly used and effective method for aircraft design. Large wind tunnel experiments, which often consume a lot of energy and money, can no longer be relied upon to solve all complex problems[1], giving rise to computational fluid dynamics (CFD), which allows for better qualitative or quantitative analysis of the physical quadrants of fluid flow by using computers to solve partial differential equations for flow, in order to optimize the discipline of the initial design[2].

The aircraft is initially evaluated for aerodynamic shape at the beginning of the design phase and iteratively optimized, using computational fluid dynamics software as a supplement. The XFLR5 is such an efficient and simple design tool. Ye Longhai et al. also used XFLR5 to analyze the aerodynamic characteristics of the KFM airfoil, and through the analysis of the surface pressure of the airfoil, when the wing angle of attack was large, turbulence would occur at the ladder of the KFM airfoil, so that the lift coefficient and lift-to-drag ratio of the aircraft were reduced[3]. Su Yang and Xu Shuang established a design method for theoretical calculation combined with XFLR5 aerodynamic estimation software analysis, and designed and analyzed the tilting wing UAV, which proved the feasibility of the design method and provided a reference for the aerodynamic design of A UAV with a similar configuration[4]. Akshay Rajesh Prasad Vivek Sharma used XFLR5 software to analyze the most favorable angle of attack and full wing performance in the design and performance analysis of the high wings of the miniature drone[5].

XFLR5's aerodynamic characteristics analysis results often have a lot of errors, but it can still correctly react to the trend, more suitable for teaching, and the study of analysis of aerodynamic characteristics, and for its results, combined with wind tunnel test verification is better.

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2. Research Methods

This paper uses CATIA to 3D model a type of UAV. From the similarity theorem, it can be seen that the experiment needs to make a model according to a certain contraction principle in order to satisfy the geometric similarity, but also to make the flow of the two belong to the same kind of phenomenon, and make its unitary conditions similar, and the qualitative criteria composed of the flow parameters are numerically equal. The miniature model is made by 3D printing, and then the AF1300 low-speed wind tunnel is used to experiment with the wind tunnel to obtain its lift characteristics and resistance characteristics. By sorting out the data through EXCEL and comparing the wind tunnel test data of the NACA0012 airfoil with the XFLR5 simulation data, it was verified that the simulation analysis of the XFLR5 was suitable for Aerodynamic analysis and design of the UAV. Then, using XFLR5, the aerodynamic characteristics of the different torsional angles of the main wings of the above-mentioned UAVs are analyzed and compared, and the relationship between the rising resistance characteristics and the torsional angle of the wingtip is obtained.

3. Modeling and Experimental Verificatio

3.1. CAtia Modeling

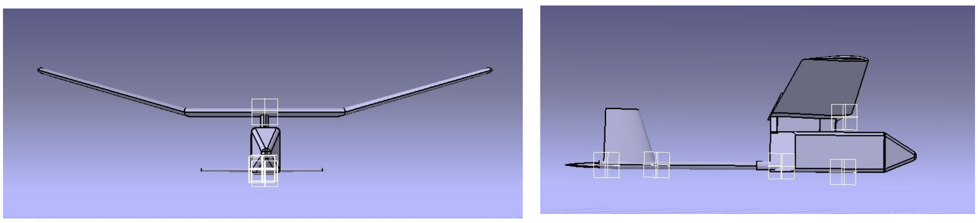

Fig 1. Model assembly drawing

Introduction of airfoils and modeling of wings: This article selects a type of UAV as the prototype, the main wing is selected as S7012, and the flat tail and vertical tail are both USA0012 airfoil. Here we use an airfoil design software, Profili, which contains a large amount of airfoil data and models, and the airfoil data used in this article is derived from this software. After the successful modeling of each part of the airframe, a new CATIA assembly file is created, the above parts are imported separately, and then the assembly is moved according to the geometric relationship, and the constraints can be set.

3.2. 3D Printing

The assembly file is converted into an STL file using STL Rapid Prototyping in CATIA's machining module, and then the assembly file is processed using cura slicing software, and then the required GCODE file is generated and imported into a 3D printer for printing. Due to the poor printing effect of the whole machine, the wings and fuselage are printed separately, and finally the ABS glue is used for bonding.

