MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aerospace University
«Kharkov Aviation Institute» Aircraft
Engineering Faculty
Department of Airplane and Helicopter Design

Explanatory note to the diploma project

_________master's degree_________

_________Light one engine aircraft_________ ___________Wing airflow analysis__________

Performed by student of 2th year, group 161fd

Direction (Speciality):

134《 *Aviation and Aerospace Engineering*》

Educational program: 《*Aircraft Designing*》

Student: Dai Qilin__________

Supervisor: ______________________

Reviewer: ______________________

Kharkov – 2023

NATIONAL AEROSPACE UNIVERSITY
«Kharkov Aviation Institute»

Faculty Airplane-design
Chair Airplane and Helicopter Design
Degree Master

Specialty 134 Aerospace Engineering
(Code and Name)
Education Program Aircraft Designing
(Code and Name)

APPROVED by
Head of Chair

PhD, Ass. Prof.
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TASK
FOR STUDENT'S DIPLOMA WORK

Dai Qilin
(Name)

Subject of Work Light one engine aircraft. Wing airflow analysis

Supervisor of Work ass. prof, PhD, Chumak
(duty, degree, scientific degree, name)

approved by University order from "___" ___________20__ No___
Work presentation deadline 10.05.23
Initial data for work $N_{pas} = 4$
$L = 300$ km
$V_{cr} = 200$ km/h

Content of explanatory note (list of problems to solve)

Summary

1. Designing section

1.1. Automated formation of the aircraft shape

Introduction, aim and tasks of design

1.1.1. Development of the aircraft concept, scientific and technical program to achieve its performance.
1.1.2. Aircraft purpose, tactical and technical requirements, the conditions of its production and operation, restrictions imposed by aviation regulations.
1.1.3. Collection, processing and analysis of statistical data. Selection of basic relative initial parameters of the aircraft.
1.1.4. Aircraft scheme selection and justification, powerplant type selection.
1.1.5. Calculation of the aircraft takeoff mass in three approximations.
1.1.6. Engines selection and takeoff length check.
1.1.7. Aircraft design parameters determination and optimization.
1.1.8. Development of aerodynamic, mass and space, load carrying structure layouts. Calculation of the aircraft centering and inertia moments.
1.1.9. Aircraft units' shapes lofting, fairings and cowlings modeling.
1.1.10. The aircraft standard specification.

1.2. Analysis of optimized aircraft design parameters influence on its aerodynamic and mass characteristics.

1.2.1. The aircraft drag determination.
1.2.2. The aircraft lift force, induced drag, polar diagram, aerodynamic efficiency.
1.2.3. The aircraft pitch moment determination and aerodynamic focus location.
1.2.4. Aircraft design parameters influence on its aerodynamic and mass characteristics
1.2.5. Calculation of the aircraft moment characteristics, static stability and controllability
1.2.6. Calculation of "Load-Range" diagram

1.3. Integrated design and computer modeling of ________wing_________ of the aircraft

(unit)

1.3.1. Unit master geometry development.
1.3.2. Determination of loads acting on the unit.
1.3.3. Refinement of load carrying structure of the unit.
1.3.4. The choice of materials for the structural elements of the unit.
1.3.5. Design calculation of geometrical parameters of load carrying elements in the assembly regular and irregular areas with specified life time.
1.3.6. Study of influence of parameters of the unit on its mass.
1.3.7. Design calculation of connections and joints of the unit with the fuselage.
1.3.8. Life time prognosing the unit in regular and irregular areas.
1.3.9. The unit geometric and structural parameters refinement.
1.3.10. The unit technical operation manual development.

2. Economics

3. Special task

Wing airflow analysis

List of drawings

- Master geometry of aircraft surface, general view drawing ;
- Master geometry of the unit;
- Analytical models of designed unit parts, subassemblies;

- Business plan scheme for the establishment of the airplane;
- Aircraft qualitative criterias table

Advisors of work sections

Section	Name and duty of advisor	Sign, Date	
		Task is given	Task is passed
1.	**Chumak A.S.**		
2.	**Pavlenko T.Y.**		
3.	**Chumak A.S.**		
4.			
5.			

Date when task is given____

CALENDAR PLAN

Nos	Diploma work milestones	Work milestones deadline	Notes

Student ________________ ____________

(Sign) (Name)

Supervisor of work

(Sign) (Name)

Abstract

In recent years, the demand for light commercial aircraft with higher fuel economy and lower carbon emissions has grown rapidly. The development of lightweight and high-strength materials has reduced the weight of the fuselage and further strengthened the structure, making the aircraft more lightweight, Further developments in the pursuit of high efficiency are possible.

In this article, the group briefly introduced the requirements and development of the four-seater aircraft, and completed the design content required by the task through statistical analysis and calculation. Aiming at this design goal, combined with the design concept of "safety, economy and comfort", and referring to the development results of the current main models of short- and medium-range commercial airliners, we have carried out the overall design of the aircraft. Through aerodynamic analysis and flight performance analysis, the flight characteristics of the aircraft are calculated. In addition, the economics and product competitiveness of the aircraft are analyzed.

The main calculation and analysis steps include: calculation of take-off weight, take-off thrust-to-weight ratio, calculation of wing load, selection of airfoil, calculation and selection of shape geometric parameters, fuselage and cabin design, selection and calculation of aircraft power system and fuel system, Weight analysis and center of gravity calculation, as well as estimation of main performance parameters, analysis of aircraft handling stability and analysis and calculation of overall flight performance parameters, etc..

Key words: Aerospace

CONTENTS

Introduction

Aircraft is a highly integrated embodiment of modern science and technology. For over 100 years, as an important representative of aviation technology, airplanes have made great progress with the progress of science and technology, and the new requirements constantly put forward by aviation technology have also played a promoting and promoting role in the development of science and technology. In modern aircraft, a series of latest achievements in basic science, applied science, and engineering technology have been comprehensively applied, including mechanics, materials science, electronic technology, computer technology, jet propulsion technology, automatic control theory and technology, and manufacturing processes. In fact, modern aircraft has become an advanced and complex engineering system. Because of this, it has also led to continuous changes and innovations in aircraft design work and methods, and gradually developed towards system engineering design methods.

Aircraft can be divided into military aircraft and civil aircraft according to their functions. The main function of military aircraft is to complete tasks such as aerial interception, reconnaissance, bombing, attack, early warning, anti-submarine, electronic interference, as well as military transportation and airborne operations. Civil aircraft refers to aircraft for nonmilitary purposes, including commercial passenger aircraft, cargo aircraft and other transport aircraft. They have become a fast, convenient, comfortable and safe means of transportation.

In order to complete various tasks, different aircraft have different technical requirements. For military aircraft, it is referred to as tactical technical requirements; For civil aircraft, it is called operational technical requirements. In addition to the maximum speed, ceiling, range, takeoff and landing distance, payload, and maneuverability (for fighter jets) of the aircraft, it also has requirements for round-theclock flight, airport maintenance, and support for the aircraft itself.

There are also some planes used in general aviation, such as those used in agricultural operations, forest protection and afforestation, disaster relief, medical aid, aerial survey and sports. Among them, electric aircraft, as a new star in general aviation aircraft, is rising strongly, which has attracted the attention of aircraft research designers.

