МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, д.т.н, проф. _______
Сергій ІГНАТОВИЧ
«__ »_________2021р.

ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»
ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Конструкція крила для покращення характеристик аеродинаміки та опору втомі»

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Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
DEPARTMENT OF AIRCRAFT DESYIGN

PERMISSION TO DEFEND
Head of the Department
Professor, Dr. of Sc.
__________ Sergiy IGNATOVYCH
«___ »___________2021

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND ROCKET-SPACE ENGINEERING"

Topic: «Wing layout for aerodynamic and fatigue enhancement»

Fulfilled by: __________ **Maoyuan LI**

Supervisor:
Dr. of Sc., professor ___________ **Mykhailo KARUSKEVYCH**

Labor protection advisor:
Ph.D., associate professor ____________**Victoria KOVALENKO**

Environmental protection adviser:
Dr.of Sc. professor ____________ **Tamara DUDAR**

Standards Inspector ____________ **Sergiy KHIZHNYAK**

Kyiv 2021

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аерокосмічний
Кафедра конструкції літальних апаратів
Освітній ступінь «Магістр»
Спеціальність 134 «Авіаційна та ракетно-космічна техніка»
Освітньо-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри
д.т.н., професор
________Сергій ІГНАТОВИЧ
«___» ___________2021 р.

ЗАВДАННЯ
на виконання дипломної роботи студента

МАОЮАНЬ ЛІ

1..Тема роботи «Конструкція крила для покращення характеристик аеродинаміки та опору втомі», затверджена наказом ректора від 08 жовтня 2021 року №2173/ст.

2.Термін виконання роботи: з 11.10. 2021р. по 31.12 2021 р.

3. Вихідні дані до проекту: Аеродинамічні характеристики легких літаків, дані про навантаження на літак в польоті.

4. Зміст пояснювальної записки: Результати аналізу існуючих розробок стосовно концепції «Рухомого» крила, результати моделювання засобами FLUENT та ANSYS, аналіз впливу запропонованої конструкції на аеродинамчні характеристики та втомне пошкодження конструкції, розділи «Охорона праці» та «Охорона навколишнього середовища».

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: Презентація PowerPoint з результатами дослідження

6. Календарний план-графік

№ пор.	Завдання	Термін Виконання	Відмітка про виконання
1	Аналіз стану проблеми та формування нової концепції крила	8.10.2021−12.10.2021	
2	Чисельне моделювання засобами FLUENT	13.10.2021−16.10.2021	
3	Аналіз пружно деформованого стану засобами ANSYS	17.10.2021−22.10.2021	
4	Розробка рекомендацій по практичному застосуванню результатів роботи	16.11.2021−30.11.2021	
5	Виконання розділу «Охорона праці»	30.11.2021- 7.12.2021	
6	Виконання розділу «Охорона навколишнього середовища»	7.12.2021- 15.12.2021	
7	Редагування, підготовка презентації	15.12.2021-20.12.2021	

7. Консультанти з окремих розділів

Розділ	Консультанти	Дата, підпис	
		Завдання Видав	Завдання Прийняв
Охорона праці	к. біол. н., доцент Вікторія КОВАЛЕНКО		
Охорона навколишнього середовища	д. т. н, професор Тамара ДУДАР		-:-

Дата видачі завдання: “11.10. 2021 р.

Керівник дипломної роботи _____________ Михайло КАРУСКЕВИЧ

Завдання прийняв до виконання _____________ Маоюань ЛІ

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Aerospace faculty
Department of aircraft design
Educational Degree "Master"
Specialty 134 «Aviation and space rocket technology»
Educational Professional program «Aircraft equipment»

APPROVED BY
Head of department
Dr. of Sc., professor
_______ Sergiy IGNATOVYCH
«___» ___________2021

TASK
For the master degree thesis
LI MAOYUAN

1. Topic: **“Wing layout for aerodynamic and fatigue enhancement»**,
approved by the Rector’s order №№2173/ст. 8 October 2021.

2. Period of work: 11.10. 2021 - 20.12.2021

3. Initial data: Aerodynamic characteristics of Light aircraft, data regarding the loads on aircraft in flight.

4. Content: Analysis of the achievements in the field of self-adjusting wing, results of processes simulating by FLUENT and ANSYS software, analysis of improvement of aerodynamic and fatigue characteristics, parts devoted to Labor and Environment protections.

5. Required material: Text of the Master’s Thesis, PowerPoint presentation with results of the work.

6.Thesis schedule:

№	Task	Time limits	Done
1	State-of-Art analysis and new design concept	8.10.2021−12.10.2021	
2	Numerical simulation methods by FLUENT software	13.10.2021−16.10.2021	
3	Stress-Strain and Fatigue life ANSYS analysis	17.10.2021−22.10.2021	
4	Development of the recommendation for practical application of the research results	16.11.2021−30.11.2021	
5	Labor protection problems	30.11.2021- 7.12.2021	
6	Environment protection problems	7.12.2021- 15.12.2021	
7	Explanatory note final revision	15.12.2021-20.12.2021	

7. Special chapter advisers

Chapter	Consultants	Date, signature	
		Task Issued	Task Received
Labor protection	PhD, associate professor Victoria KOVALENKO		
Environmental protection	Dr, of Sc., professor Tamara DUDAR		

8. Date of the issue of the task: 11 October 2021.

Supervisor ______________ Mykhailo KARUSKEVYCH
Student ______________ Маоюань ЛІ

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра
«Конструкція крила для покращення характеристик аеродинаміки та опору втомі»:

70 с., 33 рис., 5 табл., 36 джерел

Дана дипломна робота присвячена розробці крила легкого літака, яке дозволяє зменшити навантаження на крило літака за рахунок автоматичного саморегулювання кута атаки, покращити характеристики стійкості, підвищити ресурсні показники.

В роботі було використано методи компьютерного проєктування та розрахунку, зокрема системи FLUENT та ANSYS. В роботі представлено концепцію нового крила, його геометричні характеристики, результати розрахунків, рекомендації по застосуванню результатів дослідження.

Практичне значення результатів дипломної роботи магістра полягає в можливості забезпечення підвищених ресурсних характеристик легких літаків.

Матеріали дипломної роботи магістра можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проєктних установ.

Дипломна робота, легкий літак, навантаження на крило, кут атаки, ресурсні характеристики

ABSTRACT

Master degree thesis “Wing layout for aerodynamic and fatigue enhancement”

70 pages, 33 figures, 5 tables, 36 references

This master thesis is dedicated to the development of the light aircraft wing, that allows reduction of the load on the wing by the means of automatical self-ajustable angle of attack, to improve aircraft stability, to extend parameters of the service life.

Software FLUENT and ANSYS have been used in the work. The concept of new wing, its geometrical characteristics, results of calculations, recommendation on the application are presented in the work.

The practical value of the work is the possibility to provide extended service life characteristics for light aircraft.

The materials of the master's diploma can be used in the aviation industry and in the educational process of aviation specialties.

Master thesis, light aircraft, loads on the wing, angle of attack, service life characteristics

CONTENTS

INTRODUCTION.

Flying turbulence is a change in the speed of the aircraft caused by the atmospheric turbulence and a significant change in the lift of the aircraft, which leads to flight instability. The short take-off and landing capability is an important indicator of the flight performance of the aircraft. This paper proposes a new type of big and small aircraft based on the idea of free wings The wing layout can not only use the aerodynamic principle to realize the self-adjustment of the angle of attack to reduce the occurrence of flight turbulence and reduce the pressure of flight control, but also can improve the short-range takeoff and landing capability of the aircraft to a certain extent. This paper mainly studies the aerodynamic interference of the big and small wings from the chord length ratio, spacing, staggering method, and wing difference angle, and verifies the feasibility of the aerodynamic layout of the big and small wings, and analyzes the force and moment characteristics of the big and small wings when the incoming flow changes. A study was carried out, using the fluid-structure coupling method to analyze the stress characteristics of the self-adjusting angle of attack, to study its fatigue enhancement characteristics, and finally the applicability of the new wing was introduced. This paper verifies the feasibility of automatic matching between the angle of attack and the speed of the aerodynamic layout of the big and small wings, but also provides a certain reference for the design of the dual-wing layout of the aircraft.

The aim of the work is to propose new wing layout for aerodynamic and fatigue enhancement.

To gain the aim of the work, the following **objectives** should be solved:

1. To make the aircraft fly more smoothly and reduce the effect of speed disturbance on the aircraft.
2. To carry out aerodynamic optimization of the designed wing, to use numerical simulation to study its flow characteristics.

3. To verify the ability of the designed wing to automatically adjust the angle of attack, the moment characteristics of the big and small wings will be studied by numerical simulation.
4. To study the enhancement effect of the designed airfoil on the fatigue life of the airfoil by a fluid-structure coupling method based on the ANSYS software.
5. To develop recommendation on the practical application of the Master work results.

The guide for the Master work issued by the aircraft design department where used in all stages of the work on the diploma work.

PART 1. STATE OF THE ART. RESEARCH BACKGROUND

1.1 Statement of the current status of the study

Short takeoff and landing capability is one of the most important indicators of the flight performance of an aircraft. In 1945, Danil R. Zuck first proposed the concept of free wing and designed and built a small free wing aircraft, and in 1952, G.G.Spratt also used the new idea of free wing to build an aircraft shown in fig.1.1 [1]. K. Ro and J. W. Kamman and Wookje Park demonstrated the excellent takeoff and landing capability of free tilting wings and the mitigation capability for gusts in typical UAVs using experimental and computational simulations, respectively [2-4].

Fig.1.1 - Free wing model designed by Cheng Chuan [1]

Fig.1.2 - Free Wing UAV Scorpion [2]

As the name implies, the free wing is a kind of fixed wing connected to the fuselage by a rotating shaft, and the wing can be rotated with the rotating shaft. However, the free wing currently has problems such as flutter and low downward deflection rudder efficiency. In this paper, based on the free wing, the aerodynamic principle of small wing with big and small wing layout is used to realize the adaptive variable angle of attack motion of big wing to improve the takeoff and landing performance of the vehicle and to improve the flight stability of the vehicle by using the insensitivity of the free wing to gusts of wind and turbulence to reduce the impact of flight bumps caused by significant changes in lift due to atmospheric turbulence vortex [5]. Ruhao Hua et al. of Northwestern Polytechnic University demonstrated that the row layout form can retard the flow separation by the acceleration of airflow between the wings at low speeds [6-8] by studying the row layout aircraft, as shown in Fig.1.3.

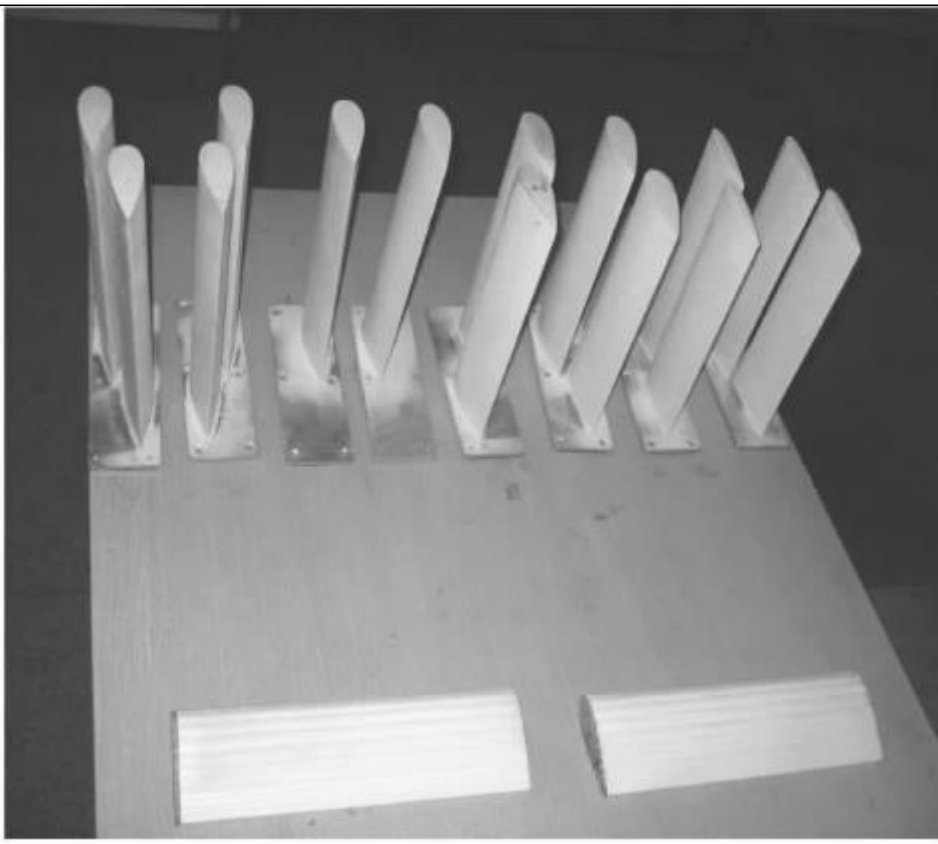

Fig.1.3 - Wind tunnel model of row wing layout [6]

Zhang Qing et al. showed by studying the low Reynolds number aerodynamic characteristics of a row biplane layout that the row layout can improve the overall aerodynamic efficiency by delaying or suppressing the flow separation at the trailing edge of the wing through aerodynamic interference between the front and rear wings [9]. Lei Luo et al. from Beijing University of Aeronautics and Astronautics studied the biplane aerodynamic interference problem at low Reynolds number, in which the biplane coupled layout eventually led to an increase in lift-to-drag ratio at low Reynolds number [10]. Kai Cao et al. studied the ground effect lift enhancement of the ground effect wing in the ground effect zone, which can effectively increase the lift coefficient and improve the aerodynamic performance of the aircraft in the takeoff and landing phase [11]. Foreign G.M. Jahangir Ala et al. showed that different structural forms of upper and lower biplane layout have different effects on the overall aerodynamic performance by studying the NACA0024 airfoil [12], and Z. Husain et al. explored the optimal position of the biplane layout airfoil under low speed conditions by using commercial hydrodynamic calculation software[13], as shown in Fig.1.4.

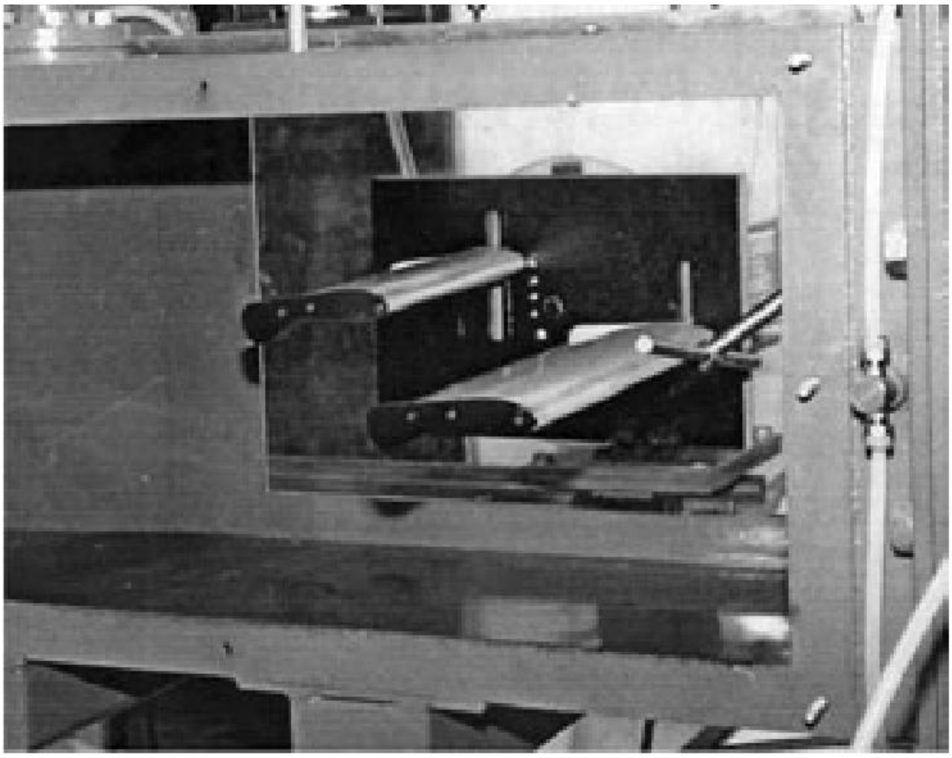

Fig.1.4 - Upper and lower wing layout wind tunnel model [11]

Zhenrong Liao et al. studied the aerodynamic disturbances of the biplane form of wing box layout at high subsonic speeds and showed that the wing box layout of the biplane could improve the flight performance of the vehicle, which proved the feasibility of the biplane layout under high subsonic operating conditions. Zhuo Meifang et al. showed that the front wing area should be appropriately increased and the rear wing should be moved forward in order to reduce aerodynamic disturbances in high subsonic flight[14], as shown in Fig.1.5. Based on the above research, this paper proposes a self-adjusting angle-of-attack type big and small airfoil, which adopts the form of biplane layout and uses the torque characteristics of the big and small airfoils on the rotating axis to realize the change of lift force with speed when the speed changes, and automatically adjusts the lift force size to make the flight more smooth.

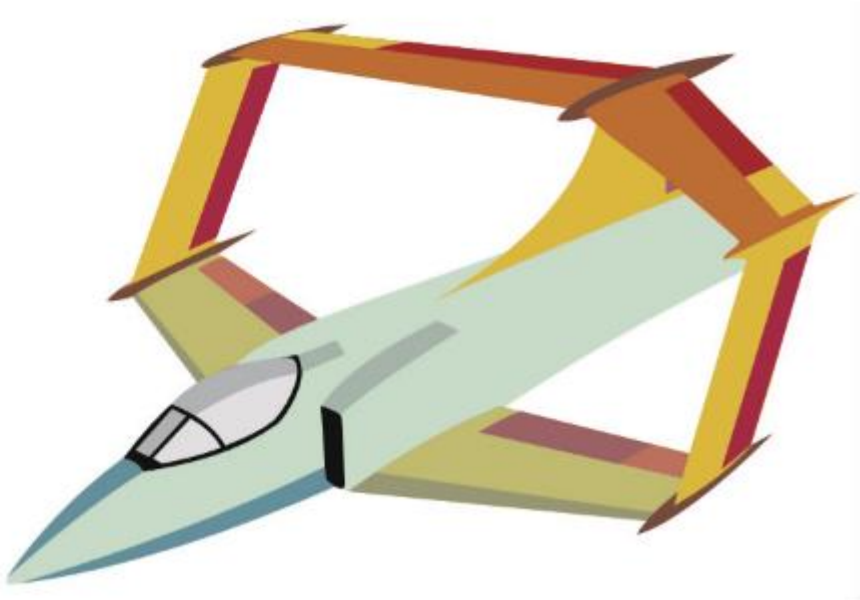

Fig.1.5 -Wing box layout [14]

1.2 Problems in aircraft flight

Since the Wright brothers invented the first airplane in the United States, people have been dreaming of flying in the blue sky and excited, but at the same time troubled by the skidding required for takeoff and landing. With the increasing development of aircraft design technology, the takeoff glide speed, weight and impact on the runway have increased the demand for takeoff and landing runways, especially for modern high-performance fighter aircraft and other special function aircraft that rely on long, smooth, solid runways, which are increasingly becoming the fatal weakness of modern air forces. In order to get rid of this development dilemma, people have been tirelessly developing aircraft with vertical/short takeoff and landing capability that can fly freely like a bird since the era of aviation pioneers.