3.3. Wind Tunnel Experiments

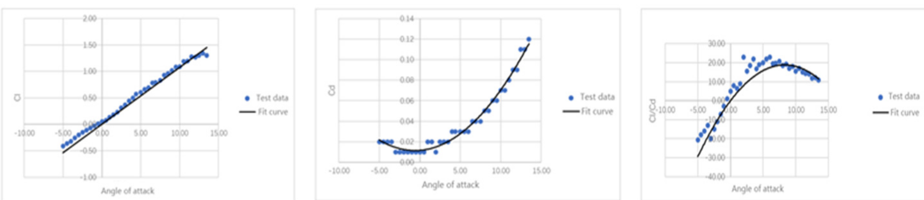

Fig 2. NACA0012 lift characteristic curve, resistance characteristic curve, and rise-to-drag ratio curve

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Measure the assembled model under test with the AF1300 low-speed wind tunnel.

Experiments on the NACA0012 airfoil were conducted at a wind speed of 20 m/s and an air density of 1.225 kg/m^3. The experimental data are integrated to obtain the lift characteristic curve and resistance characteristic curve, as well as the rise-to-drag ratio curve.

It can be seen that its lift coefficient curve and lift-to-drag ratio curve have passed through the origin, which is in line with the characteristics of the symmetrical airfoil, and the trend of its lift coefficient and resistance coefficient change is also more in line with the theory.

The model of the complete machine under test was repeated twice with a wind speed of 20 m/s and an air density of 1.2 kg/m^3, and the average of the experimental results was taken for analysis to reduce the experimental error.

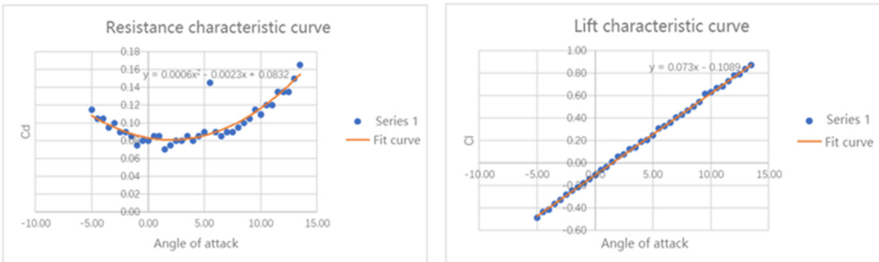

Fig 3. Resistance characteristic curve and lift characteristic curve of unmanned aerial vehicle

From the above figure, it can be seen that its lift coefficient shows a linear increasing trend with the increase of the angle of attack, and the resistance coefficient curve also shows an increasing trend with the increase of the angle of attack in the positive angle of attack, which is due to the fact that the induced resistance coefficient increases proportionally with the square of the lift coefficient. The aerodynamic characteristics reflected in it are roughly in line with theoretical requirements.

4. XFLR5 Software Reliability Verification and Simulation Analysis

4.1. Reliability Verification

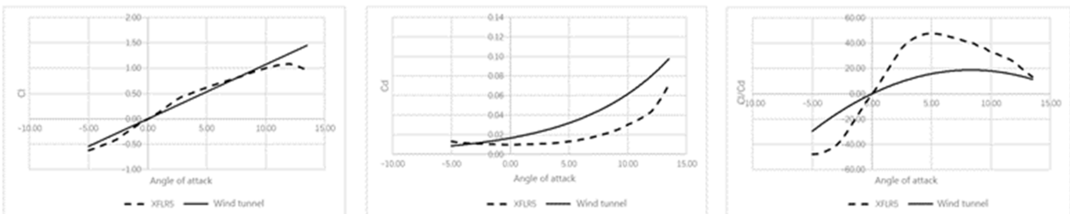

Fig 4. Lift characteristic curve, resistance characteristic curve, and lift-to-drag ratio characteristic curve comparison chart

Here, the NACA0012 airfoil with a wingspan of 300 mm and a chord length of 150 mm is compared with the XFLR5 software simulation data using a Renault number of 206460, a wind speed of 20 m/s and an air density of 1.225 kg/m^3.