Electric aircraft uses electric propulsion system instead of internal combustion engine power, thus obtaining many advantages and unique qualities. The most prominent advantages are energy conservation and environmental protection, high efficiency and low consumption, while achieving near zero emissions, low noise and vibration levels, and good riding comfort. It is truly an environmentally friendly aircraft. In addition, it also has the characteristics of safety and reliability (no explosion or fuel leakage), simple structure, easy operation and use, good maintenance/low cost, and good economy. There are also many advantages in design: the overall layout is flexible, and the best layout and unconventional/innovative layout can be adopted; Aircraft with exceptional performance can be designed to meet special usage needs.

Research purpose and significance

Compared with the traditional power forms, the electric propulsion system has a certain degree of power relative scale independence. The overall design of electric aircraft can break through the limitations of the traditional architecture, and has broad design space. On the other hand, due to the power density level of components such as batteries, compared to conventional layout aircraft using traditional power forms, the electric propulsion system can affect performance indicators such as range and payload, posing a demand for integrated design of aerodynamics structure propulsion and innovative design of aerodynamic layout.

Compared with the traditional fuel aircraft, the aerodynamic layout and propulsion system design of the electric aircraft have higher degrees of freedom and are highly coupled. The traditional independent design method limits the comprehensive optimization design of the aircraft. The integrated aerodynamic structure propulsion design can effectively improve the aircraft performance.

The integrated aerodynamic structure propulsion design technology of electric aircraft carries out comprehensive trade off analysis and iterative optimization design for the motor, propeller, wing and nacelle of the aircraft, comprehensively considers the geometric parameters, aerodynamic parameters, weight parameters and power system parameters of the aircraft, carries out sensitivity analysis and coordination of key parameters, carries out scheme evaluation, and supports layout scheme selection.

Traditional fuel powered aircraft emit a large amount of carbon dioxide and other harmful substances, which have a negative impact on climate change and air quality. Electric aircraft is designed to reduce or eliminate these emissions and reduce environmental pollution and pressure by using electric energy instead of fuel. The promotion and application of electric aircraft will help reduce carbon emissions, improve air quality, and achieve more environmentally friendly air transportation. In addition, the energy of electric aircraft can be supplied through renewable energy to further improve the sustainability and efficiency of energy.

Electric aircraft is an important part of sustainable development. With the global emphasis on sustainability and increasing demand, the design and promotion of electric aircraft can promote the sustainable development of the aviation industry. The use of electric aircraft can reduce the dependence of air transport on limited fuel resources, reduce energy consumption and waste, and provide more sustainable solutions for future air transport.

The design of electric aircraft has promoted technological innovation and progress in the aviation field. Electric aircraft needs to involve advanced motors, highperformance batteries, intelligent control systems and other key technologies, which has promoted the research and development of related fields. The promotion of this innovative technology is not only of great significance to the electric aircraft itself, but also has a positive impact on electrification and new energy applications in other fields.

Therefore, the purpose and significance of the research and design of electric aircraft is to achieve environmental protection, improve energy efficiency, promote sustainable development and promote the development of innovative technologies. Through the design and promotion of electric aircraft, it can bring more sustainable solutions to the aviation transportation industry and make contributions to building a more environmentally friendly, efficient and innovative future aviation system.

Research background and status

research background

With the rapid development of China's civil aviation industry, it has played an increasingly important role in the field of transportation in China. The increase in transportation demand has led to an increasing number of flights in China, resulting in increasingly serious environmental pollution. Among them, transportation not only accounts for a large proportion of fossil fuel consumption and emissions, but also affects people's lives. In the aviation industry, its carbon dioxide emissions account for over 2% of the total global carbon dioxide emissions and are increasing year by year. Existing aircraft face serious challenges in terms of energy consumption and environmental impact.

We are facing a series of problems, one of which is the impact of traditional fuel powered aircraft on the environment and the high dependence on limited energy resources. Traditional aircraft rely on fuel combustion to generate thrust, leading to significant carbon emissions and air pollution, exacerbating global climate change issues and causing serious impacts on the atmosphere and ecosystems. In addition, with the rise in fuel prices and uncertainty in energy supply, fuel powered aircraft are also facing challenges in terms of energy consumption and economic feasibility.

With the increasing global attention to environmental protection and sustainable development, traditional internal combustion engine aircraft generate a large amount of exhaust and noise during operation, seriously polluting the environment and posing a threat to people's health. We urgently need an innovative solution to reduce dependence on limited resources and reduce negative impacts on the environment. Electric aircraft has become an important research direction in the aviation field due to its use of electric drive system, which does not produce harmful gases and noise, and has better environmental protection and sustainability.

Electric aircraft is a kind of aircraft driven by electric power system. Compared with the traditional internal combustion engine aircraft, it has the advantages of environmental protection, low noise, low cost, etc., so it has received more and more attention and research.

Research on electric aircraft stems from the pursuit of environmental sustainability and energy efficiency in aviation. Environmental concerns and energy consumption challenges posed by conventional fuel-powered aircraft have prompted a search for cleaner, more efficient solutions. As global concerns about climate change and environmental protection continue to grow, electric aircraft are gaining traction as a potential alternative.

The research of electric aircraft involves progress and breakthroughs in many fields. First, the continuous improvement of battery technology and the emergence of batteries with high energy density provide the basis for the realization of electric aircraft. Newer battery technologies such as modern lithium-ion batteries are able to provide sufficient energy storage and output to meet the demands of flight.

Second, research on electric aircraft also benefits from innovations in motors and power systems. With the continuous development and maturity of power system technology, efficient, lightweight motors and advanced power system design enable electric aircraft to provide sufficient thrust and flight performance. In addition, the intelligent and optimized control technology of the power system enables electric aircraft to use energy more efficiently and provide safer and more reliable flight. Supported by these technological advances, the design and manufacture of electric aircraft has become more feasible and practical.

In addition, the research on electric aircraft in the field of aviation also involves the innovation of aviation materials and structural design. The application of lightweight materials and the design of structural optimization can reduce the weight of the aircraft and improve flight efficiency and endurance. These technological advances set the stage for the viability and practicality of electric aircraft.

In general, the research background of electric aircraft is the joint promotion of technological progress and environmental awareness in multiple fields. Through innovative technology and the concept of sustainable development, electric aircraft is expected to become an important development direction in the aviation field in the future, bringing cleaner, efficient and sustainable solutions to the aviation industry.

research status

As the electric vehicles on the ground become more and more popular and timely, the "electric aircraft" in the sky are also intensively studying, trying and promoting. Electric aircraft uses electric energy as all or part of the energy of the propulsion system, which is an important symbol of the "Third Aviation" era. It will usher in a new wave of innovation and transformation in the aviation industry, lead aviation technology innovation, promote green aviation development, and have a revolutionary impact on the world aviation industry.