Throughout the history of aircraft development, the road to vertical/short takeoff and landing began with rotary-wing aircraft such as helicopters, although modern helicopter technology has become increasingly sophisticated.

Although the development of modern helicopter technology has become increasingly sophisticated, the swing of the helicopter rotor blades limit its forward flight speed cannot exceed the linear speed of the rotor tips, while the swing increases mechanical vibration, wear and tear of the hinges and fatigue of the elastic components, making the reliability and speed characteristics of helicopters are always inferior to fixed-wing aircraft; Sikorsky, the leader of the U.S. helicopter industry, developed the X-wing aircraft, as shown in Figure 1.6 and Figure 1.7 As shown in Figure 1.6 and Figure 1.7, its main idea is to combine fixed wing and rotor wing; X-shaped wing can rotate in helicopter state to generate lift directly for takeoff and landing; when the preflight reaches a certain speed, the X-shaped wing will be locked and fixed, and used as a fixed wing, and the aircraft shifts to fixed wing mode, although the speed characteristics of rotor wing aircraft are solved to some extent, but the complex structural rotation system and the shift of lift mechanism Control problems during the period, etc. greatly reduce the stability of this type of aircraft. There are also speed and altitude limitations, and also time limitations, which cannot be converted anytime and anywhere. During combat, the conversion time, altitude and speed of this lift mechanism bring great trouble to tactical actions

Fig.1.6 -Dragonfly X-wing [21]

Fig.1.7 -X-142 Tilt-Wing Aircraft [22]

In the 1990s, a new family of tactical unmanned aircraft, the Scorpion, was developed by the Free-wing Aerial Robotics Corporation of the United States in collaboration with the University of Maryland, and a series of wind tunnel tests, including full-aircraft and component force and moment measurements and flow displays, were conducted; preliminary predictions were made for the longitudinal aerodynamic dynamics of this class of aircraft, as shown in Figure 1.8 [23]. The innovations in the aerodynamic layout of this UAV are mainly the use of free wing and tilted fuselage, and vector pull technology. Compared with the traditional fixed-wing and rotary-wing UAVs, the aerodynamic advantage of the free wing is that it makes the aircraft insensitive to gusts of wind and turbulence, so it can fly more smoothly even under adverse conditions, and can provide a stable flight platform for photography and telemetry, etc [3]. On the other hand, thanks to the free wing, it is possible to tilt the fuselage, change the direction of pull and use the direct force of the engine, which can make the aircraft capable of short takeoff and landing.

Samuel F. Galls et al. at Texas A&M University designed and built a model of a free-wing tilting fuselage vehicle scaled to 20% of the size of the prototype, and verified the stability and maneuverability of the vehicle under various flight conditions and flight configurations through wind tunnel experiments. The aerodynamic and handling characteristics of the vehicle were evaluated to make its application to flight measurement and control possible.

Fig.1.8 -Free wing MK-IV [23]

When an aircraft encounters turbulent airflow or is subject to uneven aerodynamic impact, it will sway left and right, lurch back and forth, throw up and down, and tremble locally, making it difficult to maneuver the aircraft with inaccurate instruments, which means the aircraft is bumpy. Once the aircraft enters the heavy bumpy area, it will be difficult for the pilot to operate and may even cause a major accident that destroys the aircraft and kills people.

When an airplane produces bumps, especially strong bumps, it has a great impact on the structure and maneuvering of the airplane, as follows: When an airplane flies in a bumpy area, irregular changes in airflow will cause irregular changes in the height, speed and attitude of the airplane. When the turbulence is strong, the aircraft can change its altitude up and down, often up to tens of meters or even hundreds of meters, which will bring great difficulties to the aircraft's maneuvering. Because of this strong change in the aircraft's status, the pilot must spend more energy to keep the aircraft in a normal state in time, thus causing great physical exertion and easy fatigue.

When there are bumps in flight, all parts of the aircraft are subjected to big and small loads, and the stronger the bumps, the greater the load change. If the aircraft is subjected to strong load changes over a long period of time, or if it is subjected to more than its maximum load, some parts of the aircraft may be deformed or even broken, such as the aircraft wings.

Conclusion to part 1

In the above study, the control of the free wing mostly uses the trailing edge of the wing to place the elevator to control the deflection of the free wing, and the wing type used in the free wing is mostly a trailing edge reverse curved S-shaped wing type, the trailing edge of the wing is reversed upward to provide a certain low head moment to the free wing, so it is said that this wing type will generate a certain amount of negative lift in the trailing edge part compared to the traditional wing type, and there is a certain degradation in the aerodynamic performance The aerodynamic performance is somewhat degraded. Secondly, the aerodynamic characteristics of the biplane layout are not applied in the above study, and there are few studies on the layout of the small wing aerodynamics to complete the self-adjusting variable angle of attack to get the small wing up form, so the aerodynamic characteristics and moment characteristics of the proposed new small and big wing layout are studied in this paper.

As a result of the state of art study the aim and objectives of the work have been formulated. These are:

The aim of the work is to propose new wing layout for aerodynamic and fatigue enhancement.

To gain the aim of the work, the following **objectives** should be solved:

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PART 2. CONCEPT OF NEW TYPE OF ANGLE OF ATTACK SELF-ADJUSTING BIG AND SMALL WING STRUCTURAL FEATURES

2.1 General idea

The general idea of the work can be illustrated by the Fig. 2.1 with a two-dimensional view of the wing with automatic angle of attack adjustment. The wing 1 is mounted into the fixed wing and fuselage by the rotating shaft 4, and the Angle of attack change limiting block 6 is inserted into the limit slot in the fixed wing, which is flexibly positioned by the damping spring 7. The upper rear edge of the wing is provided with a small wing 2 connected to the wing by a support rod 3. Wherein the damping spring 7 acts on the deflection limiting block 6 to improve the stability of the wing deflection. Fig.2.2 is the overall schematic diagram in normal cruising condition.

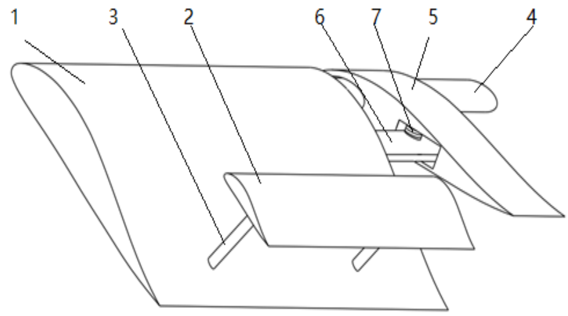


Fig. 2.1 - Schematic diagram of the structure of big and small wings

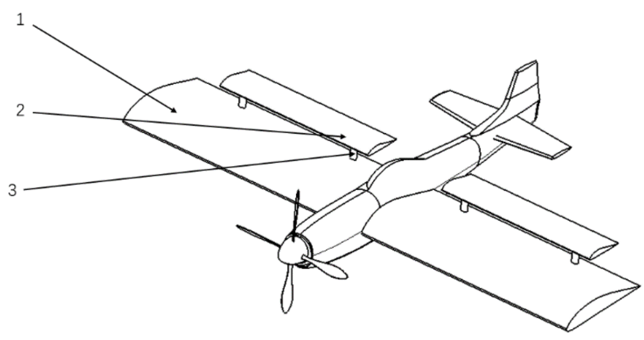


Fig. 2.2 - The size of the wing flight diagram

2.2 Aerodynamics of the new size wing

2.2.1 Introduction of the principle

This kind of automatic adjustment of wing angle of attack of small and big wing structure principle is to change the original fixed wing with the fuselage to a movable wing that can be deflected around the fuselage at a small angle by a rotating shaft, where the rotating shaft is located in the aerodynamic center of the big wing, and the upper part of its trailing edge is set to adjust the small wing, when the aircraft is in the cruise state, the gravity of the big wing, small wing and big and small wings are balanced at the rotating shaft, when the incoming flow speed increases When the incoming flow speed increases, the big and small wings will produce a low head moment to the rotor shaft due to the increase of lift, which makes the angle of attack of the big and small wings decrease, so as to maintain the basic stability of lift, and the aircraft will fly more smoothly; when the incoming flow speed decreases, the big and small wings will produce a head moment to the rotor shaft due to the decrease of lift, which makes the angle of attack of the big and small wings increase, so as to maintain the basic stability of lift. Moreover, the attitude of the airframe is not affected during the automatic adjustment of the wing angle of attack, and the flight stability is improved. When the aircraft is to be artificially controlled, the pilot can still manipulate the horizontal tail, as in conventional aircraft, and change the angle of attack of the wings together with the automatic adjustment of the angle of attack to achieve the control of aircraft lift.

In addition, the layout of the small and big wings can also generate auxiliary lift, which can generate additional lift during low-speed flight to improve the takeoff and landing performance of the aircraft, and because the big wings can be rotated, the takeoff angle of the big wings increases, reducing the aircraft's speed off the ground to shorten the takeoff and landing distance and improve the performance of the aircraft. The big and small wings are not fixed to the fuselage, but are articulated with the fixed end of the wing and can rotate around the axis within a certain limit.

2.2.2 Theoretical analysis

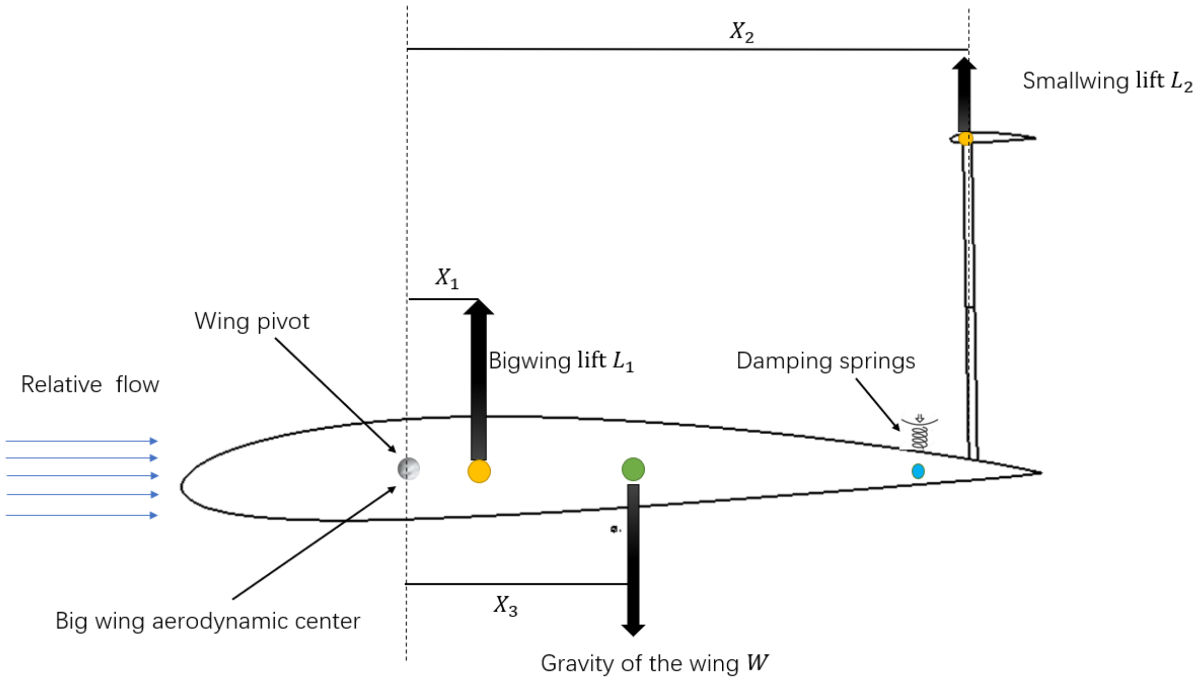


Fig.2.3 - Big and small wing force analysis diagram

The angle of attack self-adjusting size wing is in equilibrium with its forces and moments in the cruising state, and its forces are shown in Fig.2.3, where the big wing lift L_1; the distance from the big wing pressure center to the pivot axis is X_1; the small wing lift L_2; the distance from the small wing to the pivot axis is X_2, the gravity of the big and small wings is W; and the distance from the center of gravity to the pivot axis is X_3.

Assume that the torque balance is in the cruising state.

$$L_{1(v,\alpha)} \cdot X_1 + L_{2(v,\alpha)} \cdot X_2 = W \cdot X_3 \tag{2.1}$$

The torque on the rotating shaft $\sum M_0$ can be expressed as

$$\sum M_0 = L_{1(v,\alpha)} \cdot X_1 + L_{2(v,\alpha)} \cdot X_2 - W \cdot X_3 = 0 \tag{2.2}$$

The moment to the rotating axis is 0, which means that the cruising state size wing is in moment balance. When the velocity Δv perturbation occurs, here it may be useful to set $\Delta v > 0$, the increase in velocity makes the lift increase, and that is, after the speed perturbation, the moment at the rotary axis can be expressed as

$$(L_{1(v,\alpha)} + \Delta L_1)\cdot X_1 + (L_{2(v,\alpha)} + \Delta L_2)\cdot X_2 > W\cdot X_3 = L_1\cdot X_1 + L_2\cdot X_2 \quad (2.3)$$

The torque of the rotating axis becomes larger than the torque of the cruising state, $\sum M_0 > 0$, The big and small wings are lowered around the axis of rotation (angle of attack is reduced), which reduces the lift of the big and small wings.

Let the angle of attack of the big and small wings decrease to α' under the velocity perturbation to such an extent that the moments of the big and small wings are balanced again

That is:

$$L'_{1(v+\Delta v,\alpha')}\cdot X_1 + L'_{2(v+\Delta v,\alpha')}\cdot X_2 = W\cdot X_3 = L_1\cdot X_1 + L_2\cdot X_2 \quad (2.4)$$

That is:

$$(L'_{1(v+\Delta v,\alpha')} - L_{1(v,\alpha)})\cdot X_1 + L'_{2(v+\Delta v,\alpha')} - L_{2(v,\alpha)})\cdot X_2 = 0 \quad (2.5)$$

Taking the lift equation $\mathrm{L}=\frac{1}{2}\rho \mathrm{V}^2 \mathrm{C}_L S$ into account gives,

$$\frac{1}{2}\rho \mathrm{V}^2 S_1 X_1[(v+\Delta v)^2\cdot C_{L_1(\alpha')} - v^2 C_{L_1(\alpha)}] + \frac{1}{2}\rho \mathrm{V}^2 S_2 X_2[(v+\Delta v)^2\cdot C_{L_2(\alpha')} - v^2 C_{L_2(\alpha)}] = 0 \quad (2.6)$$

The relationship between the incoming velocity disturbance and the angle of attack adjustment at re-equilibration can be obtained as follows:

$$[(v+\Delta v)^2\cdot C_{L(\alpha')} - v^2 C_{L(\alpha)}] = 0 \quad (2.7)$$

According to the lift coefficient curve of this airfoil $C_L = k\alpha + b = 0.07643\cdot\alpha + 0.30895$, we can obtain:

$$\frac{(v+\Delta v)^2}{v^2} = \frac{C_{L(\alpha)}}{C_{L(\alpha')}} \rightarrow \frac{(v+\Delta v)^2}{v^2} = \frac{k\alpha + b}{k\alpha' + b} \quad (2.8)$$

Therefore, when a disturbance occurs within a certain speed range, there is always an adjustment angle of attack for the big and small wings to make the torque of the big and small wings on the rotating axis balanced again at that angle of attack.

Assuming that the aircraft is cruising at an angle of attack of 8°, when the speed disturbance is positive and the range is less than 10% disturbance,

$\frac{(v+\Delta v)^2}{v^2}=1.21 \rightarrow \frac{k\alpha+b}{k\alpha'+b}=1.21$, the moment can be obtained when it reaches the equilibrium state again, and the wing angle of attack can be automatically adjusted to the angle of attack to $\alpha'=5.91°$, and similarly, when the speed disturbance is negative and the range is less than 10%, the moment can be obtained when it reaches the equilibrium state again when $\alpha'=10.82°$.

This self-adjusting ability of the angle of attack can make the lift force not change greatly with the speed when the speed perturbation occurs, thus maintaining the relative stability of the lift force and enhancing the smoothness of flight.

After proposing this new structure, the following paper intends to conduct a corresponding study on the rational aerodynamic optimization of the big and small wings around the aerodynamic characteristics, and also conduct some numerical simulations to verify the moment characteristics of the big and small wings.

2.3 Introduction of numerical simulation method

The layout form proposed in this work is applied to a low-speed vehicle, and the NACA2412 wing type commonly used for UAVs is chosen to develop the study of small and big wings. The aerodynamic disturbance characteristics at low Reynolds number are investigated with reference to the research methods in the literature. The purpose of the aerodynamic optimization is to minimize the aerodynamic interference between the big and small airfoils and to improve the aerodynamic performance of the big and small airfoils. A brief description of the numerical simulation method is given below.

2.3.1 Introduction based on FLUENT

FLUENT is a relatively popular commercial CFD package internationally, with a 60% market share in the United States, and is available for all industries related to fluids, heat transfer and chemical reactions. It has a wide range of applications in aerospace, automotive design, oil and gas, and turbine design with its rich physical models, advanced numerical methods, and powerful pre and post processing capabilities. FLUENT software contains a rich set of engineering-validated physical models and achieves optimal convergence speed and accuracy due to the use of multiple solver methods and accelerated convergence of multiple meshes. Flexible unstructured meshing and solution-based adaptive meshing techniques and mature physical models allow simulation of complex mechanistic flow problems in hypersonic flow fields, heat transfer and phase change, chemical reactions and combustion, multiphase flow, rotating machinery, dynamic/deformation meshing, noise, material processing, etc.

2.3.2 Numerical simulation methods in FlUENT

The finite volume method (FVM) is mainly used to solve conservation type control equations for flow and heat transfer problems. In these cases the control variables of the original equations need to be solved by integration and assumptions need to be made about the way the control variables are constituted during the integration process, however different assumptions will lead to different solution methods. As long as the interpolation method on the interface is the same for the control volume located on both sides of the interface, the discrete equations derived by applying the integral form of the finite volume method tend to have good conservation, and also the finite volume method has better adaptability to the structure and shape of the region than the finite difference method, so it is by far the most widely used numerical value method. At present, the widely used commercial CFD software, such as FLUENT, STAR-CD, STAR-CCM+, CFX, PHOENICS, etc., use the finite volume method.

2.3.3 Control equations and turbulence model

The layout form proposed in this work is applied to a low-speed vehicle, and the NACA2412 wing type commonly used for UAVs is chosen to develop the study of small and big wings. The aerodynamic disturbance characteristics at low Reynolds number are investigated with reference to the research methods in the literature[15]. In this paper, the finite volume method is used to solve the incompressible N-S equation for simulation. For fluid simulation grid quality is particularly important, the grid in this paper uses ICEM to divide, the flow field solving software uses Fluent software, for incompressible fluids choose pressure-based solution, double precision solution, using simple algorithm, pressure term and convective phase and turbulence term using second-order headwind, the second-order headwind has better calculation accuracy[11]. The turbulence model is chosen to SST k-ω model, compared to the k-ω standard model, the model SST k-ω incorporates the cross-diffusion derived from the ω equation and the turbulent viscosity takes into account the propagation of turbulent shear stress, which makes the SST k-ω model more accurate and credible in a wide range of flow domains.