As can be seen from the above figures, the wind tunnel test and the software simulation are basically the same as the lift coefficient curve, but in the resistance coefficient part, it can be seen that the resistance coefficient of the wind tunnel test is large, which also leads to a discrepancy in the later resistance curve, which may be caused by the roughness of the model and the cave wall effect [6]. Considering the effect of the cave wall effect, the wind tunnel test is basically consistent with the XFLR5 test results and the general trend.

4.2. Wingtip Torsion Analysis

XFLR5 software was used to set the torsion of the model wing tip to -10°, 0°, 10°, respectively, and simulate the analysis. The air density is 1.225 kg / m^3.

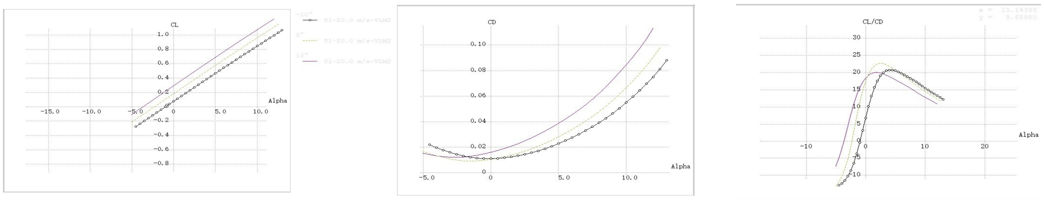

Fig 5. Flow field and downwash strength diagram of wingtip torsion of -10°, 0°, 10°

In this experiment, it can be seen that changing the torsional angle of the wingtip will have an effect on its aerodynamic characteristics. At the same angle of attack, when the wing tip torsion angle is 10°, the lift coefficient is the largest, and its zero-liter angle of attack is the smallest, which shows that the positive torsion of the wing can optimize the aerodynamic characteristics of the wing to a certain extent.

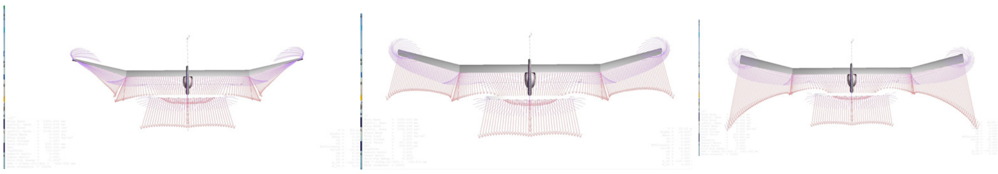

Fig 6. The influence of torsional angle on lift coefficient, resistance characteristics, and rise-to-drag ratio

As can be seen in the resistance characteristic curve chart, in the positive angle of attack area, at the same angle of attack, the resistance coefficient is the largest when the wingtip is twisted to 10°, and the resistance coefficient is the smallest when the torsion is -10°. As can be seen from the downwash strength chart and the induced resistance chart, this is due to the greater lift generated when the torsion is 10°, the wingtip downwash is stronger, and the induced resistance is also greater.

According to the rise-to-drag ratio curve, the model with a torsional angle of 0°has a rising-to-drag ratio greater than -10°and 10°at a favorable angle of attack, and with the increase of the angle of attack, its position becomes between the two, at this time, because in the small angle of attack, the lift coefficient is small, and the proportion of induced resistance to the total resistance of the aircraft is small, so the influence of the torsional angle is difficult to reflect. With the increase of the torsional angle, the pressure center of the wing moves forward, which will affect the stability of the aircraft.

5. Conclusion

Through the wind tunnel test and XFLR5 software in the same Number of Renault aircraft aerodynamic characteristics analysis, and compare the experimental results, combined with the wind tunnel wall effect analysis, knowing that XFLR5 software can obtain more accurate aircraft aerodynamic characteristics, suitable for UAV aerodynamic characteristics research, as well as UAV design field.

Through the study of the torsional angle of the wing, it is found that for the same airfoil, under the same angle of attack, within a certain range, the larger the torsional angle, the greater the lift coefficient of the aircraft, the greater the down washing strength, the greater the induced resistance generated, and the strength of the wingtip vortex is also enhanced. However, at the same time, its pressure center position is also moved forward with the increase of the torsional angle, which will also have a certain impact on the stability of the whole machine.

Acknowledgments

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