Electric aircraft is a research hotspot in the aviation field in recent years. It has the advantages of environmental protection, low noise, low cost, and is gradually becoming the trend of future aviation development. The research field of electric aircraft is undergoing rapid development and continuous breakthroughs. Research institutions, airlines and manufacturers at home and abroad are investing a lot of resources in the research and development of electric aircraft related technologies. In the research field of electric aircraft, there are currently the following research status: *(i) Progress in design and manufacturing technology*

Material selection of electric aircraft is critical to its performance and efficiency. By optimizing the structural design of the aircraft and adopting advanced manufacturing technology, researchers have made electric aircraft lightweight, highstrength and efficient. For example, the use of composite materials, 3D printing technology, and advanced flight control systems can significantly reduce aircraft weight and aerodynamic drag, improve aircraft performance and energy efficiency. At the same time, we are committed to developing lightweight, high-strength, and corrosion-resistant materials to reduce aircraft weight and improve flight efficiency. Composites, advanced alloys and nanomaterials are widely used in the structures and components of electric aircraft.

(ii) Development of battery technology

Battery technology is the core of electric aircraft, and the energy density, weight and safety of batteries have always been the focus of research. At present, research institutions and companies both domestically and internationally are actively exploring different types of electric power systems. In recent years, the development of new battery technologies such as lithium-ion batteries, solid state batteries and metal air batteries has significantly improved the range of electric aircraft. In addition, researchers are also committed to developing new energy storage technologies, such as hydrogen fuel cells and supercapacitors, to meet the long range and high power requirements of electric aircraft.

(iii) System control and optimization

System control and optimization of electric aircraft is the key to ensure flight safety and performance. The application of technologies such as autopilot, intelligent flight control and flight management system can improve the flight stability, energy utilization efficiency and safety of electric aircraft. Researchers are committed to developing efficient and stable flight control systems and coordinating them with motors, batteries, and aircraft systems. At the same time, the development of UAV technology also provides new opportunities and challenges for the flight control of electric aircraft. By utilizing advanced control algorithms and artificial intelligence technology, aircraft can achieve autonomous flight, energy management, and intelligent navigation functions. At present, domestic and foreign research institutions and enterprises are committed to developing advanced flight control systems and intelligent flight management solutions.

(iv) Charging and infrastructure construction

The charging facilities and infrastructure construction of electric aircraft is an important part of the development of electric aircraft. Researchers are actively exploring efficient and intelligent charging technology and infrastructure to meet the charging needs of electric aircraft. For example, fast charging technology, wireless charging technology, and the construction of charging station networks are all current research hotspots. Airlines and airport operators at home and abroad are actively promoting the construction of electric aircraft charging infrastructure to support the charging demand and rapid development of electric aircraft.

(v) Environmental impact and sustainability

Research on electric aircraft also focuses on its environmental impact and sustainability. The researchers are committed to improving the safety performance of electric aircraft, including preventing the battery from overheating, improving the battery life and developing emergency fault handling systems. Compared with traditional fuel driven aircraft, electric aircraft has zero emissions and low noise, which is expected to reduce the impact of air transport on the environment. Researchers are focusing on environmental assessment, noise control and establishment of sustainable production chain of electric aircraft to promote sustainable development of electric aircraft.

With increasing global attention to environmental protection and sustainable development, people are seeking more environmentally friendly and low-cost air transportation solutions. As a new technology and development direction, electric aircraft has gradually attracted the attention and research in the aviation field. In addition to the traditional aviation field, the application field of electric aircraft is expanding. For example, in the agricultural field, electric aircraft can be used for plant protection and crop monitoring to achieve precision agriculture; In the logistics field, electric cargo planes can be used for fast and environmentally friendly cargo transportation; The tourism field can provide low altitude sightseeing experience through electric aircraft. The expansion of these application fields also provides more opportunities and challenges for the research and development of electric aircraft.

Many scientific research institutions at home and abroad have carried out relevant research work on electric aircraft. From the current research, the electric aircraft has passed the theoretical design stage, and its application is the focus of the current research. Since the 1950s, many developed countries in the world have taken electric aircraft as a key research direction and rapidly launched a full range of research.

Domestic research status

Domestic research on electric aircraft is relatively late, but in recent years it has received accelerated development and widespread attention. The Chinese government has issued a series of policies to support the R&D and application of electric aircraft and encourage scientific research institutions and enterprises to increase investment and innovation. The policy support provides a strong guarantee for the research and development of electric aircraft. The Chinese Academy of Aeronautics will organize domestic advantageous forces to study and propose the White Paper on the Development of electric aircraft from the aspects of the necessity, definition and classification, key products, key technologies, measures and suggestions for the development of electric aircraft.

The white paper proposed that China should focus on the development of four types of electric aircraft, including urban air transport, light sports, commuter transport and trunk and feeder transport; Focusing on the development of key technologies in key areas such as overall design technology, efficient and high power to weight ratio electric propulsion technology, energy comprehensive management technology, and energy system technology; It is suggested to formulate a strategic plan for the development of electric aircraft, increase R&D investment, and pay attention to airworthiness capacity building and talent training, so as to promote the development of electric aircraft in China.

Some progress has been made in the research of electric aircraft at home and abroad, but there are some differences in the research situation, advantages and disadvantages, and future development direction. Below is a detailed analysis and comparison from the following aspects:

(i) Policy and Support

In recent years, with the improvement of environmental awareness, both at home and abroad have increased investment in the research of electric aircraft. China's National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Finance and other departments have issued policies to support the R&D and application of electric aircraft, providing policy support and financial guarantee for the research and development of electric aircraft. Accordingly, domestic enterprises and universities are also gradually paying attention to the research of electric aircraft, and competing to carry out some major electric aircraft research projects. For example, AVIC and China Aerospace Science and Technology Corporation have cooperated to carry out electric aircraft research and development projects to promote the breakthrough and application of electric aircraft technology.

(ii) Research and Innovation

Domestic aviation manufacturing enterprises, scientific research institutions and universities have carried out a series of innovative research in the field of electric aircraft. Both domestically and internationally, efforts are being made to address issues such as battery capacity, battery life, and charging efficiency. The research covers key technical fields of electric aircraft, such as battery technology, motor design, flight control system, etc. Some research institutions and enterprises have successfully designed and manufactured prototypes and experimental machines. However, at present, the application of electric aircraft in China is still relatively limited, and it still needs to further improve the technology and create a good application environment.

(iii) Technology and achievements

Domestic research on electric aircraft mainly uses traditional battery technologies such as lead-acid batteries and lithium-ion batteries. For example, the "Yun-20" electric aircraft developed by Aviation Industry Corporation of China uses lead-acid batteries, and its endurance is about one hour. In addition, lithium-ion batteries are also used in the electric aircraft research project carried out by the Institute of Mechanics of the Chinese Academy of Sciences. Tsinghua University has also carried out a series of battery research work, mainly involving materials, design, and manufacturing.

Domestic research on electric aircraft mainly focuses on the improvement and application of motor technology. For example, the research team of Harbin Institute of Technology has developed a high-performance permanent magnet synchronous motor and successfully applied it to the propulsion system of the electric aircraft test machine.

There are also breakthroughs in the design and manufacturing technology of electric aircraft. Scientific research institutions and enterprises are actively developing the design and manufacturing technology of electric aircraft. Nanjing University of Aeronautics and Astronautics and China Aviation Development Commercial Aeroengine Co., Ltd. have jointly developed an electric aircraft called "Hummingbird", which adopts the lightweight design concept, reduces the structural weight, and thus improves the flight efficiency.