For incompressible flow, the Reynolds-averaged momentum equation is as follows:

$$\rho(\frac{\partial \bar{u}_i}{\partial t}+\bar{u}_k\frac{\partial \bar{u}_i}{\partial x_k})=-\frac{\partial \bar{p}}{\partial x_i}+\frac{\partial}{\partial x_j}(\mu\frac{\partial \bar{u}_i}{\partial x_j})+\frac{\partial R_{ij}}{\partial x_j} \tag{2.9}$$

where the Reynolds stress tensor $R_{ij}=-\rho\overline{u_i^{'}u_j^{'}}$

The Reynolds stress equation can be written as：

$$\begin{aligned}&\frac{\partial u_i}{\partial x_i}=0\\&\frac{\partial u_i}{\partial t}+\frac{\partial}{\partial x_i}\left(u_i u_j+\frac{p}{\rho}\delta_{ij}\right)=\frac{\partial}{\partial x_i}\left(\tau_{ij}+\tau_{ij}^{t}\right)\end{aligned} \tag{2.10}$$

Where τ_{ij} and τ_{ij}^{t} Indicates molecular stress tensor and Reynolds stress tensor：

$$\begin{aligned}&\tau_{ij}=2vS_{ij}\\&\tau_{ij}^{'}=2v_t S_{ij}\\&S_{ij}=\frac{1}{2}(\frac{\partial u_j}{\partial x_i}+\frac{\partial u_i}{\partial x_j})\end{aligned} \tag{2.11}$$

For incompressible fluids, the closed RANS equation for the SST k-ω model can be written in the form of：

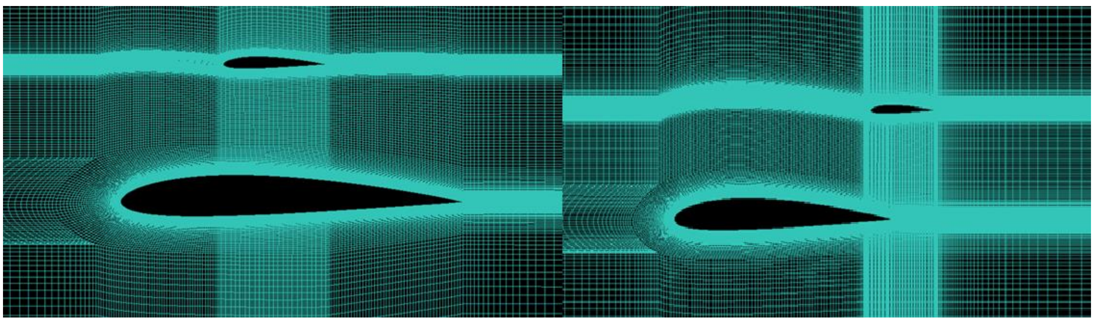
$$\frac{\partial k}{\partial t}+u_j\frac{\partial k}{\partial x_j}=\tau_{ij}^{'}\frac{\partial u_i}{\partial x_j}-\beta\omega k+\frac{\partial}{\partial x_j}\left[\left(v+\sigma_k v_t\right)\frac{\partial k}{\partial x_j}\right] \tag{2.12}$$

$$\frac{\partial \omega}{\partial t}+\mathrm{u}_{\mathrm{j}}\frac{\partial \omega}{\partial x_j}=\frac{\gamma}{\mathrm{v}_{\mathrm{t}}}\tau_{ij}^{'}\frac{\partial u_i}{\partial x_j}-\beta\omega^2+\frac{\partial}{\partial x_j}\left[(v+\sigma_{\omega}v_t)\frac{\partial \omega}{\partial x_j}\right]+2(1-F_1)\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j} \quad (2.13)$$

2.3.4. Numerical verification

The numerical simulation method is very simple and the cost requirement is relatively low. In this paper, the flow field size is chosen to be 35 times the chord length at the front and rear and 25 times the chord length at the top and bottom for meshing, and the area between the big and small wings is appropriately encrypted with the global mesh growth rate not exceeding 1.2 and the boundary layer mesh growth rate is 1.05 to reduce the calculation error caused by the excessive mesh growth rate.

According to the incoming flow velocity of 20m/s, the viscosity coefficient of air $1.78\times10^{-5}\,\mathrm{Pa}\cdot\mathrm{s}$, the density of incompressible gas $1.225\mathrm{kg}\cdot m^{-3}$ and the chord length of the airfoil of 1m, the Reynolds number of the calculated working condition is 1.4×10^{6} , and the optimal Y+ value of the SST k-ω model is about 1. In order to ensure the accuracy of the calculation and accurately simulate the boundary layer flow, the height of the first grid normal to the boundary layer is 2×10^{-6},which satisfies the optimal Y+ value of the model SST k-ω [10].



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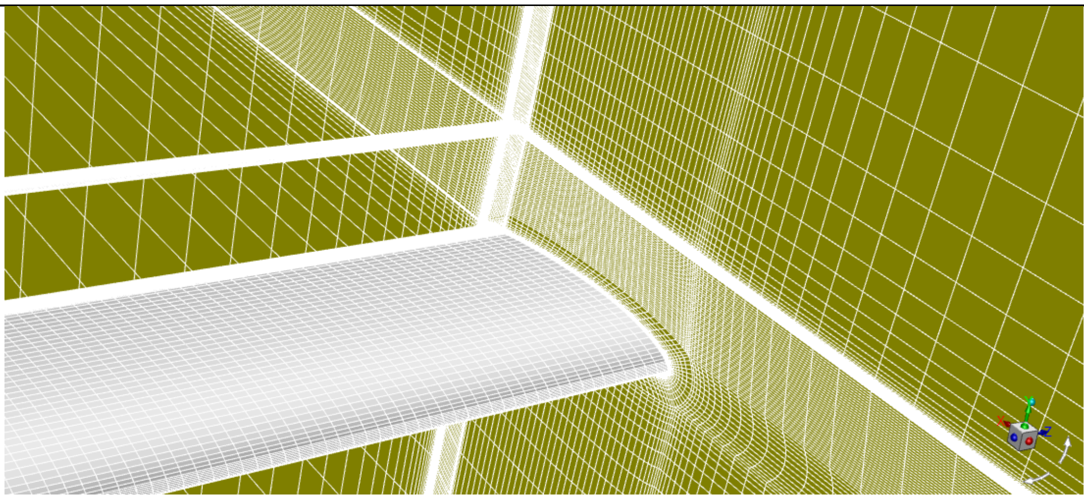


(b)

Fig.2.4 - Different types of meshes for big and small wings:a-Two-dimensional grid diagram of big and small wings; b- 3D grid diagram of big and small wings

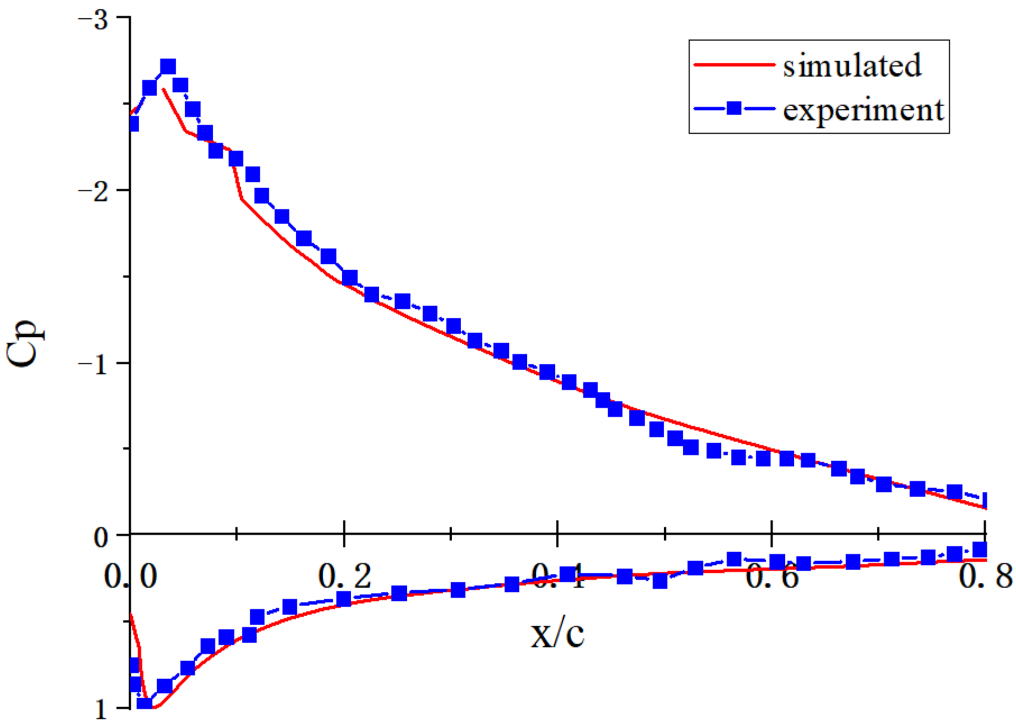


Fig.2.5 - Comparison of simulated and experimental values of surface pressure coefficient

The schematic diagram of the mesh at different positions is given in Fig.2.4 , and the pressure coefficient curves for the calculated and experimental values of the NACA2412 airfoil are given in Fig.2.5， Table 1 Comparison of the simulation results and experimental values of the lift coefficient with angle of attack. From Fig. 4 and Table 1, it can be seen that the simulated results of the surface pressure coefficient at $Re = 4.2 \times 10^5$, with an angle of attack of 10°, are similar to those of Dr. John E Matsson[16-17].The errors of the lift coefficient with angle of attack also meet the requirements of the flow field calculation.

Table. 2.1- Comparison of simulation results and experimental values of lift coefficient with angle of attack

AOA	Experimental value of lift coefficient	Simulation value of lift coefficient	Percentage difference
0	0.20514	0.20443	0.34611 %
2	0.43085	0.41150	4.49112 %
4	0.75574	0.61669	18.39918 %
6	0.83953	0.81590	2.81467 %
8	0.97253	1.00600	3.44154 %
10	1.15722	1.18160	2.10677 %

2.4 Pneumatic optimization

2.4.1 Parameter definition

Considering that the relative position of the small and big wings about the upper and lower is fixed, the following call of the big wing is used for the lower wing and the small wing is used for the upper wing. In this paper, the trailing edge of the wing is used as the reference point, and the parameters are shown in Fig.2.6 Interlacing S is the longitudinal distance parallel to the incoming flow direction, with the trailing edge point of the small wing in front of the trailing edge point of the big wing as positive and the rear as negative, interval g is the distance between the big and small wings perpendicular to the incoming flow direction, and wing difference angle δ is the intersection angle of the chord length line of the small and big wings, and the angle shown is specified as positive, interlacing s, interval g, and wing difference angle δ are all relative to the big wing The intersection s, interval g, and wing difference angle δ are all dimensionless parameters relative to the chord length of the big wing. where K denotes the ratio of the overall lift and drag coefficients when the small and big wings are coupled. $K_{\text{noninterference}}$ denotes the lift-to-drag ratio in the case of no small wing, and the optimal aerodynamic position between the small and big wings is determined by comparing the overall lift-to-drag ratio of the two wings with the interference-free lift-to-drag ratio to study the influence of each geometric parameter on the lift-to-drag characteristics of the layout.

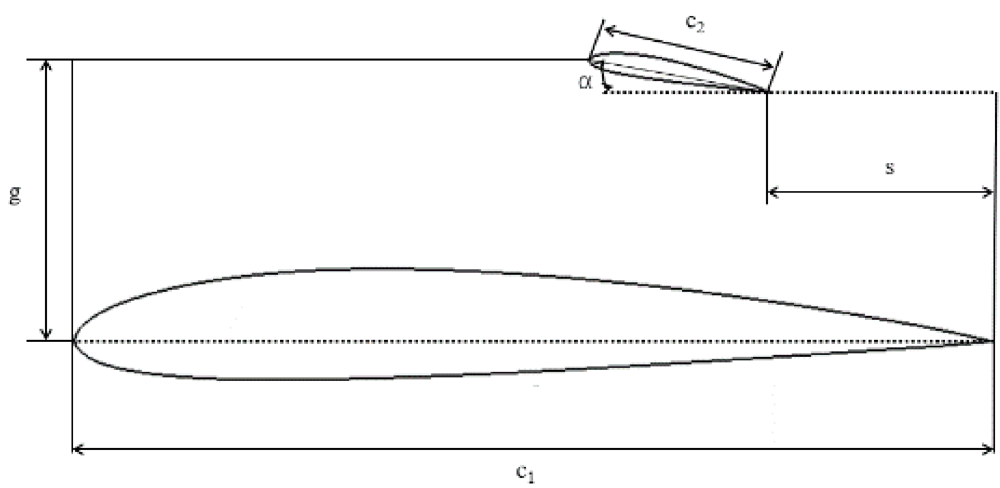
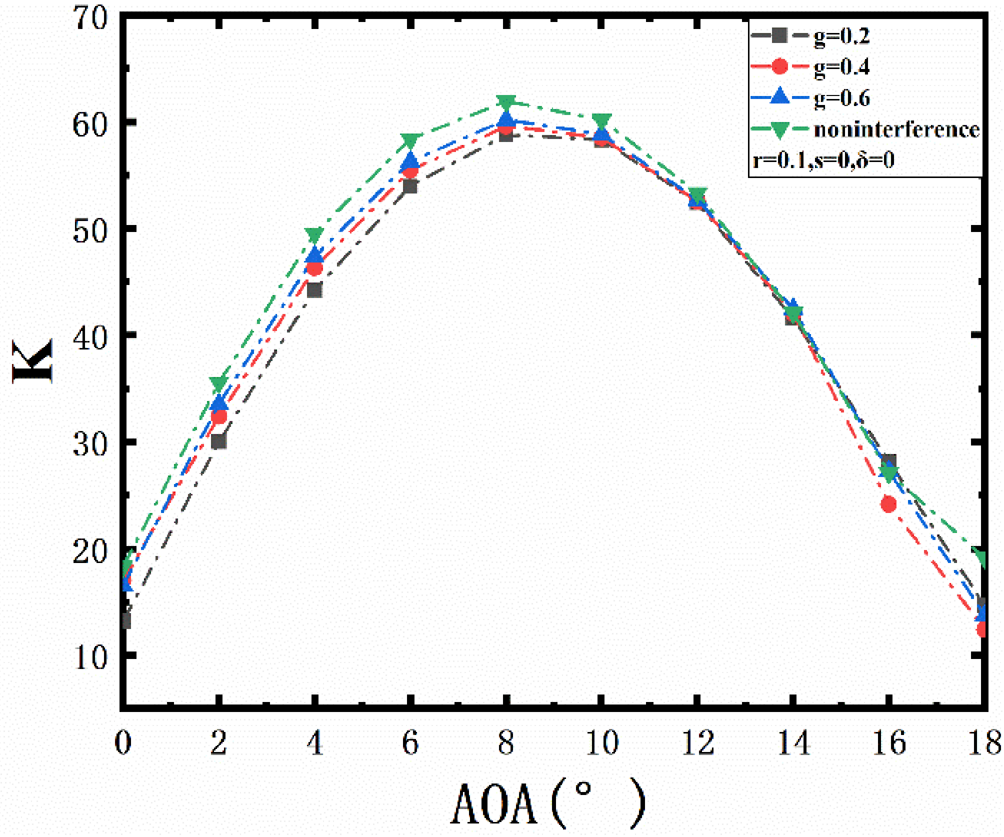


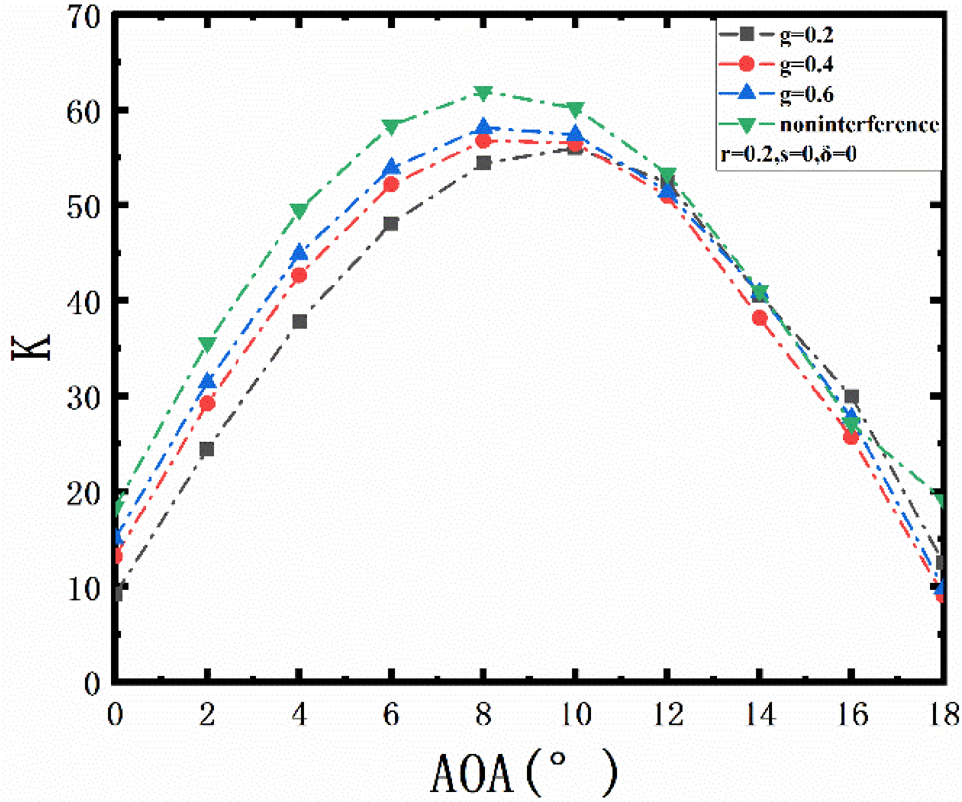
Fig.2.6 - Parameters Definition

2.4.2. Effect of different spacing and chord length ratio on the aerodynamic characteristics of small and large airfoils

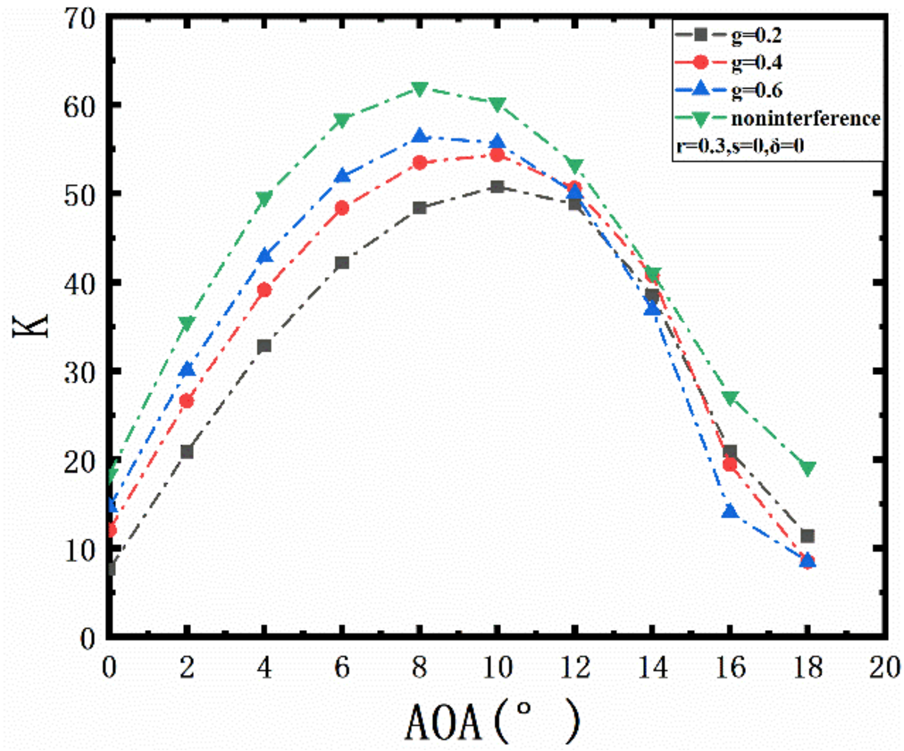
At g=0.2 and above, the staggered distance is 0 and the wing difference angle is 0. From Fig.2.7, it can be seen that the change of spacing does not affect the K_{max} angle of attack of the big and small wings, and the overall maximum lift-to-drag ratio of the big and small wings is at 8° angle of attack, and it can be seen that the lift-to-drag ratio K of the three different chord length ratios of the big and small wings all increase with the increase of the spacing of the big and small wings before the K_{max} angle of attack. It can be seen that before the 10° angle of attack, the lift-to-drag ratio increases with the increase of the spacing of the big and small wings, but after 10°, when approaching the critical angle of attack of 16°, the lift-to-drag ratio of the big and small wings becomes larger with the smaller spacing, which is due to the fact that, when approaching the critical angle of attack, the big and small wings are at a small spacing, and as the angle of attack becomes larger, the backpressure gradient of the trailing edge of the big wing becomes Then, due to the presence of the small wing above, a channel is formed and the separation of the trailing edge of the big wing is suppressed to some extent, which improves the lift-to-drag ratio of the whole big and small wings. It also shows that the aerodynamic performance of small and large spaced airfoil is better under large angle of attack, and small and medium spaced airfoil is better under small angle of attack.


g=0.2
g=0.4
g=0.6
noninterference
r=0.1,s=0,δ=0
K
AOA (°)

（a）


g=0.2
g=0.4
g=0.6
noninterference
r=0.2,s=0,δ=0
K
AOA (°)

(b)



(c)

Fig.2.7-Variation of lift-to-drag ratio with angle of attack： a - $r = 0.1, s = 0, \delta = \mathbf{0}$ ； b- $r = 0.2, s = 0, \delta = \mathbf{0}$;c - $r = 0.3, s = 0, \delta = \mathbf{0}$

2.4.3 Effects of different staggered layout forms and wing difference angles on the aerodynamic characteristics of small and big wings

From Fig.2.8 and Fig.2.9, it can be seen that in different staggered forms, when the staggered position of the small wing tends to be close to the leading and trailing edges of the big wing, the overall lift-to-drag ratio of the big and small wings increases relatively when the wing difference angle is 0. Considering that the small wing needs to transfer torque to the big wing, it is not good to be close to the leading edge, so the layout of the big and small wings should be close to the trailing edge. From the aspect of aerodynamic performance, the best condition is when r=0.1, g=0.4, s=0, δ=0, which can make the maximum overall lift-to-drag ratio.

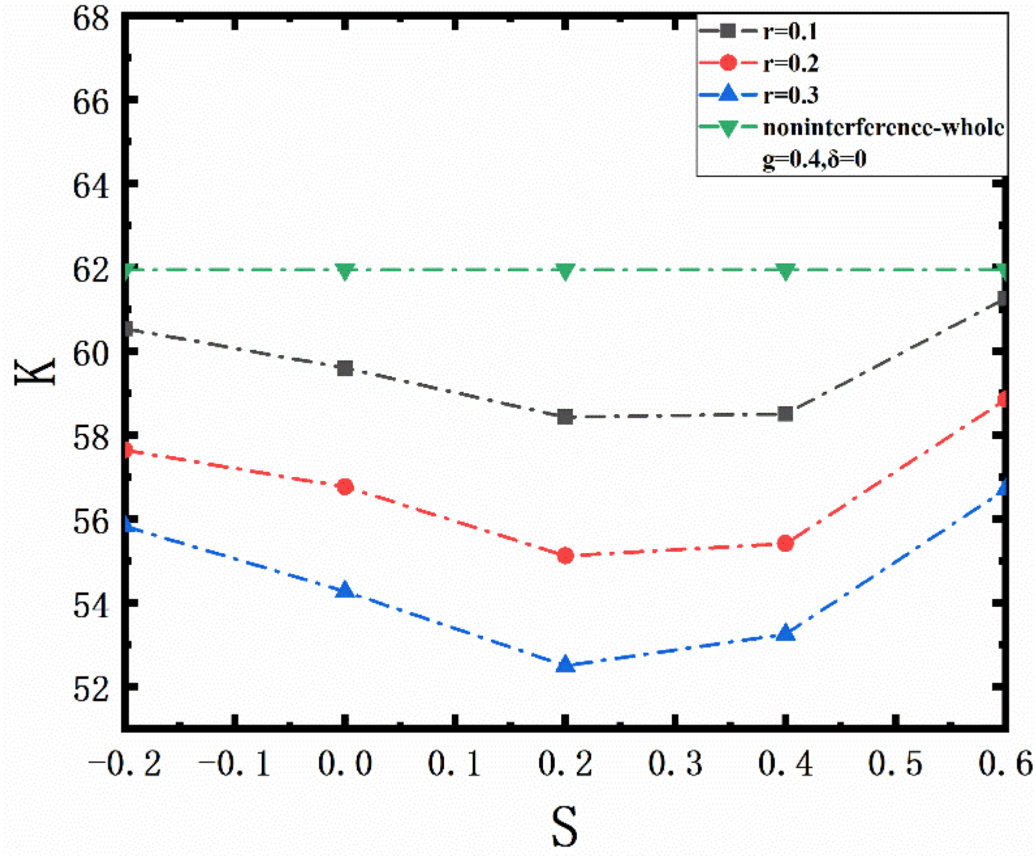


Fig.2.8 -Overall lift-to-drag ratio variation curve with interleaved position

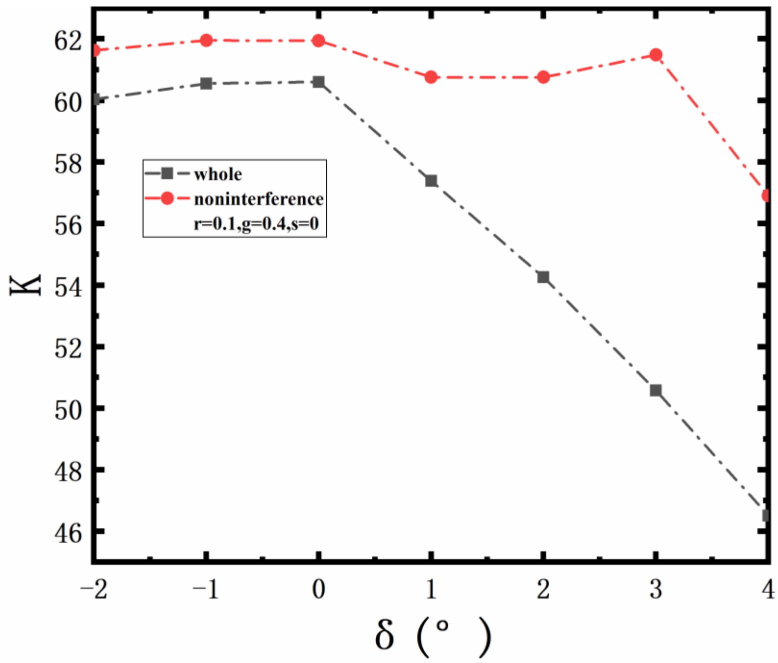
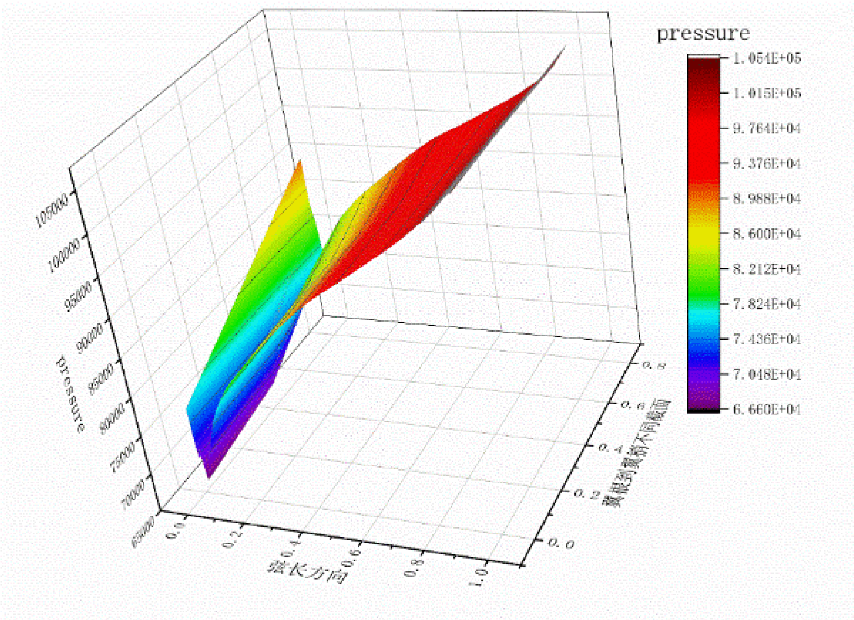


Fig.2.9 - Lift to drag ratio varies with wing differential angle

2.5 Aerodynamic properties of new wing in compressible flow flight

The aerodynamic performance of the small and big wings was not verified in high-speed compressible flow. With the better relative position layout selected above, the aerodynamic simulations of the small and big wing layouts as well as the separate wing layouts were carried out for an incoming flow Mach number of 0.35 and an angle of attack of 8°. The surface pressure values of small and big wing layout and single wing layout are derived from the 0%, 40% and 80% cross-sections along the span direction, as shown in Fig.2.10 and Fig.2.11. The pressure cloud at 40% of the span is shown in Fig.2.12, which shows that the position of the leading edge of the big wing is basically unchanged, while the actual angle of attack of the small wing is slightly reduced due to its position in the leeward area of the big wing, and the leading edge is shifted upward. The pressure gradient distribution on the upper wing surface of the big and small wings and the single wing layout also remain the same, and there is no obvious pressure abrupt change in the channel formed between the big and small wings, which indicates that the relative positions of such big and small wings are also applicable in the low and medium subsonic compressible flow.



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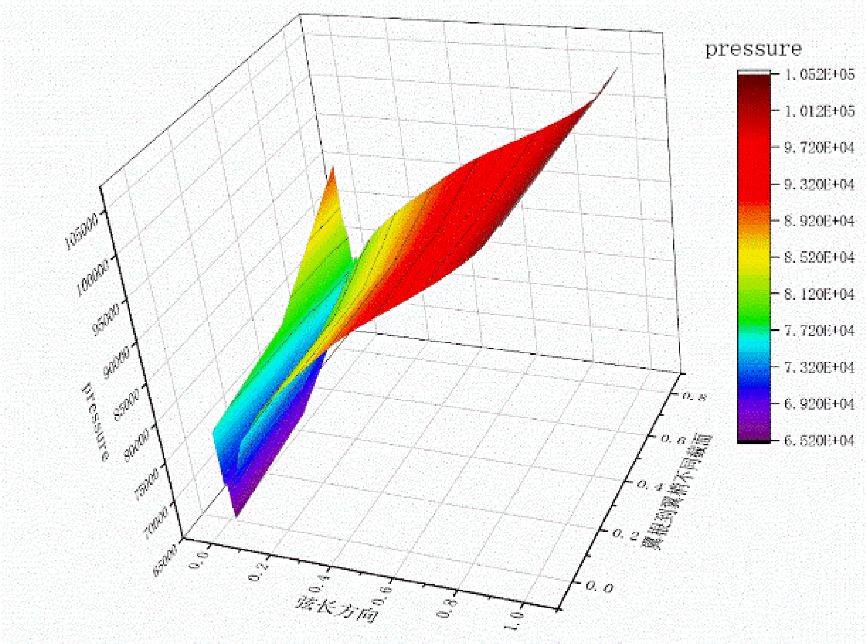

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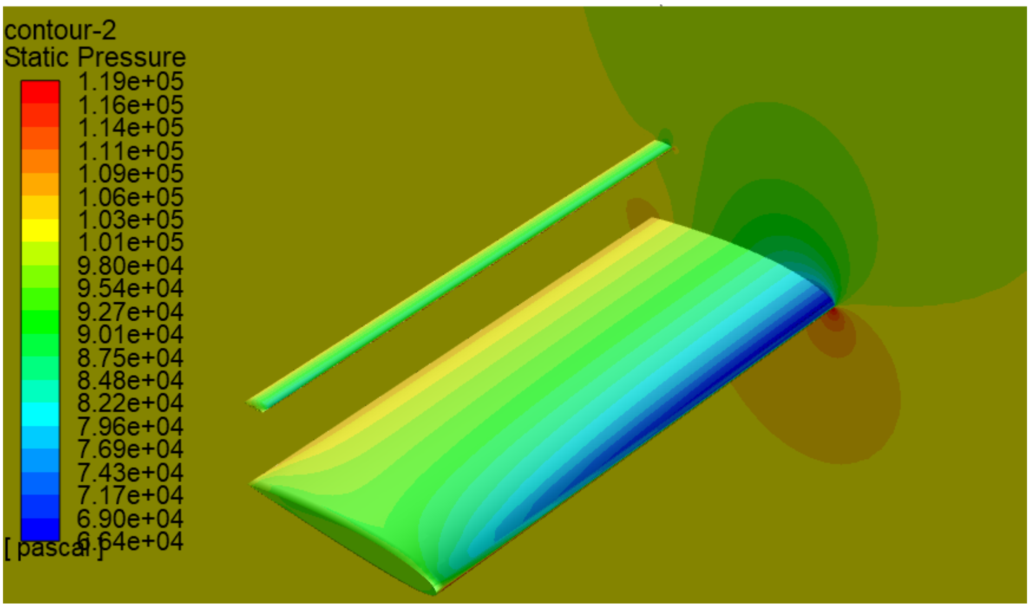
Fig.2.10 - Surface pressure of big and small wing at different cross sections:a- Big and small wing layout; b- Monoplane layout - wing surface pressure



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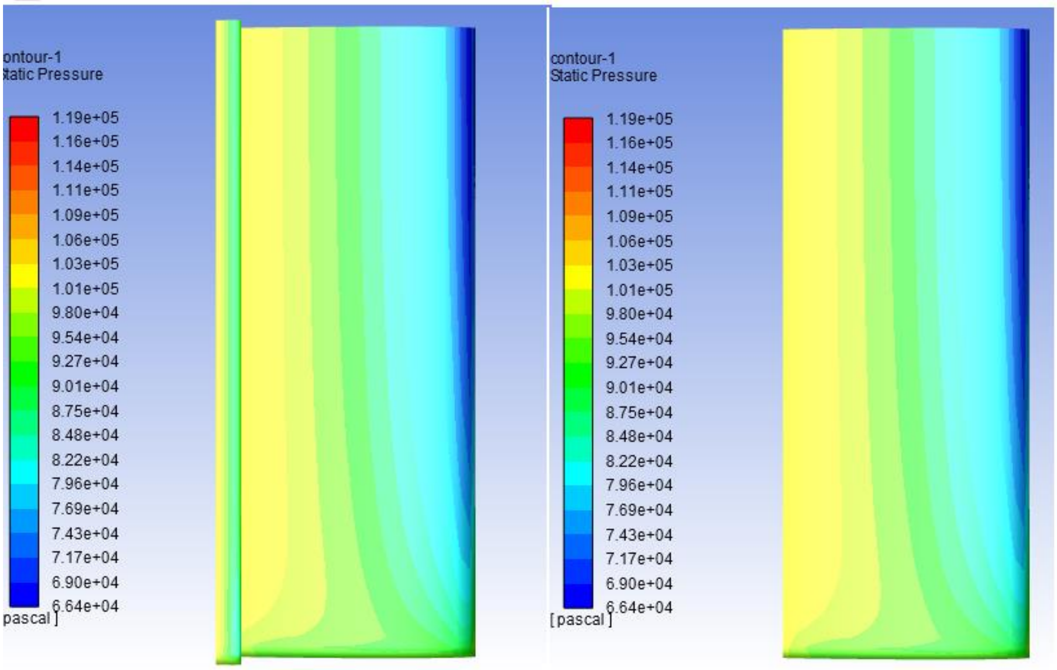
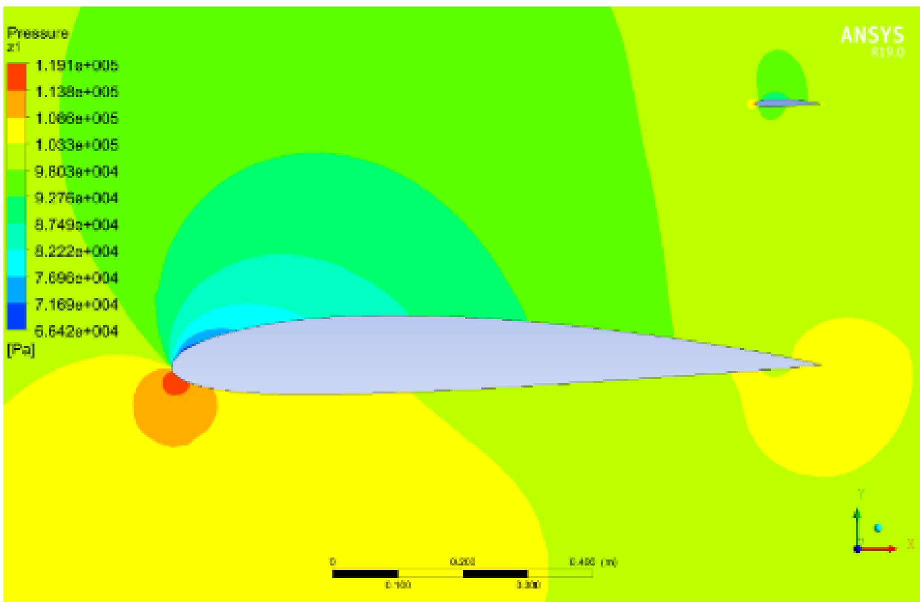
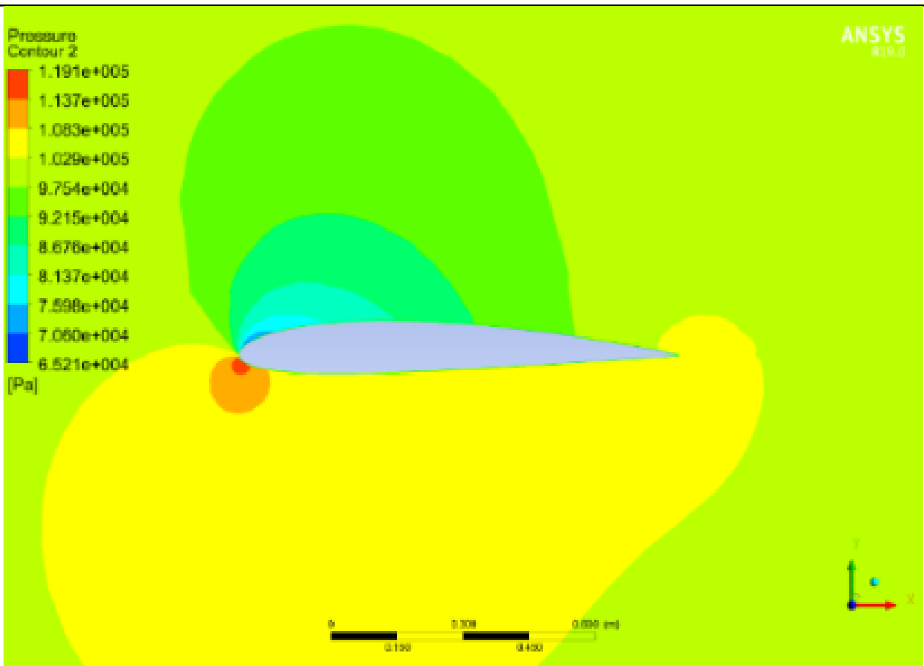


（b）

Fig.2.11- Overall cloud map of big and small wings AOA=8; 0.35 Ma: a - Overall pressure cloud diagram of big and small wing; b - Normal pressure clouds of big and small airfoils



(a)



(b)

Fig.2.12 - Pressure cloud at 40% spreading section：a- Big and small wing; b-Monoplane wing

Conclusion to part 2

This chapter introduces the new layout structure form of big and small airfoil, and analyzes the principle of self-adjustment of its angle of attack, and uses numerical simulation to optimize the design simulation of the layout form of big and small airfoil. The smaller the chord length ratio, the larger the interval, the closer the overall lift-to-drag ratio of big and small wings is to the interference-free lift-to-drag ratio, the interval is 0.4 times the chord length, and the layout form with a chord length ratio of 0.1 has a smaller loss of lift-to-drag ratio, and the maximum lift-to-drag ratio decreases by 3.78% compared to the interference-free lift-to-drag ratio. In this relative position, the leading edge of the small wing near the leading and trailing edges of the big wing reduces the overall interference between the big and small wings. The compressible subsonic flow is also verified to some extent, and the results show that this layout also uses compressible subsonic flow to some extent.