The research on electric aircraft in China is still in its infancy compared with that abroad, and most of the research is still in the laboratory stage, with relatively few practical applications. But good results have also been achieved. At present, most of the domestic research on electric aircraft focuses on vertical takeoff and landing UAVs, and multi rotor aircraft is one of the research hotspots. For example, the " Deep Space1" vertical takeoff and landing aircraft developed by the Institute of Automation of the Chinese Academy of Sciences has adopted a multi rotor design and successfully completed a number of important tasks, including emergency rescue, disaster monitoring, etc.

In addition to vertical takeoff and landing UAVs, domestic research on electric aircraft also includes electric gliders to achieve the goal of environmentally friendly aviation technology. For example, the "Black Whale" electric glider developed by Beijing University of Aeronautics and Astronautics adopts the world's advanced lightweight structural design, with a maximum speed of 250 kilometers per hour and a longer range. The research on this electric glider has an important driving role for future environmentally friendly aviation technology.

International research status

The research and development of electric aircraft has an important background and significance. It is a comprehensive function of environmental protection, sustainable development, technological progress, policy support, scientific research and exploration and other factors. International research on electric aircraft has made a lot of progress. The following aspects are analyzed and compared in detail:

(i) Policies and support

Overseas research on electric aircraft began earlier. Scientific research institutions, aviation manufacturers and start-ups in many countries are actively engaged in relevant research, such as Boeing, Airbus, Cessna, Tesla, Scheme First, Yuneec, PC Aero, etc. Internationally, European airline EasyJet has put into operation a electric aircraft prototype called E-Fan X, and carried out a series of flight tests. At the same time, Boeing is also developing electric aircraft, and plans to launch commercial electric aircraft in the future.

(ii) Research and Innovation

The system control and optimization of electric aircraft is also an important research direction of electric aircraft. At home and abroad, researchers have begun to explore how to optimize the system of electric aircraft to improve its efficiency and safety. For example, researchers from Stratford University in the UK developed a model predictive control based electric aircraft control system, which can predict and optimize the flight state of electric aircraft based on real-time data.

(iii) Technology and achievements

At present, domestic and foreign scientific research institutions and enterprises are actively developing the design and manufacturing technology of electric aircraft. For example, the electric aircraft E-Fan X, which was jointly developed by General Electric Company of the United States and Lekoot of Sweden, uses two electric engines and a fuel assisted generator. During flight, it can independently choose to use electric or fuel powered generators to provide power, and can achieve two modes of all electric flight and hybrid flight.

Many foreign scientific research institutions, aviation manufacturers and start-ups are committed to technological innovation and application of electric aircraft. These institutions have made important breakthroughs in battery technology, motor design, material application and other aspects, promoting the development of electric aircraft. Some advanced electric aircraft have begun to use new battery technologies, such as lithium polymer batteries, sodium ion batteries, supercapacitors, etc., which can significantly improve the endurance and performance of electric aircraft. Some enterprises have successfully manufactured electric aircraft that can fly long distances. For example, the Slovenian Pipistrel Company has developed the Alpha Electro electric aircraft, which uses advanced lithium polymer battery technology and has a endurance of more than 2 hours; In addition, Groves, an American lithium battery manufacturer, has developed a kind of lithium ion battery with light weight, high density and long life, which can provide enough power to support the long flight of electric aircraft; The American Eviation Company launched Alice electric aircraft, which uses another kind of lithium-ion battery with high energy density.

Many achievements have been made in the research of electric aircraft abroad. Now, many commercial electric aircraft have emerged, such as Alpha Electro in the United States and Pipistel in Slovenia. These electric aircraft have begun to be used in training, sightseeing, operations and other fields, and some airlines have also begun to test and apply electric aircraft as an alternative to regional and short haul flights, indicating that electric aircraft technology is relatively mature. Cisco in the United States has developed a solar powered drone that can fly at high altitudes for long periods of time without the need for refueling. This type of drone has a wide range of applications, including environmental monitoring, agricultural crop inspection, and so on.

In addition, foreign research on electric aircraft also includes electric aircraft based on hydrogen fuel cells. For example, Japan's "SkyDrive" company has developed an electric vertical takeoff and landing aircraft based on hydrogen fuel cells, with a maximum flight altitude of 500 meters and a longer endurance. The research of this electric aircraft will further promote the application of hydrogen energy in the aviation field.

Some progress has been made in the research of electric aircraft at home and abroad. The advantages of foreign countries in the research of electric aircraft lie in their early start and accumulated experience, and their technology innovation and market application are relatively mature. Some foreign enterprises have made commercial progress, and the degree of marketization of electric aircraft is relatively high, but domestic enterprises are also gradually paying attention to the research of electric aircraft. However, China has more advantages in policy support and innovative research, and in the future, it is necessary to continue to strengthen technological innovation and international cooperation. In general, significant progress has been made in the research of electric aircraft at home and abroad, involving design and manufacturing technology, battery technology, system control and optimization, etc. With the continuous breakthrough and development of electric aircraft technology, it is believed that electric aircraft will play a more important role in the future aviation field.

Research ideas

Aircraft is a complex system. Develop the concept of creating a planned aircraft and a scientific and technological plan to achieve its characteristics. Determine the purpose, tactical and technical requirements, production and operation conditions, and aviation regulations' limitations on aircraft design. After having preliminary aircraft design requirements, the layout form of the aircraft should be studied. On the basis of accumulating a large amount of information, it is easy to naturally form the concept of airplanes. After having the concepts and ideas, draw a sketch and prototype to conceptualize the basic shape of the aircraft. Then, based on this, the preliminary overall design parameters are selected, and the overall layout is further refined to make the preliminary estimated weight, engine characteristics, and aircraft aerodynamic characteristics more accurate. Then, the original overall design parameters are corrected, and the design requirements indicators are further verified until they meet the requirements. Based on the determined parameters, use 3D modeling software such as UG and CATIA to create a 3D model. Then use finite element software, such as ANSYS, to simulate and calculate it, and obtain its corresponding aerodynamic characteristics. Finally, we calculate its economic cost and complete the overall design of the electric aircraft. Figure 1.1 provides a detailed description of the design process of the aircraft scheme.

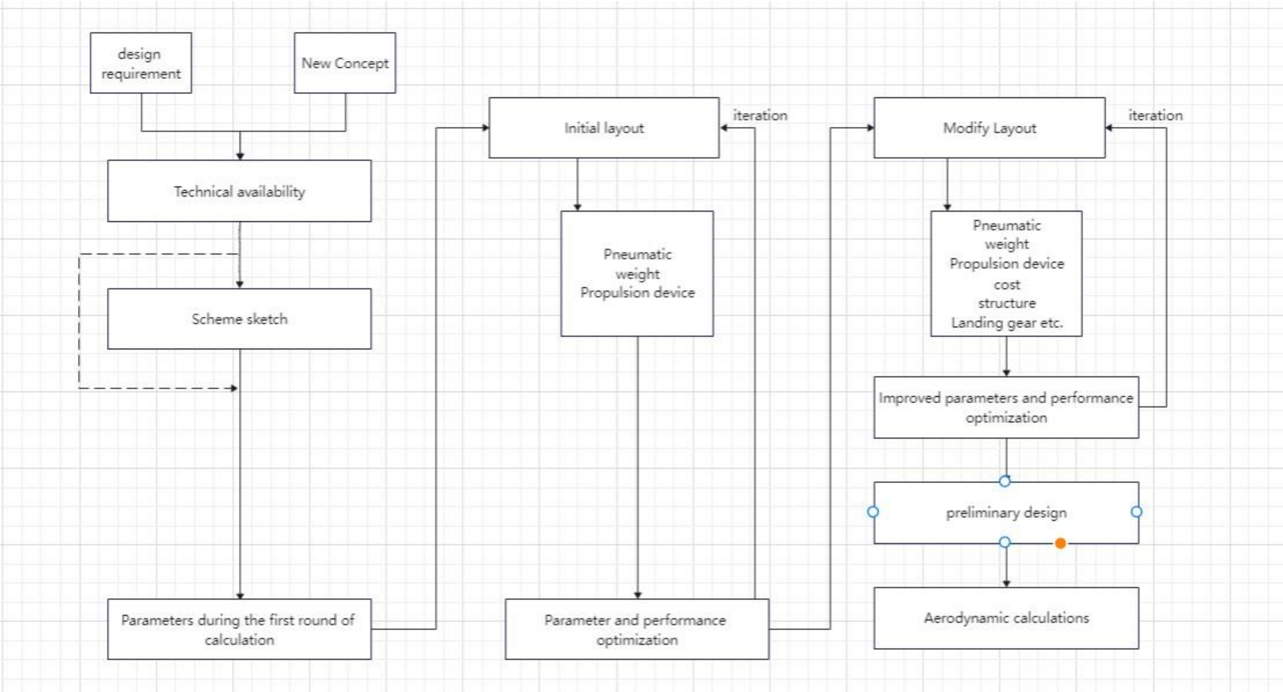

Figure1.1- Design ideas

Research contents

The first chapter "Introduction" comprehensively analyzes the existence of electric aircraft, that is, its research purpose and significance, then introduces its research status at home and abroad with the overall background, and finally briefly explains its research ideas and content.

1 Initial design

1.1 Design requirement

Electric light aircraft or electric helicopters can be widely used in fields such as flight training, private flight and business travel, which will make the entire general aviation industry achieve a qualitative leap.

Electric aircraft are designed to:

- Create highly economical next-generation electric aircraft, fully compliant with modern and future aviation standards;
- Replacing outdated conventional fuel-powered aircraft;
- Provide national and other customers with new competitive electric aircraft, whose performance is comparable to or even surpasses similar foreign products in some aspects;
- Create electric aircraft with high fuel efficiency, environmental friendliness, high reliability, enhanced pilot comfort and safety, and low operating costs;
- Create an electric aircraft with a significantly expanded range of operating conditions and wider adaptability than its modern counterparts;

- Further develop domestic scientific and industrial potential and create jobs in high-tech fields

Achieving these goals is possible under the following conditions.

- A large number of technical verification machines have been successfully developed, and the endurance time has been significantly improved, making some models close to practical use;
- Developed a specific aircraft overall design method, which has been proven and perfected day by day;
- The key design technologies of aerodynamics and overall layout, structure, materials, etc. are continuously improved;
- Electric propulsion systems (primarily electric motors and battery technology) have played a vital role in the development of electric aircraft with significant results.

In such a big environment, this paper puts forward the corresponding design requirements, explores a conceptual design method of electric aircraft, and provides a conceptual design scheme with reference value for the development of electric aircraft:

The name of the electric aircraft studied in this paper is E40-LC (E stands for electric, 4 stands for four-seater, 0 stands for basic type, and LC stands for lithium battery. The basic design requirements of the aircraft are as follows:

(1) Number of seats: The number of seats for the electric light aircraft in this paper is 4 people (including a pilot).

(2) Performance requirements: be able to fly at a cruising speed of 200km/h, and have a range of more than 300km.

(3) Climb rate (sea level): greater than 2m/s.

(4) Shape requirements: wingspan less than 15m.

1.2 Data collection

According to the type of electric aircraft, it is divided into solar electric aircraft, battery electric aircraft, fuel cell electric aircraft and hybrid aircraft.

Solar Electric Airplane:

Solar electric aircraft use solar panels to convert sunlight into electrical energy, which is supplied to the aircraft's electric motor to drive the flight. It can realize longterm unmanned flight and is suitable for meteorological observation, environmental monitoring and search and rescue missions. The Solar Impulse 2, an electric aircraft with a solar charging system, successfully completed a circumnavigation of the globe, demonstrating the potential of solar-electric aircraft. The Zephyr6 solar-powered aircraft with a wingspan of 18m from British company QinetiQ broke the world record with a continuous flight of 82 hours and 37 minutes. After that, the Zephyr7 flew for two weeks.

Figure1.1- Solar Impulse 2

Figure1.2- Zephyr7

Lithium battery electric aircraft:

The high energy density, light weight, and long cycle life of lithium-ion batteries make them a viable option for electric aircraft. The Pipistrel Velis Electro is the world's first certified lithium battery electric aircraft. It uses a lithium polymer battery that provides 30 minutes of flight time plus 30 minutes of backup power. The Velis Electro is a two-seater training aircraft widely used in aviation schools and flight training institutes. It features zero emissions, low noise and low operating costs, providing an environmentally friendly and economically viable option for flight training. RX1E is China's first new energy two-seater general-purpose aircraft. The aircraft uses a pure lithium battery as the power source, and the flight time is 1h. There is also Yuneec's E430 in China. The E430 is the world's first commercial two-seater electric aircraft. It has a round shape, a V-shaped tail, a wingspan of 13.8m, and a fuselage length of about 7m. It is equipped with a 40kW motor and is powered by a 100AH lithium polymer battery. The time is as long as 2 hours, and the product performance is much better than similar products in the world.

Figure1.3- RX1E

Figure1.4- YuneecE430

Fuel Cell Electric Aircraft:

Fuel cell electric aircraft uses fuel cells as the main energy supply device, and reacts hydrogen and oxygen to generate electricity to drive the aircraft. It has the advantages of high energy density, fast refueling and long range. The fuel cell electric aircraft developed by ZeroAvia has successfully conducted several test flights in the UK, demonstrating the potential of fuel cell technology in aviation.

Hybrid aircraft:

Hybrid aircraft combine multiple energy sources and power systems, such as internal combustion engines and electric motors, to achieve energy efficiency and flexibility. It can achieve zero-emission low-speed flight through electric drive, and use internal combustion engine to provide long-range and high-speed flight capabilities. For example, NASA's X-57 Maxwell, a hybrid electric aircraft prototype, employs 12 electric propellers and an internal combustion engine for efficient, environmentally friendly and flexible flight.

Collecting and processing statistical data during aircraft design can:

- Visualize the current state of development in the construction of electric aircraft and their flight performance;

- Identification of trends and development prospects of aircraft types under development, quantitative and qualitative changes in aircraft tactical and technical requirements, production and operating conditions. – Some aircraft parameters were determined.

In order to collect statistical data, it is necessary to use data from aircraft of similar design, with similar flight performance and operating conditions.

The following aircraft were taken as similar aircraft: Pipistrel Sinus (Fig. 1.5), Bye Aerospace eFlyer 4 (Fig. 1.6), Yuneec E430 (Fig. 1.7), RX1E (Fig. 1.8).