3.1 Effect of the new size wing layout on takeoff and landing phase

The takeoff glide distance of the aircraft is influenced by the lift coefficient, and the method to improve the lift coefficient can improve the angle of departure from the ground. This paper's new angle of attack self-adjusting big and small wings can be rotated due to the characteristics of the big wing can be rotated within 5 °, which makes the ground rubbing angle of the aircraft less restrictive, the size of the wing can be rotated through the wing rather than the aircraft lift to obtain a greater lift coefficient, which makes the takeoff angle closer to the critical angle of attack to obtain a greater lift coefficient to reduce the takeoff speed, shorten the glide The small wing above the big wing also provides additional lift coefficient to further reduce the glide distance. According to the formula provided in reference [18].

$$V_{l0}=\sqrt{\frac{2W}{\rho SC_l}} \tag{3.1}$$

V denotes the speed off the ground; W denotes the gravity of the aircraft; ρ denotes the air density; S denotes the reference area of the wing; C_L denotes the lift coefficient, if the elevation angle of the wing off the ground is 10°, assume

$W=800N，\rho=1.25kg/m^3, S=2.5m^2, C_l=1.18160（v=20m/s, AOA=10）$

Ignoring the effect of the change of departure speed on the lift coefficient, the departure speed can be obtained as about 20m/s. At this speed, the maximum takeoff angle of attack can reach 15° due to the rotational characteristics of the big and small wings, and the lift coefficient is 1.18160 relative to the maximum takeoff angle of 10° for the monoplane layout, and the big and small wings are able to reduce the departure speed for takeoff. As shown in Table 3.1, the effect of elevated angle of attack on ground departure speed can be seen.

Table 3.1 - Effect of ground clearance angle of attack on ground clearance speed

Angle of attack when leaving the ground（°）	Big and small wing lift coefficients	Rate of speed reduction off the ground（%）
10°	1.227611	1.89%
11°	1.309777	5.02%
12°	1.382753	7.56%
13°	1.442645	9.50%
14°	1.514117	11.67%
15°	1.577457	13.45%

3.2 Numerical simulation verification

3.2.1 Moment characteristics of big and small airfoils

The variation of speed is particularly common in atmospheric wind fields, where the wind variation can reach 11 m/s[19] , and the variation of wind speed can make the aircraft go up and down. The numerical simulation method is used to simulate the lift and moment characteristics of the big and small wings to verify the existence of the self-adjusting angle of attack, and to calculate the contribution of the self-adjusting angle of attack to the variation of lift with speed.

Table 3.2 - Wing design parameters

Parameters	Bigwing	Smallwing
Airfoil	NACA 2412	NACA 2412
Root chord length	1	0.1
Tip chord length	1	0.1
Half wing span	2.5	2.5
span to chord ratio	2.5	25
Wing Area	$2.5m^2$	$0.25m^2$

The overall lift of the big wing varies with the angle of attack and speed as shown in the figure, and the focal point of the big wing is located at the relative chord length

0.23219 using the software, and the moment of the big wing aerodynamic force on the rotor shaft is negative (it produces a low head moment on the rotor shaft), and since the rotor shaft is at the focal point, the moment of the big wing also does not change with the angle of attack, so the moment at the rotor shaft changes with the speed, and the moment of the big wing aerodynamic force on the rotor shaft changes with the The size of the velocity changes when the size is shown in the figure, it can be seen that the low head moment of the big wing to the rotary axis at the same speed basically does not change with the angle of attack, increases with the increase in speed and decreases with the decrease in speed. As shown in the figure is the change curve of the torque of the small wing to the rotor shaft with the speed and angle of attack, it can be seen that compared with the torque to the rotor shaft in the cruising state, the low head torque of the small wing to the rotor shaft increases when the angle of attack is constant and the speed increases; when the speed is constant and the angle of attack decreases, the low head torque of the small wing to the rotor shaft decreases.

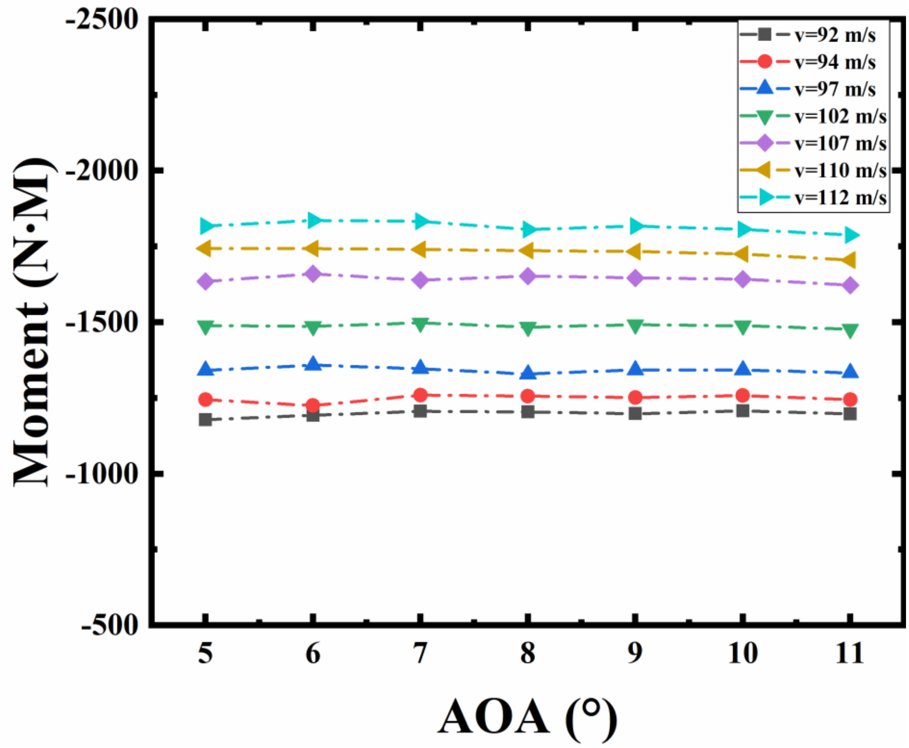


Fig. 3.1 - Big wing-to-shaft torque variation curve with

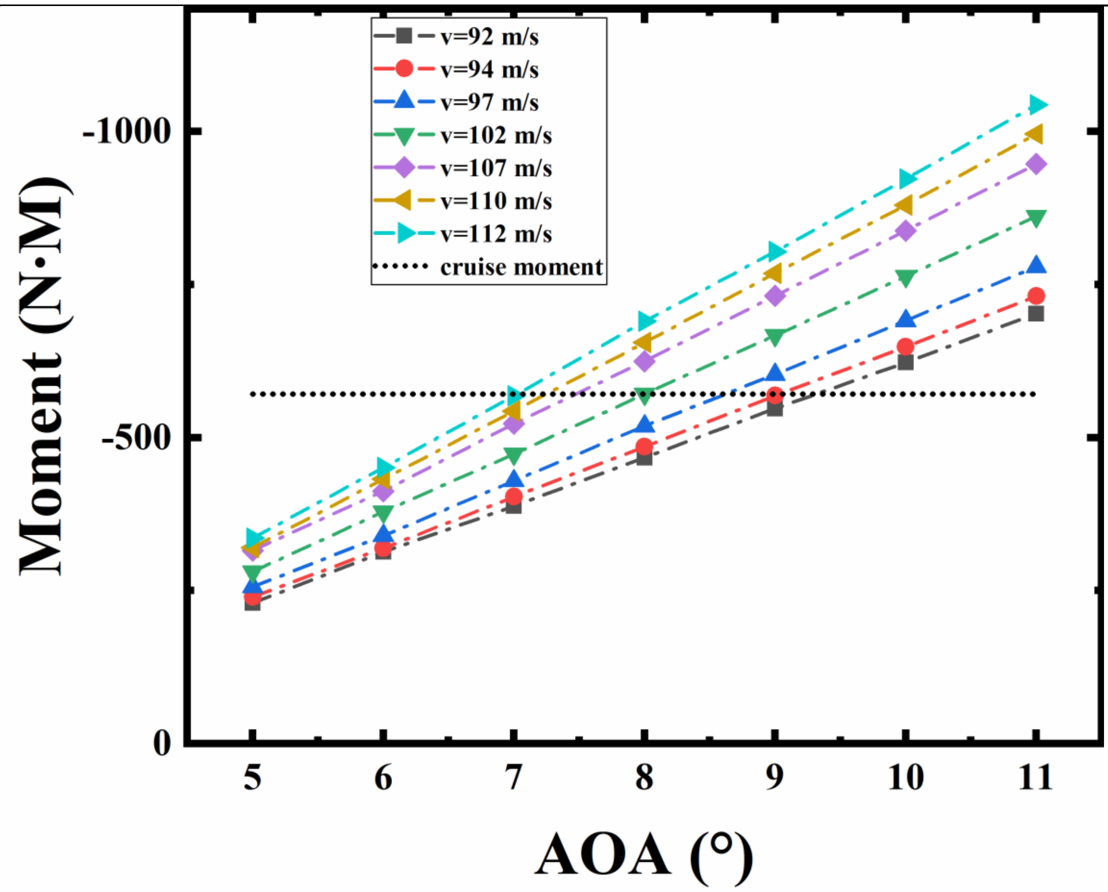


Fig.3.2 - Variation curve of the torque of the winglet on the rotating shaft with speed and angle of attack

The big wing and the small wing can rotate around the rotating shaft at the same time, so the angle of attack of the big wing and the small wing and the speed change in line, when the incoming speed increases the disturbance, the low head torque of both the big and small wings have an increment, making the big and small wings have a tendency to low head, with the low head of the small wing, the torque of the small wing to the rotating shaft gradually decreases, when the angle of attack is adjusted to the point that the decrease in the torque of the small wing to the rotating shaft is equal to the increase in speed brought about by the large When the angle of attack is adjusted to the point where the decrease in the moment of the small wing to the shaft is equal to the increase in the moment of the big wing to the shaft low head due to the increase in speed, that is the equilibrium angle of attack after the speed disturbance. Therefore, it is only necessary to analyze the increment of the torque of the big and small airfoils to the rotor shaft, and the new equilibrium angle of attack is when the increase of the low head torque of the big airfoil to the rotor shaft relative to the cruise state is equal to the decrease of the low head torque of the small airfoil to the rotor shaft relative to the cruise state, relative to the equilibrium torque.

3.2.2 Angle of attack self-adjustment simulation analysis

As can be seen from the above, when the speed increases by 5m/s due to the gust of wind, the big wing has an incremental low head moment relative to the cruise state, and the small wing will decrease its low head moment relative to the rotation axis as the angle of attack decreases, and there exists an angle of attack that makes the reduced low head moment of the small wing equal to the increased low head moment of the big wing, and the big and small wings reach moment balance again.

As can be seen from the figure, the black line indicates the absolute value of the increment of the moment of the big wing relative to the equilibrium state when the speed increases by 5m/s, and the red line indicates the amount of change of the moment of the small wing to the rotor shaft relative to the moment of the rotor shaft at equilibrium when the speed increases by 5m/s. The intersection line between the two indicates the angle of attack at which the moment of the big and small wings rebalance at that speed in the case of 5m/s. It can be seen that when the speed varies within a certain range When the speed varies within a certain range, the big and small wings can self-adjust the angle of attack so that the moment is balanced again at that angle of attack.

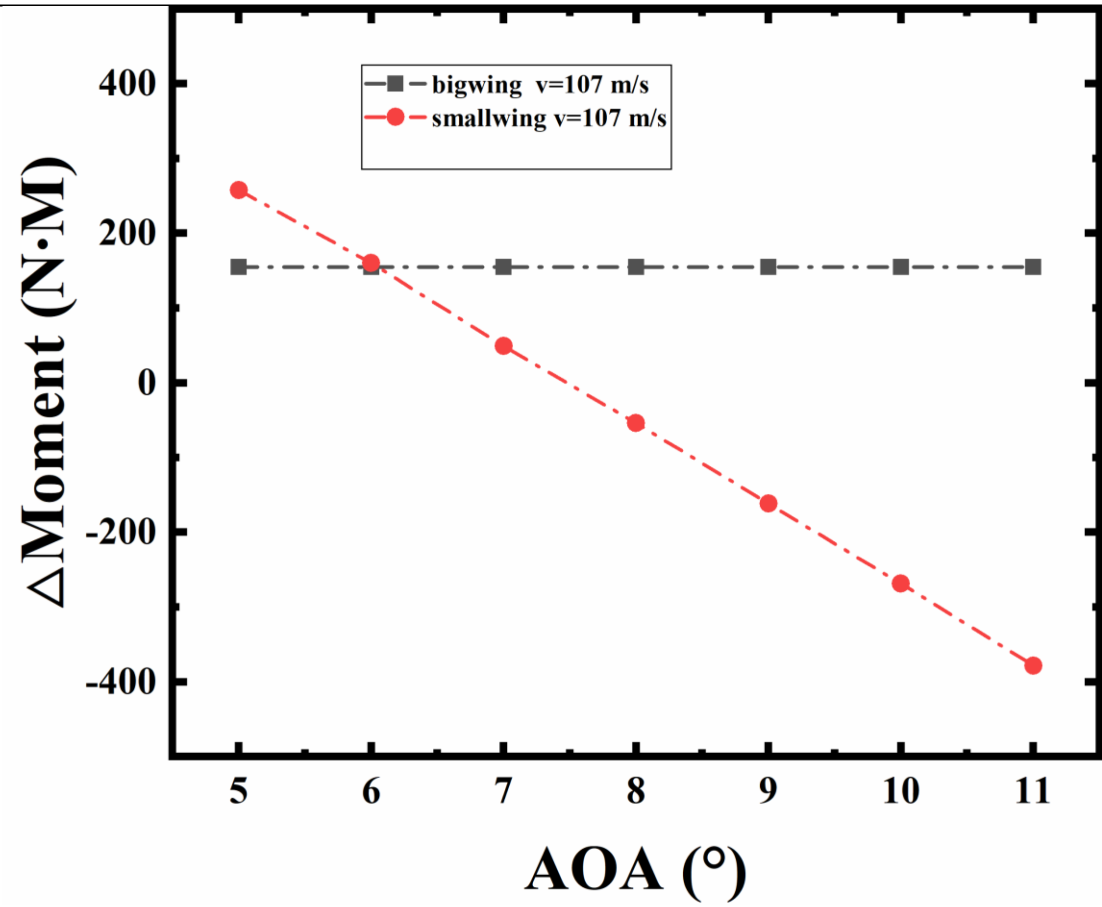


Fig.3.3 - Variation of the increment of big and small airfoil moments with the angle of attack when the velocity incoming flow increases by 5m/s