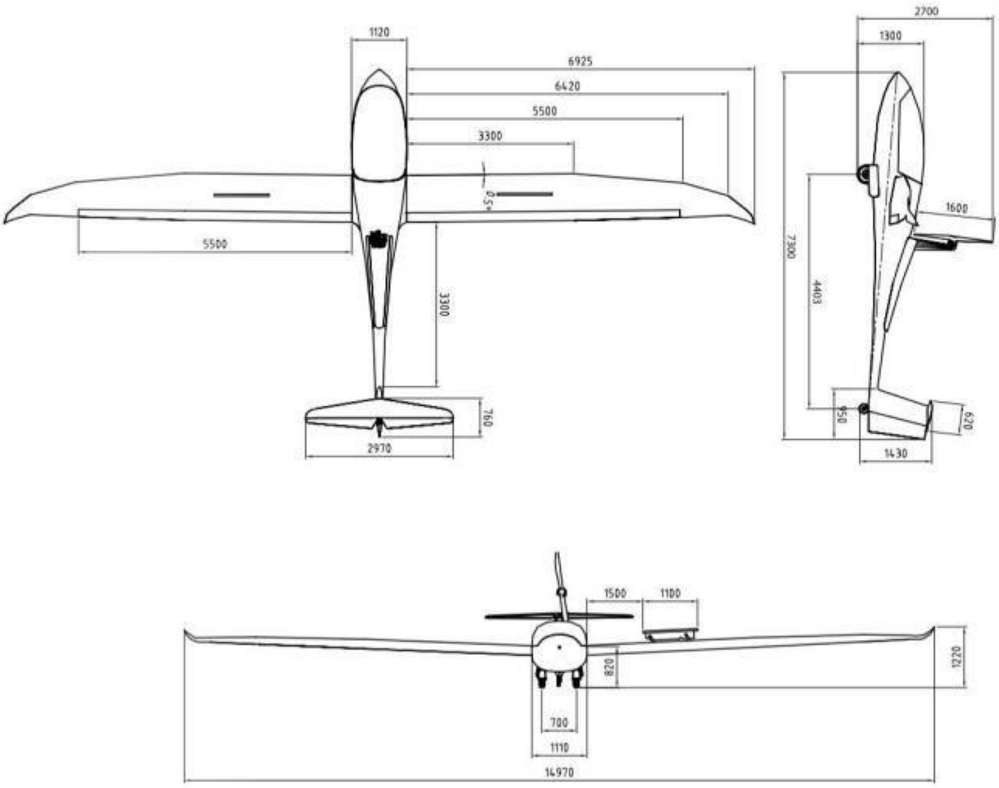

Fig. 1.5 Scheme of the Pipistrel Sinus

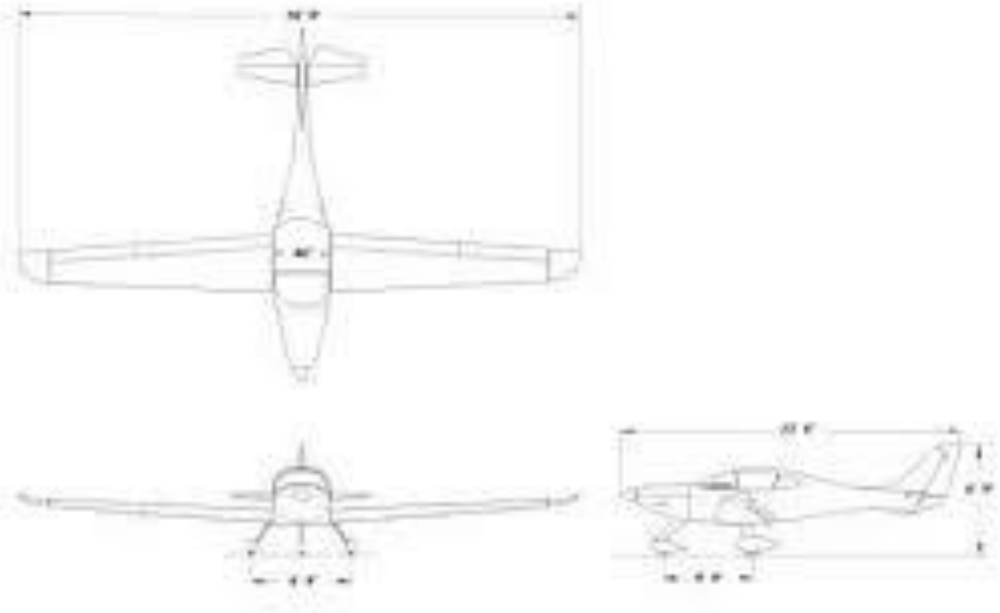

Fig. 1.6 Scheme of the Bye Aerospace eFlyer 4

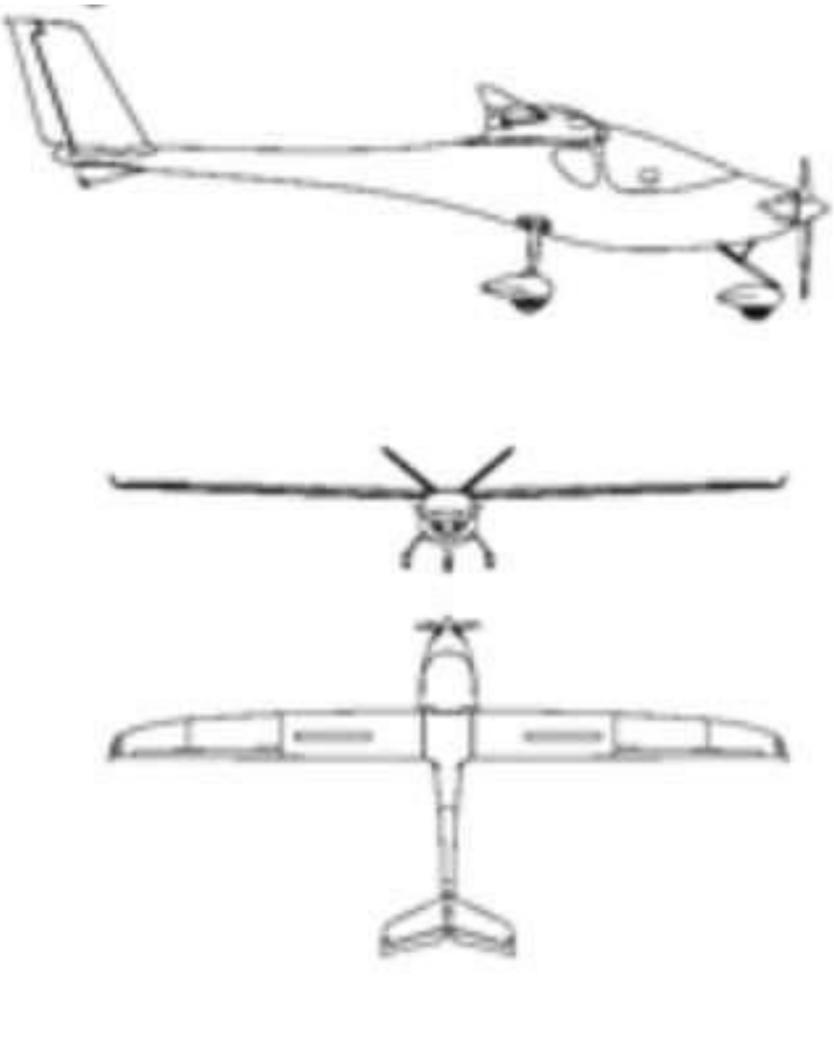

Fig. 1.7 Scheme of the Yuneec E430

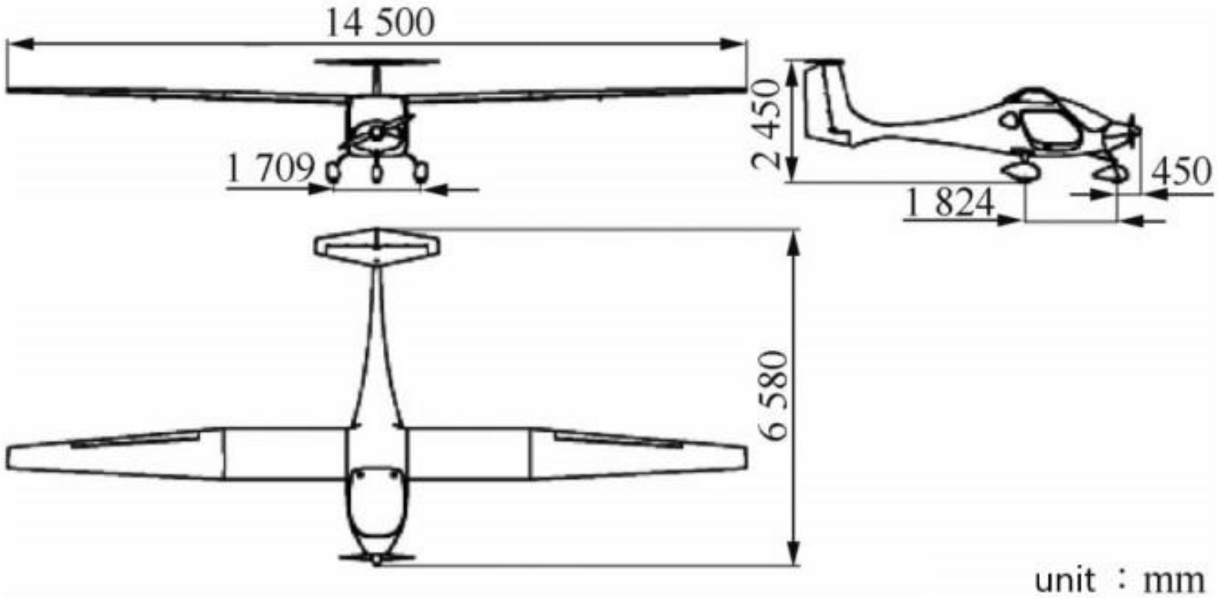

Fig. 1.8 Scheme of the RX1E

Statistics for similar aircraft are listed in the table 1.1.

Table 1.1 – Statistics of aircraft-analogues

Parameters	The name of the aircraft				
	Pipistrel Sinus	eFlyer 4	Yuneec E430	RX1E	Projected aircraft
Flight data					
V_{max}, km/h	220	324	150	160	260
H_{max}, km	8800	5300	1200	1300	1500
V_{cr}, km/h	200	95	90	110	200
H_{cr}, km	7000	1500	1000	1000	1000
L, km	1200	350	227	110	300
$L_{T,R}$, m	400	83	370	160	380
$L_{L,R}$, m	420	70	350	150	400

Mass characteristics					
m_0, kg	450	390	470	500	
m_e, kg	285	250	250	340	
Power plant data					
P_{0eng} , kw	40	25	25	12	
P_{maxeng} , kw	60	40	40	40	
BC, Ah	40	30	30	32	
T_{cr}, h	5.8	3	2.5	1	
Geometric data					
S, m^2	12.26	11.35	11.37	12	12
L_w ,m	14.97	9.408	13.8	14.495	13.5

Continuation of table 1.1

Geometric data					
b, m	0.819	1.221	0.824	0.868	0.889
λ	18.3	7.798	16.749	17.52	15.19
η	4.22	2.1	3.75	2	1.5
χ_w,deg	4	8	8	5	6
L_f,m	6.6	4.14	6.98	6.596	8.4
H_f,m	1.7	1.278	1.875	2.446	1.8
$S_{H\bar{T}}$	0.188	0.35	0.277	0.286	0.3

$S_{\bar{VT}}$	0.182	0.28	0.25	0.223	0.2
λ_{HT}	4.06	1.73	3.71	3.89	3.5
λ_{VT}	2.7	1.15	2.50	2.6	2.5
η_{HT}	3.1	2.1	2.3	2.2	2
η_{VT}	1.22	1.42	2.1	2	2
χ_{HT},deg	20	30	17	15	15
χ_{VT},deg	25	30	30	15	15
Derived quantities					
$p_0 = \frac{m}{S_0}$ kg/m^2	36.71	34.36	41.34	41.67	100
$t_0 = \frac{p_{0eng}}{m_0}$ W/kg	88.89	102.56	85.12	80	

End of Table 1.1

Derived quantities					
$\bar{m} = \frac{m_{p,1}}{m_0}$	0.2	0.34	0.25	0.26	

When designing a new aircraft, the problem of choosing its master plan arose. This is basically the initial stage of the integrated design of the aircraft. It is not possible to fully formalize the decisions taken on this matter.

Nevertheless, within the framework of the solution that has been implemented or proposed, a formal search can be organized to find the best solution based on the evaluation criteria and the satisfaction of the task of tactical, technical requirements. and technical specifications.

The choice of the general scheme of the aircraft means not only the choice of its aerodynamic scheme, although it is decisive in the implementation of the principle of operation of the aircraft, but also the scheme of the power plant, takeoff and landing devices, the placement of the crew and the payload, etc.

The final choice of the general scheme is made from a number of competing options based on the optimization of each of them and further comprehensive analysis. As an evaluation criterion for an aircraft, we take its take-off mass, and as limitations - flight performance, specified tactical and technical requirements and technical specifications.

After collecting statistical data, we proceed to the development of tactical and technical requirements. This stage will be carried out on the basis of the analysis of statistical materials, complementing the specified tactical and technical requirements of the designed aircraft. The RX4E was taken as the prototype.

Designed airplane with a capacity of up to 4 passenger and a range of L=300 km, the runway length $L_{TO} = 380\ m$ is assigned, then the cruising altitude $H_{cr} = 1000\ m$, and cruising speed $V_{cr} = 200\ km/h$.

The tactical and technical requirements are listed in table 1.2.

Table 1.1 – Tactical and Technical Requirements of Projected Aircraft

L(*with max* m_f) *km*	n_{crew}	L_{TO} m	V_{cr} km/h	H_{cr} m	H_{max} m	$V_{y\,H=0}$ *m/s*
300	4	380	200	1000	1500	5

1.3 General Layout

Selection and justification of the scheme of the aircraft
Layout form: Orthodox
Wing layout: upper single wing
Tail layout: T-shaped tail layout
Landing gear: front three-point non retractable
Airfoil: NACA 23012
Power: Tesla 4680 Cell

According to statistical data, the main geometrical parameters of the projected aircraft are determined such as λ, η , χ_w , b, fuselage parameters, horizontal tail, vertical tail, and listed in the table 1.3.