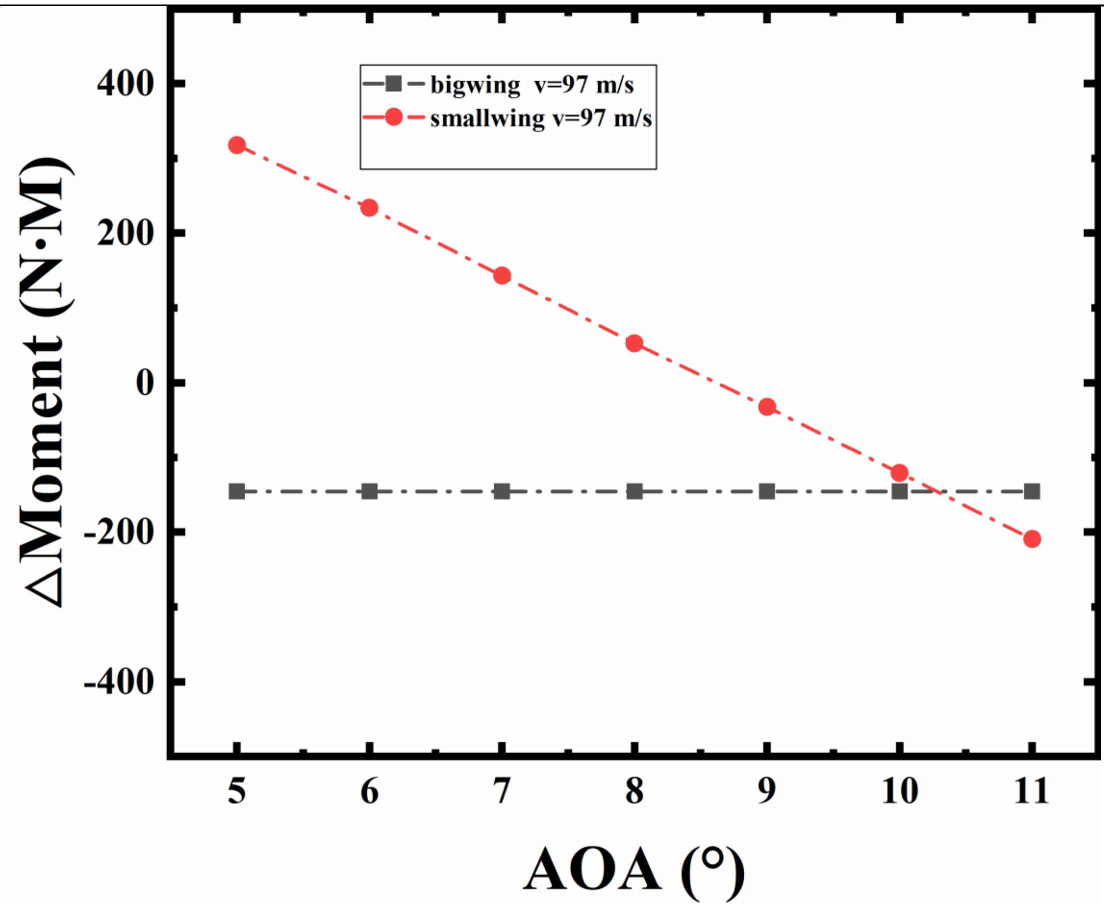
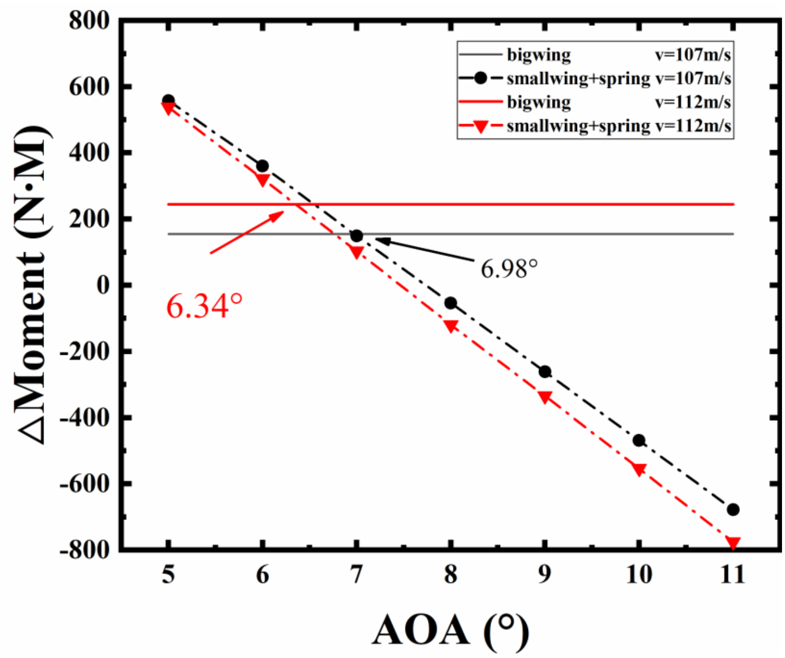


Fig.3.4 - Variation of the increment of big and small airfoil moments with angle of attack when the velocity incoming flow decreases by 5m/s

Although the small and big wings can automatically adjust the angle of attack when the incoming flow changes, such as automatically reducing the angle of attack to an equilibrium state when the incoming flow velocity becomes large, the self-adjusting moment balance angle of attack at this time has the problem of over-adjustment, i.e., the self-balancing angle of attack at this time still has a large change in lift, which is not conducive to the stability of flight. The damping spring at the limit block can apply a damping moment, so that the small wing in the angle of attack is reduced at the same time, the damping spring is compressed to provide an additional moment, and finally make the lift force in the moment balance angle of attack basically does not change.

According to the design parameters, the chord length of the big wing is 1m, the rotor position is 23.219% relative to the chord length, the damping spring is 90% relative to the chord length, and the stiffness factor of the damping spring is 8578 N/M. The calculation shows that for every 1° change in the angle of attack of the small wing, the damping spring can provide 100 N · M moment to the rotor. The moment balance of the big and small wings when the incoming velocity increases is shown in the figure 22. When the incoming velocity increases by 5m/s, the angle of attack of the moment balance is automatically adjusted to 6.98°, and when the incoming velocity increases by 10m/s, the angle of attack of the moment balance is automatically adjusted to 6.34°. When the incoming flow speed decreases by 5m/s, the balance angle of attack of the torque is adjusted to 9.05° automatically, and when the incoming flow speed decreases by 8m/s, the balance angle of attack of the torque is adjusted to 9.79° automatically.



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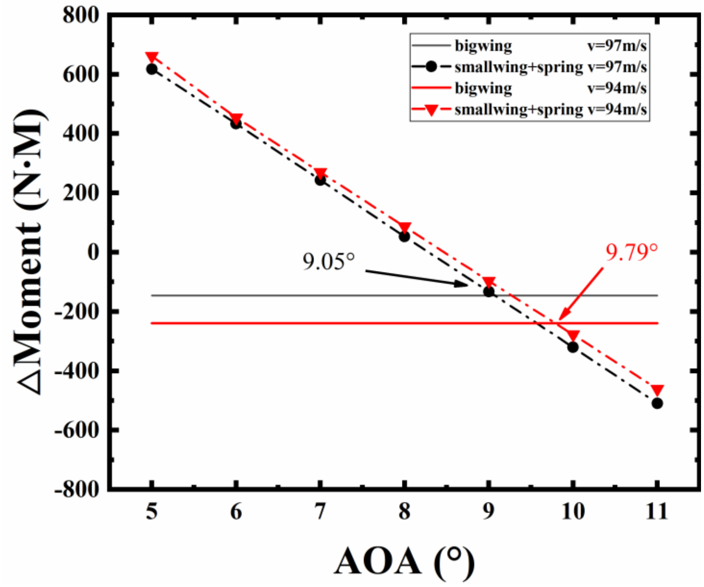

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Fig.3.5 - Variation of rotational torque increment with angle of attack under damping spring and small wing adjustment: a- Increase in speed; b- Decrease in velocity

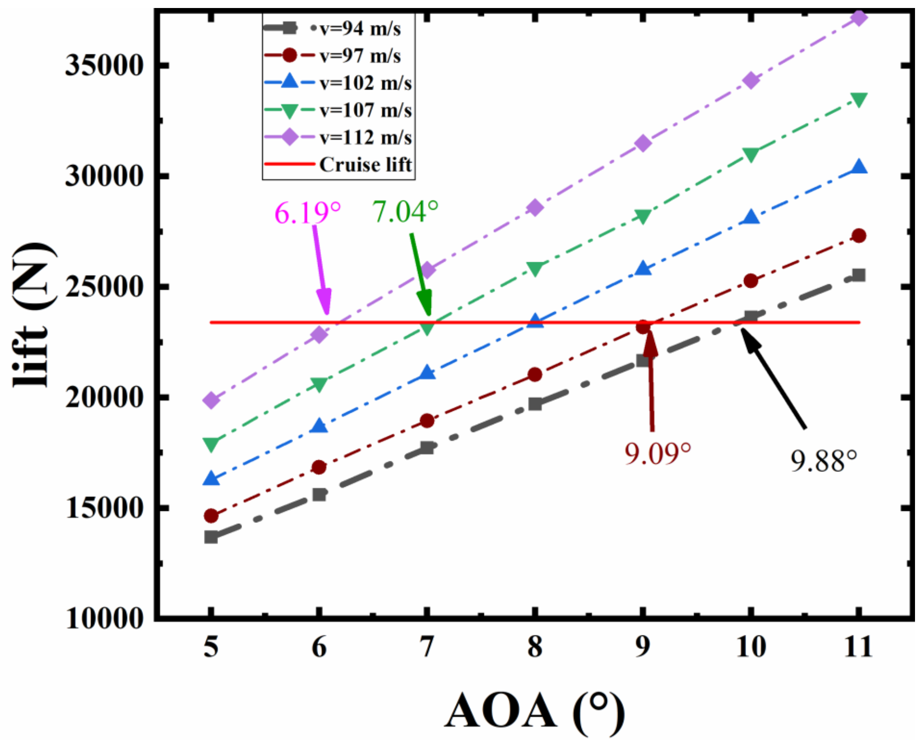


Fig.3.6 -Variation curves of big and small wing lift with speed and angle of attack

From Figure 23, we can compare the angle of attack of self-adjustment caused by velocity perturbation and the angle of attack of lift invariance under velocity perturbation can be seen that the angle of attack of self-adjustment is very close to the angle of attack of lift invariance, in which the angle of limitation of the free movement of the small and big wings should be kept between 6.19° and 9.88° when the incoming flow perturbation is plus10m/s or minus 8m/s. The table shows the comparison between the lift of the self-adjusted wing after the speed perturbation and the cruise lift. From the table, it can be seen that under the action of self-adjustment, the lift generated by the wing when the incoming flow speed changes is very small with the change of speed, which can basically maintain the stability of the lift, and the aircraft will not produce the phenomenon of up and down bumps, thus maintaining the stability of flight.

Table 3.3 - Rate of change of self-adjusting angle of attack relative to cruise lift

Speed perturbation（m/s）	Theoretical lift constant angle of attack（°）	Self-adjusting angle of attack（°）	Cruise lift（N）	Lifting force generated under self-adjustment（N）	Difference percentage（%）
+10	6.19	6.09	23405.78	23100.057	1.30%
+5	7.04	6.98	23405.78	23045.57	1.53%
-5	9.09	9.15	23405.78	23624.87	0.94%
-10	10.31	10.44	23405.78	23641.87	1.01%

3.3 Effects on wing fatigue

The wing of the aircraft in its flight, due to the existence of wind gusts and turbulence phenomenon, will make the wing produce aerodynamic force and aerodynamic moment, which will bring a great additional load to the wing, if the wing is in the role of this additional load for a long time, it will inevitably occur fatigue damage, the impact on the wing is great. The load on the wing is basically determined by the external aerodynamic load, which makes the wing bend and twist, and the horizontal dimension of the wing is large, so the vertical shear force, vertical bending moment and vertical torque of the wing must be paid attention to, which has a great impact on the structural performance of the wing.

3.3.1 Introduction to metal fatigue

The concept of metallic fatigue was first introduced by J. V. Poncelet in 1830 when he lectured at the University of Paris. At that time, the term "fatigue" was used to describe the deterioration of the strength of a material under cyclic tensile and compressive loading. To quote the American Society for Testing and Materials (ASTM) definition in "Standard Definition of Terms Relating to Fatigue Testing and Statistical Analysis of Data" (EZ06-72): The development of a localized, permanent structural change in a material when a point or points are subjected to flexural stresses and cracks or complete fractures form after a sufficient number of cycles of flexural action. The process of development of permanent structural changes in the material is called "fatigue". Metal fatigue refers to the process in which the material, zero component, under the action of cyclic stress or cyclic strain, gradually produces local permanent cumulative damage in one or several places, and cracks or sudden complete fracture occurs after a certain number of cycles. In the material structure subjected to repeated changes in the role of the load, the stress value although always not exceed the strength limit of the material, or even lower than the elastic limit of the case may occur damage, this repeated effect of alternating loads in the material and structure damage phenomenon, called the fatigue damage of metals. According to statistics, 80% of metal material failure is caused by fatigue, and the performance of sudden fracture, whether the material is ductile materials or plastic materials are manifested as a sudden fracture, great harm.

3.3.2 Effect on the wing structural stress

Table 3.4 - Performance parameters of aluminum alloy materials

Parameters	E（Stiffness）	NU(Poisson's ratio)	UTS（Ultimate tensile strength）
value	70GPa	0.33	600MPa

For the high cycle fatigue problem, the classical fatigue algorithm is the stress-life method, which is solved analytically according to the S-N curve of the material, because the S-N curve is obtained from the standard test piece with symmetric cyclic load, and the corresponding stress is also uniaxial stress, and the mean value of stress is 0. But the actual structure is generally in a complex stress state, so the stress needs to be converted into the equivalent nominal stress. For brittle materials, the absolute maximum principal stress is suitable as an equivalent nominal stress, while for plastic materials, the Von Mises stress (fourth strength stress) is suitable as an equivalent nominal stress.

The following section uses numerical simulations to analyze the fatigue as well as the stress conditions of small and large airfoils. When solving for the flow field, FLUENT calculates the initial values of the flow field acting on the structure pressure, which is prepared for use in solving for the initial values of the structural deformation.

For structural analysis, the steps of structural analysis in ANSYS are.

1) definition of the unit parameters.

2) importing the geometric model.

3) dividing the mesh.

4) applying boundary conditions such as constraints.

5) loading, pressures calculated by FLUENT.

6) Analysis of the results

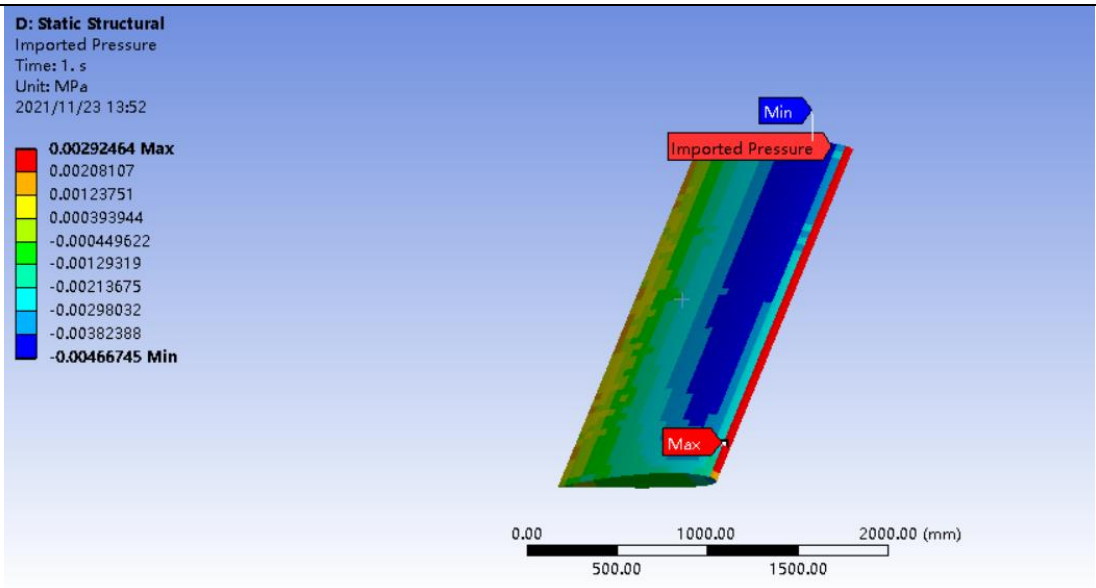
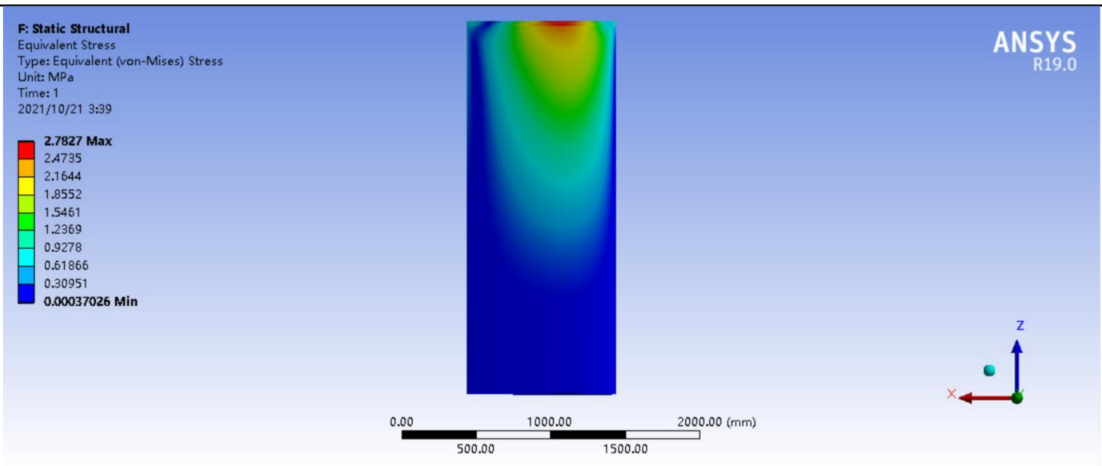


Fig.3.7 - Importing fluid calculation data to the structural analysis module

Using the fluid-structure coupling method, the aerodynamic forces on the wing are introduced into the hydrostatic analysis, and the fluid pressure calculation is loaded into the structural boundary calculation. The stresses and deformations of the model increase from the wing tip to the root. Since the applied distributed forces are close to the leading edge of the wing, the stresses at the leading edge of the wing reach their maximum values at the root. The stress values and action range increase gradually from the wing tip to the wing root. From Fig. 38 and Fig. 39, it can be seen that the big and small wing equivalent stresses are mainly concentrated at the wing root, and the distribution trend with the angle of attack and speed basically does not change, and the equivalent stresses gradually become larger with the change of speed and angle of attack.