Table 1.3 – The basic main parameters of the aircraft

λ	η	χ_w	b	L_f	H_f	$S_{\bar{HT}}$
15.19	1.5	15	0.889	8.4	1.8	0.3
$S_{\bar{VT}}$	λ_{HT}	λ_{VT}	η_{HT}	η_{VT}	χ_{HT}	χ_{VT}
0.2	3.5	2.5	2	2	15	15

According to the preliminary geometric parameters, the scheme of the projected electric aircraft is developed. (Figure 1.9)

name	Diameter *length(mm)	weight (g)	energy density(Wh/kg)	Capacity (Ah)	Unit voltage(V)
Tesla 4680	46*80	355	300	26.136	3.7

2 Parameter calculation

Weight calculation
Center of gravity analysis
Flight performance analysis

In this module, I will add the quotes that best fit my research topic to the table, and I leave the rest out.

3 Aerodynamic analysis

Wing airflow analysis

Next is the analysis of wing airflow. In this section, based on the previously determined data, the creation of the wing model was completed in CATIA, together with the creation of flow field boundaries that are much larger than the wing model. The purpose is to simulate real environmental conditions more realistically and make the simulation results closer to reality.

Then import the model into ANSYS. ICEM, define various parameters, and divide the shell mesh. After dividing the mesh, export it and check the mesh quality. The mesh quality is good, and the results are shown in the figure. The number of grids is approximately 700000.

Then import the file into Fluent, set calculation parameters, and perform simulation calculations.

This is the calculation of wing body combination in ideal gas, where the fluid velocity is 0.5Ma. The angle of attack ranges from - 4 ° to 20 °. The lift coefficient, drag coefficient, pitching moment coefficient CL, Cd, MZ and pressure nephogram under different angles of attack are calculated every 2 degrees, 13 times in total.

Based on the obtained data, use Excel software to draw a relationship curve and calculate the relevant aerodynamic characteristic parameters of the wing body combination based on the curve.

4 Economic section

4.1 Calculation of aircraft and engine operation cost and transportation cost

of one cargo ton per kilometer

The operating costs of this type of aircraft per 1:00 flight (flight hour) consist of direct and indirect (airport) expenses (formula (4.1)):

4.2 Conclusion

In this section, we calculated the costs of operating the aircraft and the engine at $ 35.67 / h and the cost of transporting one ton of cargo per kilometer, and determined the price of the ticket, which amounted to $ 645. The indirect costs for one hour of flight are $ 1371.9 / h.

5 Special list

Firstly, it is environmentally friendly,

electric aircraft uses batteries or other clean energy as a power source, which does not produce direct emissions and exhaust gases, reducing environmental pollution. Compared with traditional fuel aircraft, electric aircraft have zero emissions, which can help improve air quality and reduce carbon emissions.

secondly, it is energy saving,

The electric system of electric aircraft has high energy utilization rate, can convert electrical energy into power output, and has lower energy consumption than fuel aircraft. In addition, electric aircraft has potential in energy recovery and reuse, such as through braking energy recovery systems, to further improve energy efficiency.

then it is Sustainability

Compared with traditional fuel aircraft, the mechanical structure of electric aircraft is relatively simple, which reduces the complexity of some transmission systems and lubrication systems. In addition, the electric system of an electric aircraft has relatively low maintenance costs due to fewer parts and a simpler structure, and because it has fewer mechanical parts, it is more reliable.

And finally, it is Noise Reduction

Noise from conventional fuel-fueled aircraft is a major problem in urban and community environments. However, electric aircraft can significantly reduce noise pollution, reduce disturbance to surrounding residents, and improve the living environment due to the low noise generated by the motor. As a new technology, electric aircraft has many advantages, but it also has some disadvantages. I will still introduce it from four aspects.

Limited range: Current battery technology for electric aircraft limits their range. Electric aircraft require more frequent recharging, or replacement of batteries than traditional fuel-powered aircraft, limiting the time and range of their flight. That's a challenge for long-haul flights and commercial flights.

Lack of charging infrastructure: Electric, aircraft require charging infrastructure o power them. However, charging, infrastructure is currently relatively limited globally, especially where it is needed at airports and airlines. lack of charging facilities can pose challenges to the operation and development of electric aircraft.

Limited flight performance: Due to the weight and volume limitations of batteries. Electric aircraft have relatively low payload capacity and speed. This limits the use of electric aircraft for certain applications, such as long-distance commercial flights or the need to transport large quantities of cargo.

long charging time: Electric aircraft batterie stake a long time to charge, of ten taking hours. This requires longer downtime and planned flight time compared to traditional fuel aircraft, which poses challenges to flight operations and scheduling. It should be noted that with the continuous development and innovation of technology, some shortcomings of electric aircraft may be gradually reduced or solved.

Long charging time: Electric aircraft batteries take a long time to charge, often take hours. This requires longer downtime and planned flight time compared to traditional fuel aircraft, which poses challenges to flight operations and scheduling.

It should be noted that with the continuous development and innovation of technology, some shortcomings of electric aircraft may be gradually reduced or solved.

General conclusions

Learning the Scientific And Research, to be exact, is to be able to write good, qualified and excellent papers. By doing my work, I can understand each process of science and research step by step, and be familiar with what tasks need to be done in these processes, and be familiar with the possible problems and solutions, as well as the ways to realize these processes.

During this process, I tried to search for some materials that I was interested in or needed in my research through a variety of ways, including some free e-book websites, official aircraft websites, and various comprehensive journal websites. Then the collected data are sorted out and summarized into tables or summarize the characteristics.

After doing this, I have a better understanding of scientific and research, especially in the area of data collection. I have learned a lot about the methods of data acquisition, and have tried them myself. Secondly, after collecting the data, I have purposefully sorted and summarized them for later using.

As a result of the implementation of the master's degree project by various research methods, the following results were obtained:

1 The main parameters and characteristics of analog aircraft are analyzed

2. The takeoff mass of the projected aircraft was determined in three approximations and amounted to 1200 kg. The masses of the main components of the aircraft, depending on the takeoff mass of the aircraft, were calculated wing mass - 131 kg; fuselage mass - 146 kg; tail unit mass - 84 kg; power plant mass - 200 kg; landing gear mass - 80kg; and payload - 320 kg.

3 The basic geometric parameters of the projected jet trainer aircraft have been determined: $S = 12$ m^2,L_{wing}= 13.5 m, L_{fus}= 8.4 m, $\lambda = 15.19$, $\eta = 1.5$,b= 0.889 m. the flight characteristics: L=300 km, V_{cruis}=200 km/h. theoptimal wing load po=100 daN/m^2

4 The center of gravity of the projected aircraft has been calculated. The position of the center of mass is at 0,287 of b_A.

5 The values of the coefficients of the lifting force are determined. Polar graph was built during cruise flight, takeoff and landing. It was determined that the maximum aerodynamic quality is 10.03 units.

6 The scheme of wing front spar with its components was built. the shape. Location and material of its components were determined according to its strength and force condition.

7 The estimated cost of the projected aircraft for the design bureau was calculated, which to \$8.7 million. The estimated cost of manufacturing the aircraft was \$4.45 million.

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APPENDIX

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