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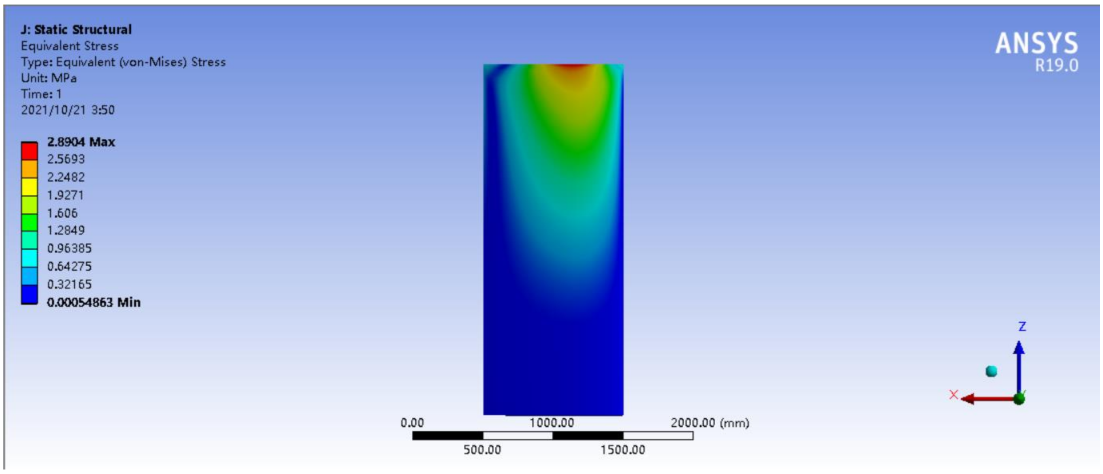

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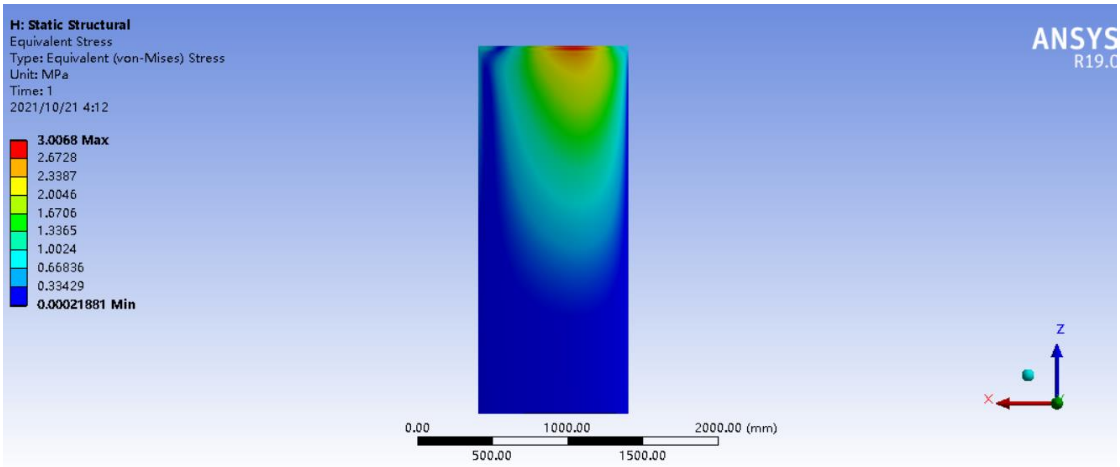
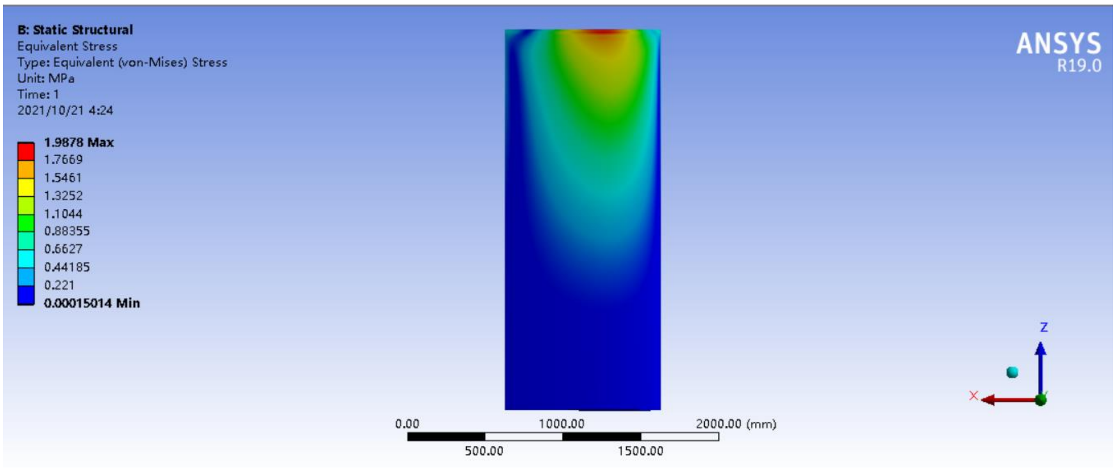


(c）

Fig.3.8- Variation of wing structure equivalent force with angle of attack: a -v=102m/s , AOA=6°Wing equivalent stress; b - v=102m/s ,AOA=8°Wing equivalent stress; c - v=102m/s , AOA=10°Wing equivalent stress



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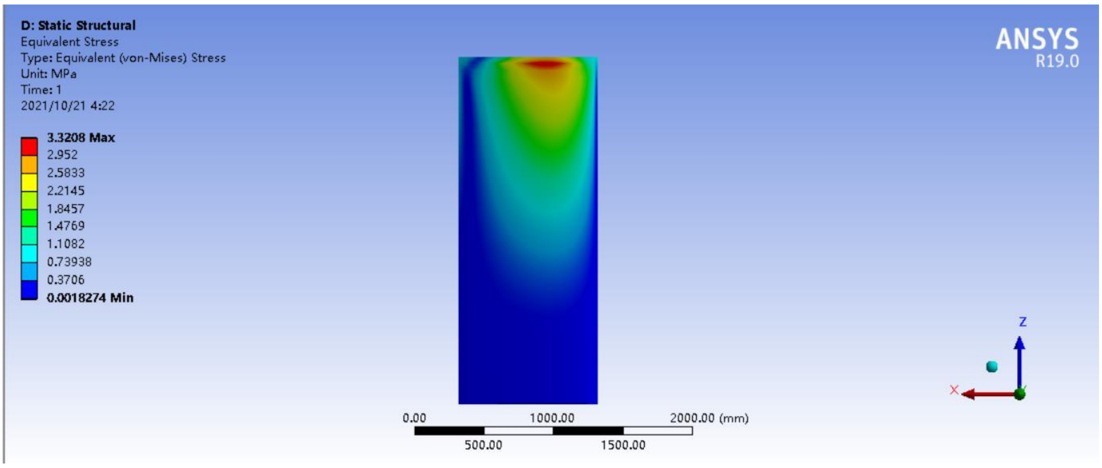

(b）

Fig.3.9- Wing structure equivalent stress variation with velocity:
a - v=92m/s ,AOA=8°Wing equivalent stress; b - v=112m/s ,AOA=8° Wing equivalent stress

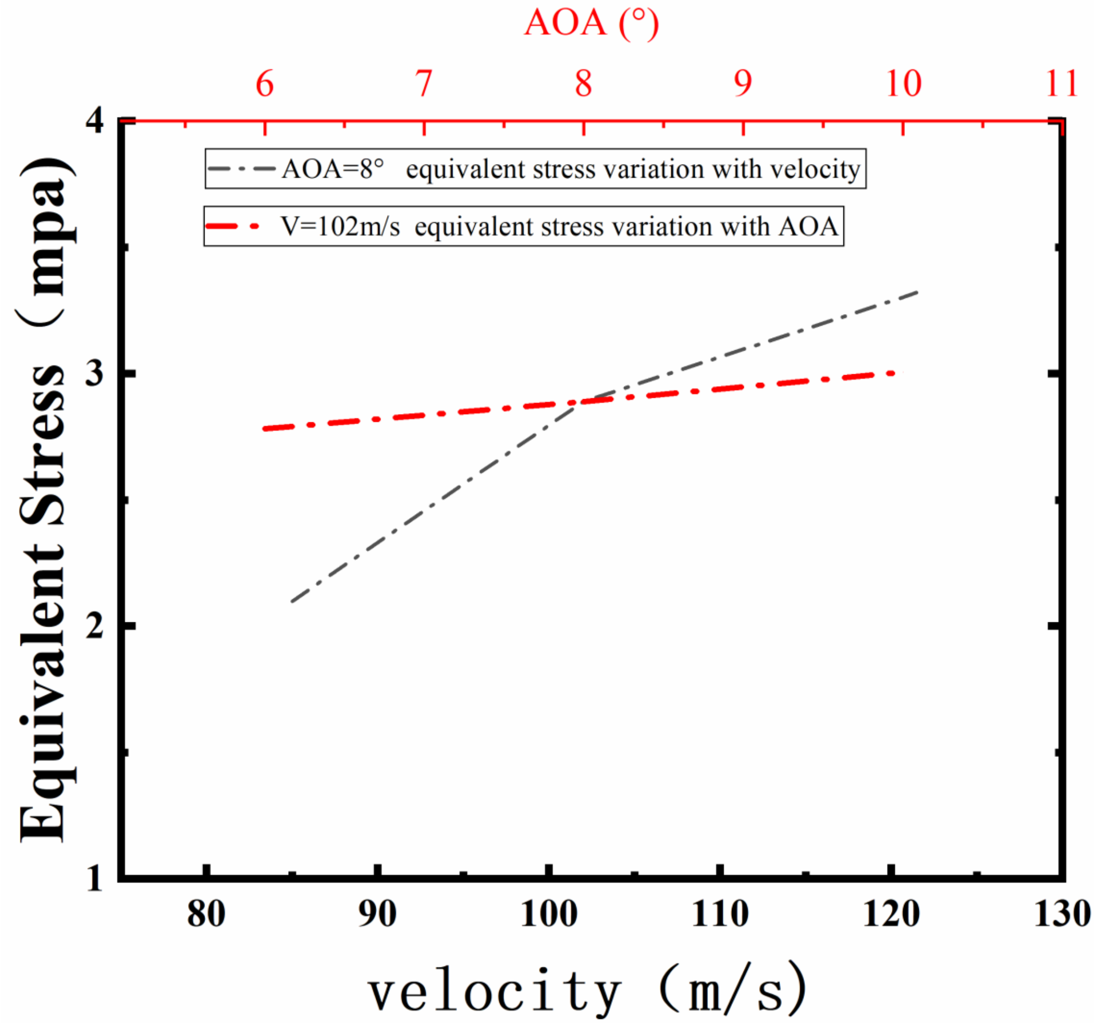

Fig.3.10-Wing structure equivalent stress variation with velocity and AOA

As can be seen from Fig.3.10, the maximum equivalent force will increase with the increase of speed, and after the wing achieves self-adjustment of the angle of attack, the angle of attack can be self-adjusted to reduce when the incoming velocity becomes larger, and the maximum equivalent force will be reduced accordingly due to the reduction of the angle of attack, and the reduction of the equivalent force has positive significance for extending the fatigue life of the wing.

3.4 Practical application

Countries around the world are vigorously developing drones as well as small personal flying machines, flying cars may be the future of urban flying transport. And aerial photography drones, plant protection drones and other small drones will also be widely used in the city.

Flying car concept is that the car can drive on the ground while also being able to fly in the air, and the low-altitude environment, gusty wind disturbance, which is not conducive to flight control, the new wing layout form proposed in this paper can be well applied to the future of flying cars, reducing the difficulty of the flying car driver's control. For the shipborne UAV that needs short takeoff and landing, the takeoff angle of attack is larger, the takeoff distance is shortened, the landing speed is reduced when landing, the landing glide distance is reduced, and the flight performance is greatly improved. UAV plant protection operation has the advantages of precision, high efficiency, environmental protection, intelligence and easy operation. In addition, due to the small size and light weight of plant protection drones, easy transportation and flexible flight control, the disadvantage is that the wind resistance is low, the continuous operation ability is poor, and the efficiency is not high. For fixed-wing plant protection drones the layout form proposed in this paper can also be applied to enhance the flight stability of plant protection drones and make their work efficiency higher. UAVs are also developing in the direction of civil use. They are widely used in remote sensing aerial photography, earthquake relief, agriculture and forestry, environmental monitoring, communication relay and courier services, etc. Using the new layout form in this paper can reduce the difficulty of handling UAVs and thus reduce the burden on the flight control system. There are more obstacles in the low-altitude area where logistics UAVs fly. The current obstacle avoidance technology is not enough to perfectly cope with all threats, and UAVs crash into buildings and trees, etc., so it is necessary to keep the flight stable for UAVs flying at low altitude, etc. Meanwhile, the wind field at low altitude changes greatly, so the variable angle of attack self-adjusting wing can self-adjust according to the wind field disturbance and keep the flight stable.

Conclusion to Part 3.

Through the study of moment characteristics in this work, the results show that the speed has a great influence on the stability of the aircraft, and the aircraft flying over the area with large speed gradient will produce great flight instability. The results show that the model can cope with the impact of the change of incoming flow on flight stability, i.e., when the incoming flow velocity changes, the angle of attack of the small wing will be balanced again and the angle of attack of the big wing will be changed at the same time so that the overall lift remains stable, which verifies the feasibility of automatic matching of angle of attack and velocity.

The preliminary study on the flow-solid coupling of the wing with self-adjusting angle of attack shows that the equivalent force changes with the adjustment of the angle of attack, and when the speed increases, it can ensure that the lift force remains stable and the equivalent force is reduced when the wing speed increases, which helps to extend the fatigue life of the wing.

Therefore, the new layout form proposed in this paper is very suitable for application in the future in short takeoff and landing UAVs, flying cars, logistics UAVs and other aircraft configurations. In the context of the current vigorous development of general aviation, the new design scheme is innovatively proposed in the aerodynamic layout, which also provides some reference and guidance for the development of future platoon layout aircraft.

PART 4. LABOR PROTECTION

Introduction

Workplace protection is something that every graduate student of the Master's degree should get to know, not only as a sign of responsibility for the safety of the school laboratory, but also as a sign of responsibility for the safety of one's life. In this regard, we first need to analyse our laboratory environment, the size of the laboratory, the equipment it contains, and the main work content of the laboratory. We need to analyse the hazards in the laboratory and the characteristics of these hazards to ensure that we can use the laboratory in a way that ensures personal safety, and we also need to analyse the possible hazards of fire in the laboratory to ensure that we can properly regulate the fire extinguishing process in the event of an accident. The school regulations make clear provisions for the working environment, the kind of environment in which students can complete their experiments, what harmful gases and liquids are included in the laboratory environment, and the handling of dangerous chemicals, and for the engineering environment, the specifications for the use of computers and machine tools are also very noteworthy. The following is an analysis of the university's requirements for laboratories and the hazardous elements of the working research environment, as well as how to deal with them in case of emergencies, in the context of the relevant regulations for laboratories in China and Ukraine.

4.1 Analysis of working conditions at workplace

As showed in the Fig 4.1 , the completion of this thesis is mainly done through computer simulation technology, also known as numerical simulation technology, which is mainly used to model the required model in 3D structure through computer software, and then import the model into the simulation software for simulation and analysis to produce results. So the experimental conditions required for the completion of this paper are a computer and a computer room, as shown in Figure 4.1 for a general computer laboratory. The computer room I used was approximately $40m^2$, with a personal area of approximately 2 m^2. The equipment used was a laptop computer, a mechanical keyboard, a computer mouse, a laptop power cord, and a power supply provided by the laboratory.

Fig 4.1 Example diagram of a computer room

4.2 Characteristics of dangerous and harmful factors

Expert research has found that, in fact, all the daily household equipment with electricity will produce electromagnetic radiation, whether there is harm to the human body, the most important thing is to look at the size of the radiation energy.

Some specialized research institutions have tested the strength of the computer's electromagnetic field, the results found that, close to the fluorescent screen at the electromagnetic field strength of 0.9, but about 5 cm away from the screen, the strength of less than 0.1, and then a little farther to 30 cm (which is the customary distance between the computer operator's body and the screen), the strength can hardly be measured. In addition, the electromagnetic waves in space is indeed ubiquitous, but in general, the intensity of this electromagnetic radiation is very small, will not cause harm to human health.

The hazards of radiation.

Computer radiation causes hair loss

Radiation is not the number one factor leading to hair loss. Computer use too long is the key to hair loss: a high degree of concentration on the use of computers, too long brain excitement will increase, endocrine disruption, and hair follicles connected to the sebaceous glands secretion of excessive events leading to hair follicle embolism, hair nutrient supply obstacles, hair will become brittle, hair will fall off. For minor hair loss, you can reduce the time of computer use and adjust your lifestyle to relieve.

Eye damage.

These "unsuitable light" continued exposure to our eyes, will cause dysfunction, especially LED lights, computer screens and other light, which contains a large number of irregular frequency of high-energy short-wave blue light, these short-wave blue light has very high energy, can penetrate the lens directly to the retina. Blue light exposure to the retina will produce free radicals, and these free radicals will lead to the decay of the retinal pigment epithelial cells, the decay of epithelial cells will lead to a lack of nutrients for photosensitive cells and thus cause vision damage.

Radiation avoidance methods.

1. Avoid long periods of continuous operation of the computer, pay attention to the intermediate rest. To maintain an optimal posture, the distance between the eyes and the screen should be in 40-50 cm, so that the eyes flat or mildly downward looking at the fluorescent screen.

2. Research has found that radiation from computers can affect the development of the fetus and can cause serious fetal malformations. Indoor to maintain a good working environment, such as a comfortable temperature, clean air, the appropriate concentration of anions and ozone concentration, etc..

3. Computer room light should be appropriate, not too bright or too dark, to avoid direct light on the fluorescent screen and produce interference light. The workroom should be kept ventilated and dry.

4. The computer's fluorescent screen should use color filters to reduce visual fatigue. Preferably use glass or high-quality plastic filters.

5. Computer placement is important. Try not to let the back of the screen towards someone's place, because the strongest computer radiation is the back, followed by the left and right sides, the front of the screen and the weakest radiation.

When using the computer, to adjust the screen brightness, generally speaking, the greater the screen brightness, the stronger electromagnetic radiation, and vice versa, the smaller. However, it can not be adjusted too dark, so as not to affect the effect of too little brightness, and easy to cause eye fatigue.

4.3 Work with electrical equipment

The use of electronic equipment is an indispensable part of the aviation industry, in contact with electronic equipment has to consider is the contact with the energized equipment, in contact with the energized equipment must pay attention to their own safety, including compliance with safety guidelines for the correct installation and use of these devices. Also ensure that in the event of breakage of energized equipment to use insulating materials to contact, to ensure that the body does not produce electric shock phenomenon. Not to touch the lack of leakage protection equipment, when found that the temperature of some equipment is too high in time to check the work of electronic equipment, the use of standard practices to ensure their own safety, check whether it is working properly, whether the work of abnormalities. At the same time should pay attention to the sound issued by the electronic equipment is normal, if found that the electronic equipment produced an abnormal sound should promptly go to check its working status. At the same time, attention should be paid to the use of electronic devices when trying to keep a certain distance from people to ensure that in the event of an accident will not threaten the safety of others.

4.4 Measures to ensure safe working conditions

This paper combines China's laboratory safety management requirements to propose some measures to ensure the safety of the working state.

1. Each laboratory should have a part-time safety officer who is responsible for the safety work of the laboratory. Safety officers should be trained and have certain safety knowledge and skills.

2. The first experimental operation of the personnel must be safety education and training, in mastering the laboratory safety management methods and basic knowledge, familiar with the operating procedures before starting experimental operations.

3. The laboratory should actively promote and popularize general first aid knowledge and skills, such as: burns, trauma, poisoning, electrocution and other first aid treatment. The laboratory should regularly conduct safety inspections, the formation of a system to actively commend the advanced, serious investigation and punishment of accidents.

4. The laboratory in contracting off-campus teaching, scientific research, experimental tasks, should be clear safety responsibilities.

5. The laboratory instruments and equipment, materials, tools and other items should be neatly arranged, reasonable layout. Each laboratory should promptly clean up waste items, not pile up items not related to the work of the laboratory, to ensure that the safety channel is clear.

6. The laboratory to strengthen the safety of electricity management, no unauthorized modifications, disassembly and repair of electrical facilities; do not pull the wires, the laboratory shall not have bare wire; power switch box shall not be stacked items to avoid electrocution or burning; the use of high-voltage power electricity, should wear insulated rubber shoes and gloves, or with a safety bar operation; someone electrocuted, should immediately cut off the power, or use insulated objects to separate the wire from the body after Then implement rescue.

7. The laboratory in the use of flammable, explosive, highly toxic and bacterial vaccines and other hazardous materials, to be used and stored in strict accordance with relevant management regulations, while having reliable safety precautions, and make detailed records.

8. The laboratory in the use of radioactive materials should avoid radioactive substances into the body and contamination of the body; minimize the measurement of

external radiation received by the human body; minimize the harm caused by the proliferation of radioactive substances; radioactive waste to be stored in a special dirt cylinder and regular treatment in accordance with the provisions.

9. The laboratory in relation to pressure vessels, electrical, welding, vibration, noise, high temperature, high pressure, radiation, bright light flashes, bacteria vaccines and radioactive substances in the operation and experiment, to strictly develop relevant operating procedures, the implementation of appropriate labor protection measures.

10. The laboratory for environmental safety management should have a full understanding of the exhaust gas, waste, waste liquid treatment shall be strictly in accordance with the relevant provisions of the implementation, shall not be discharged at will, shall not pollute the environment. New construction and expansion of the laboratory shall be hazardous substances, toxic gas treatment program included in the construction plan.

11. According to the performance requirements of the instruments and equipment, to provide the installation and use of instruments and equipment premises, good water and electricity supply, and should be implemented according to the different circumstances of the instruments and equipment fire, moisture, heat, frost, dust, shock, anti-magnetic, anti-corrosion, radiation and other technical measures.

12. The laboratory should be regularly maintained, calibrated and calibrated instruments and equipment.

13. Instrumentation failure to organize timely repair, and maintenance records, do not allow their own disassembly.

14. To pay attention to the large instruments and equipment of water and power outage protection, to prevent damage to instruments and equipment due to voltage fluctuations or sudden power and water outages.

15. The safety of equipment to be responsible for the work of the instrument, the management of the instrument and equipment is the safety of the instrument and equipment responsible.

16. Personal use or borrowing and personal custody of instruments and equipment (such as laptops, etc.), the recipient or borrower should be properly stored to avoid damage or loss.

4.5 Fire Safety

This paper uses a computer simulation, which will bring a large computational load to the computer due to the large amount of calculations, making the temperature of the computer itself in a high state, it is very necessary to propose an emergency treatment plan when a laboratory fire occurs. This has a very positive effect on fire extinguishing as well as escape in emergency situations.

Fire accidents are universal and can occur in almost any laboratory. The direct causes of such accidents are:

1. Forgetting to turn off the power supply, resulting in equipment or electrical appliances energized for too long, the temperature is too high, causing a fire.

2. Power supply lines aging, overload operation, resulting in line heating, causing a fire.

3. Careless operation or improper storage of flammable and explosive substances, so that the source of fire contact with flammable substances, causing a fire.

4. Littering cigarette butts, contact with flammable substances, causing a fire.

In the face of fire, we must be familiar with the location of fire extinguishers so that they can be accessed in a timely manner, but also must be the following kinds of awareness:

1. In combustible liquids on fire, should immediately take away all combustible materials in the area of fire, close the ventilator to prevent the expansion of combustion.

2. Alcohol and other water-soluble liquids on fire, you can use water to put out the fire.

3. Gasoline, ether, toluene and other organic solvents on fire, the application of asbestos cloth or dry sand to extinguish. Absolutely no water, otherwise it will expand the burning area.

4. Metal potassium, sodium or lithium fire, absolutely not: water, foam fire extinguishers, carbon dioxide, carbon tetrachloride, etc., available dry sand, graphite powder to extinguish.

5. Note that electrical equipment such as wires on fire, can not use water and carbon dioxide extinguishers (foam extinguishers) to avoid electrocution. Should first cut off the power, and then use carbon dioxide or carbon tetrachloride fire extinguishers.

6. When the clothes on fire, do not run, should immediately use asbestos cloth or thick coat cover extinguished, or quickly take off clothes, the fire is larger, should lie down and roll to extinguish the flame

7. It is found that the oven has an odor or smoke, you should quickly cut off the power supply, so that it slowly cool down, and prepare a fire extinguisher spare. Do not rush to open the door of the oven, so as not to suddenly supply air to fuel the combustion (explosion), causing a fire.

8. In the event of a fire should pay attention to protect the scene. Larger fire accidents should be immediately reported to the police. If there are serious injuries, should be immediately sent to the hospital

9. Familiar with the location of fire extinguishing equipment in the laboratory and the use of fire extinguishers.

In addition, you should be familiar with the location of the safety exits in the laboratory, and when the fire cannot be extinguished, try to use the safety exits to escape, avoid taking the elevator to escape, and move to an open outdoor location.

Conclusion

In this chapter, we have analyzed the safety of the experimental equipment used in the completion of this thesis and the experimental equipment, and proposed measures to help protect the human body according to the environment, including the norms for the use of electronic equipment, the matters that should be paid attention to when using electronic equipment, the hazards to the human body in the process of using electronic equipment and the possible risk factors. The corresponding analysis is made, and the methods of safe and standardized use of electronic equipment are proposed in the process of completing this paper. At the same time, we propose some measures to protect the experimental environment and students by combining the requirements of labor protection in China. Finally, we analyze the emergency disposal methods in case of fire accidents around labor protection, and use different classifications of suitable fire extinguishers to extinguish the fire when we can ensure that the fire is put out in accordance with the regulations, and escape through the safety exit in time when the fire is large.

PART 5. ENVIRONMENT PROTECTION

5.1 ICAO requirement towards aircraft engine emission

5.1.1 Air traffic development and serious carbon emission problems

The world is facing great environmental problems, such as rising sea levels and deteriorating air quality, etc. In China, also facing serious environmental protection problems, the Chinese government has introduced many relevant measures to limit the emission of harmful gases in civil aviation, thus making people's living environment better. Global air traffic activities maintain a continuous and rapid growth, and while air transportation is convenient for public travel, it also has a serious impact on the global and regional environment, mainly in terms of CO2 emissions during aircraft flight and noise impact around airports during the takeoff and landing phases. Statistics show that carbon emissions from civil aviation transport flights account for about 2% of the total carbon emissions from human activities [29], making it the fastest growing emitter of greenhouse gases. With the further growth of flight volume, the total GHG emissions still have the tendency to increase further.

On July 21, 2016, the World Meteorological Organization (WMO) released the bulletin "Global Climate Breaks New Records in 20161-June" that global climate indicators have once again set new records. Evidence suggests that the Earth's ecosystems and climate system may have reached or even breached important tipping points that could lead to irreversible changes, with extreme weather such as high temperatures, fog and strong thunderstorms occurring frequently. These weather extremes in turn cause massive flight cancellations and delays, which in turn can affect and constrain the development of the air transportation industry.

The world trend of sustainable development has put forward more stringent requirements for carbon emission of air transportation. In order to cope with the damage to human living environment caused by global warming, the United Nations held the Earth Summit in 1992 and reached the United Nations Framework Convention on

Climate Change (UNFCCC), which took the first step to solve this problem, and then proposed the Kyoto Protocol. on November 4, 2016, the Paris Agreement has officially entered into force. The Paris Agreement is the third landmark international legal text in human history to address climate change, shaping the post-2020 global climate governance landscape. The 175 parties, including China, have jointly committed to reducing greenhouse gas emissions and keeping the global average temperature increase to within 2°C above pre-industrial levels [30]. The Paris Agreement establishes a ratcheting mechanism of "no regression". The action targets set by countries are based on continuous progress, and a binding mechanism is established to periodically assess the effectiveness of countries' actions every five years starting in 2023.

The International Civil Aviation Organization (ICAO), in its comprehensive statement on environmental protection, requires member states to mitigate environmental impacts through optimization of air traffic management. In 2010, ICAO adopted a resolution to improve fuel efficiency in flight to protect the environment at the 37th ICAO Assembly. The long-term goal of improving flight fuel efficiency by 2% per year by 2050 will be achieved, and a medium-term goal of no further growth in net emissions from international aviation from 2020 was proposed [31]. 2013 International Air Transport Association (IATA) adopted the Carbon Neutral Growth Program. The programme proposes a target for the air transport industry to improve fuel efficiency by 1.5% per annum by 2020 [32].In 2014, the EU set a target to include emissions from the internal segments of the European Economic Area in its emissions trading system by the end of 2016 [33

Currently, there are three main ways to reduce the environmental impact of air traffic: (1) improving and manufacturing more environmentally friendly engines and aircraft aerodynamic profiles; (2) using bio-alternative fuels; and (3) improving and optimizing the operational quality of air traffic. Given that the current engine and aircraft aerodynamic design technologies are quite mature, the fuel saving potential from the addition of wingtip winglets has been exhausted. The limited raw materials and production of bio-alternative fuels are not sufficient to support large-scale use in air transportation. Therefore, the use of improved and optimized air traffic management operational quality to improve the efficiency of available airspace utilization and flight track fuel efficiency has great potential in civil aviation energy saving and emission reduction.

The Special Plan for Energy Saving and Emission Reduction in Civil Aviation Air Traffic Management System [34 developed by the Air Traffic Management Bureau of the Civil Aviation Administration in 2015, proposes to achieve, with 2015 as the base year, by 2020: a 1% increase in ATM (ATM, Air Traffic Management) operational efficiency, a 3% reduction in average flight fuel associated with ATM, a 3 percent reduction in average flight delay time after closing the doors at busy airports minutes, an average annual reduction in flight CO2 emissions of about 2.6 million tons and an increase in the number of people affected by noise no more than 2% as specified in the "Environmental Standards for Aircraft Noise around Airports". However, a systematic quantitative index system and measurement standards are not proposed.

ATC operation energy saving and emission reduction index system is an important tool to reflect the operational efficiency and effectiveness of ATC green development. On the one hand, it can scientifically, accurately and objectively show the total fuel consumption and carbon dioxide emissions of aircraft in different flight phases, and clarify the relationship definition and impact degree of flight delays caused by airports, airlines and air traffic control, and also lay the foundation for fair assessment and incentive for the industry. Secondly, it can accurately reflect the utilization efficiency of civil aviation airspace, the operational efficiency of air traffic management, and the effect on the environment, which helps ATC to find out the shortcomings, clarify the focus points, improve the technology and make precise efforts. Thirdly, it helps to scientifically assess the contribution of various management and technical improvements to civil aviation energy saving and emission reduction. Third, air traffic management energy saving and emission reduction key performance areas and index measurement methods

Through extensive research, combined with the actual air traffic control operation, this paper divides the key performance areas of air traffic management energy saving and emission reduction into four areas: carbon emissions, environmental efficiency, operational efficiency and noise impact. The calculation of all indicators should take individual flights as the basic research object, and when a large number of flights need to be evaluated as a whole, the corresponding indicator measurement values of the relevant flights can be added up.

5.1.2 Introduction of engine pollution to the environment

As showed in the Fig.5.1 Current ICAO Standards for emission certification of aircraft engines are contained HC,CO,NOx, and smoke. Concern about local air quality(LAQ) in the vicinity of airports focus on the effects of emissions released below 3000 feet.

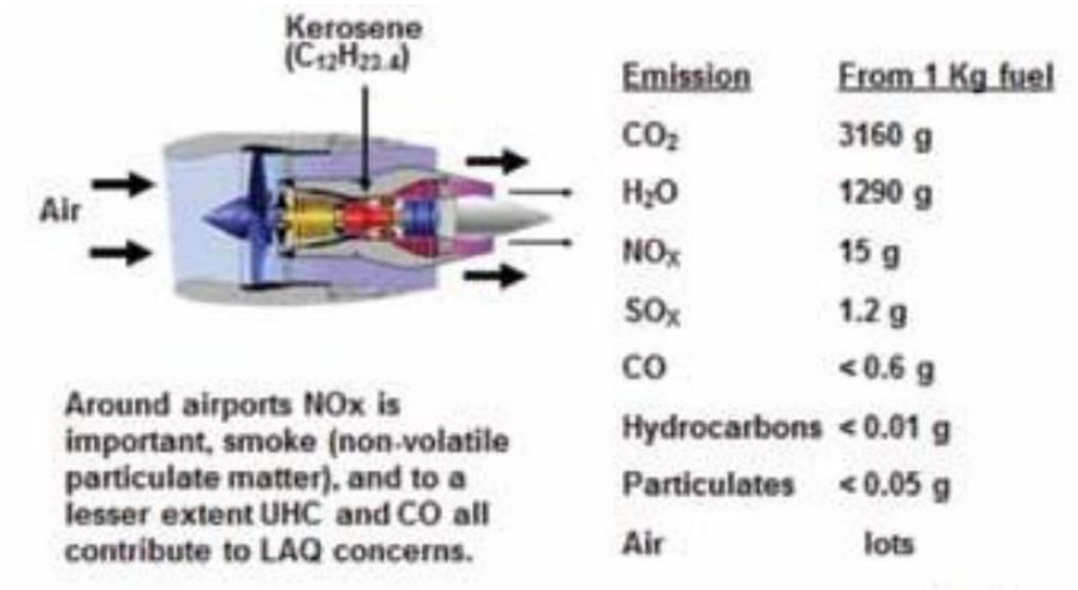

Fig.5.1 The engine emission standard cover HC, CO, NOx and smoke

As showed in the Fig.5.2 The ICAO adopted its first smoke,fuel venting and gaseous emissions from turbojet and turbofan engines in 1981.

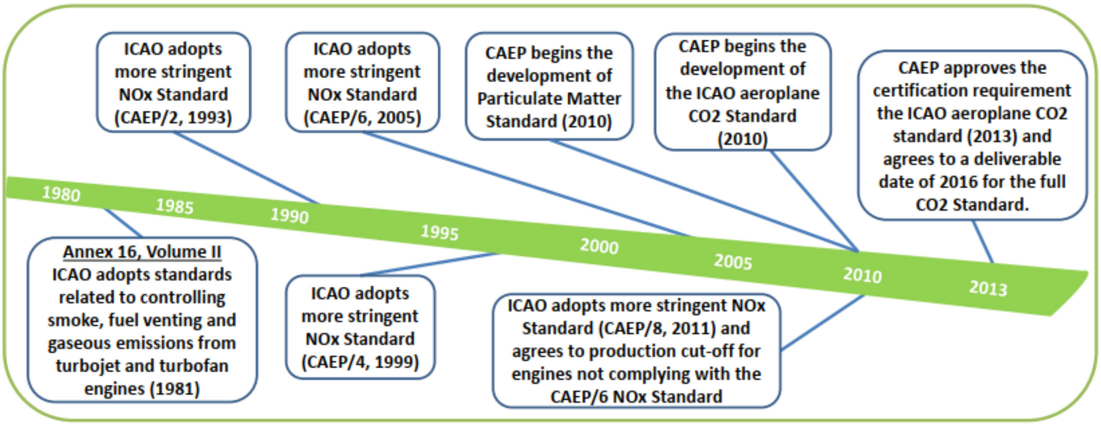

Fig.5.2 ICAO adopted its first smoke, fuel venting and gaseous emission

The engine emission certification procedure is based on the landing take-off(LTO) cycle, including take-off(100% available thrust) for 0.7 minutes, Climb(85% available thrust) for 2.2 minutes, Approach(30% available thrust)for 4 minutes, taxi(7% available thrust) for 26 minutes, the certification process involves running the engine on a test bed at each thrust setting.

5.2 The impact of new design layout on environmental protection

5.2.1 Measures to protect the environment

Air transportation has become the fastest-growing sector in the world in terms of greenhouse gas emissions. The carbon emissions generated by air transportation have constrained the development of air transportation while causing global climate change. In order to achieve sustainable development of air transportation, the international community and our government have developed policies and measures to actively save energy and reduce emissions. After improving engines and bio-alternative fuels, the optimization of air traffic management is an important grasp to tap into energy saving and emission reduction in civil aviation. In this paper, with the starting point of discovering the shortcomings of ATC operation and improving the performance of ATC operation, fuel consumption, fuel efficiency, operational efficiency and conducted research

Fast take-off and landing, reducing the impact time of the aircraft on the surrounding environment has a positive effect on reducing the impact of noise.

The airspace system is becoming increasingly congested as the number of aircraft operations grows to meet passenger and goods demands. The bulk of traffic contributes to airport traffic saturation. Due to this increase, populations living near airports, as well as the environment, are impacted by commercial aircraft.

Aircraft noise is considered to be one of the most significant environmental concerns in the local communities of modern cities, affecting people living near airports. This is supported by evidence that aircraft noise exposure is associated with reduced well-being, lower self-reported quality of life and higher levels of self-reported stress, anxiety, depression and psychological morbidity. Significant work has been done in the area of noise effects reflecting different aspects of annoyance and human health considerations. This is a critical issue that affects the sustainability of commercial aviation. Different solutions have been attempted to control aircraft noise at airports. Nevertheless, noise levels in the vicinity of airports, in particular under the take-off and landing flight paths remain high and disrupt the quality of life of local residents. This is considered today to be one of the most significant environmental concerns affecting population and the environment.

Contributors to noise reduction should encompass technology related elements such as the Quiet Aircraft and Rotorcraft of the future as well as further actions aimed at establishing efficient Environmental Practices by way of Noise Abatement Procedures and Management of Noise Impact.

Conclusion to part 4

The enhanced short take-off and landing capability of the new wing designed in this paper means that the aircraft can take off and land at a lower speed, so the lower speed means lower engine thrust and lower minimum take-off speed required for the aircraft to take off, and at the same speed, the new wing can provide more lift, so it can reduce the power of the engine during take-off and landing, further reducing the engine's This will further reduce the emission of polluting gases from the engine, which will have a positive impact on environmental protection.

The enhanced short takeoff and landing capability of the new wing designed in this paper means that the aircraft can take off and land at a lower speed, so the lower speed means lower engine thrust, and the minimum takeoff speed required for the aircraft to take off is reduced. It can reduce the engine power during takeoff and landing, and further reduce the emission of polluting gases, which has some positive significance for environmental protection.

The new wing layout proposed in this paper, in addition to having short take-off and landing capability, also has a better performance in dealing with speed disturbance. The new wing designed in this paper can automatically adjust the angle of attack to make the angle of attack larger when the incoming speed decreases, so that the aircraft's attitude remains stable. This saves unnecessary fuel consumption to increase thrust, saves fuel and reduces CO_2 emissions, which is very beneficial to the environment. The shorter take-off and landing distances help to reduce engine pollutant emissions and reduce the impact of noise disturbances on the surrounding environment during take-off and landing.

In addition to the short takeoff and landing capability, the new wing layout proposed in this paper also has better performance in coping with the speed disturbance. The new wing designed in this paper can automatically adjust the angle of attack to make the angle of attack bigger when the incoming speed decreases, so that the attitude of the aircraft can be kept stable. The airplane saves unnecessary fuel consumption to increase the thrust, saves fuel and reduces the emission of CO_2, which is very beneficial to environmental protection. The shortened takeoff and landing distances help reduce the emission of engine pollutants and reduce the impact of noise disturbance during takeoff and landing on the surrounding environment.

GENERAL CONCLUSION

A a result of the new wing layout for aerodynamic and fatigue enhancement has been proposed.

To gain the aim of the work, the following **objectives** where solved:

The aircraft becomes possible to fly more smoothly and reduce the effect of speed disturbance on the aircraft.

The aerodynamic optimization of the designed wing with application of the numerical simulation to study its flow characteristics has been carried out.

The ability of the designed wing to automatically adjust the angle of attack, the moment characteristics of the big and small wings will be studied by numerical simulation was verified.

To study the enhancement effect of the designed airfoil on the fatigue life of the airfoil by a fluid-structure coupling method based on the ANSYS software has been used.

Recommendation on the practical application of the Master work results have been developed.

For the Labor protection, proposing some measures to protect the experimental environment and students by combining the requirements of labor protection in China. Finally, analyze the emergency disposal methods in case of fire accidents around labor protection, and use different classifications of suitable fire extinguishers to extinguish the fire when we can ensure that the fire is put out in accordance with the regulations, and escape through the safety exit in time when the fire is large.

For the environment protection , the enhanced short take-off and landing capability of the new wing designed in this paper means that the aircraft can take off and land at a lower speed, so the lower speed means lower engine thrust and lower minimum take-off speed required for the aircraft to take off, and at the same speed, the new wing can provide more lift, so it can reduce the power of the engine during take-off and landing, further reducing the engine's This will further reduce the emission of polluting gases from the engine, which will have a positive impact on environmental protection.

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