National Technical University of Ukraine
“Igor Sikorsky Kyiv Polytechnic Institute”
Education and Research Institute of Aerospace Technologies
Department of Aircraft and Aeronautical Engineering

Admitted to defense
Performing duties of the Department head
__________ Oleksandr BONDARENKO
(signature) (initials, last name)
"____" __________ 2023 year

DEGREE PROJECT
to obtain a bachelor's degree

under the educational and professional program "Airplanes and Helicopters"
specialty 134 "Aviation and Aeronautical and space engineering"

on the topic: _______________”Twin-engine Utility Aircraft”___________________

Performed by: student of ___4th___ course, group ____AL-94___
(group code)

___________________________**Park Seungyon**_____________________________
(surname, first title, patronymic) (signature)

supervisor ____assistant lecturer, Povarov Serhii Anatoliiovych___________________
(position, academic title, scientific degree, surname and initials) (signature)

Reviewer ____
(position, scientific degree, academic rank, surname and initials) (signature)

I certify that this diploma project does not contain any borrowings from the works of other authors without appropriate references.

Student _________________
(signature)

Kyiv 2023

National Technical University of Ukraine
“Igor Sikorsky Kyiv Polytechnic Institute”
Education and Research Institute of Aerospace Technologies
Department of Aircraft and Aeronautical Engineering

Level of higher education - first (bachelor's)
Specialty – 134 "Aviation and Aeronautical and space technology"
Educational and professional program "Airplanes and helicopters"

APPROVED
Performing duties of the Department head
__________ Oleksandr BONDARENKO
(signature) (initials, last name)
"___" __________ 2023 year

TASK
for the diploma project of the student

Park Seungyon
(Surname, first name, patronymic)

1 Project topic ________”Twin-engine Utility Aircraft”____________________ ,
project supervisor ____Povarov Serhii Anatoliiovych, assistant lecturer_____ ,
(Surname, first name, patronymic, academic degree, academic title)
approved by the university order dated "___"_________ 2023, No._______

2 Deadline for submitting project by student "_6_" __June__ 2023

3 Initial data for project

3.1 Useful load $m_{UL} = 2000$ kg
3.2 Cruising speed $V_{CR} = 550$ km/h
3.3 Ceiling H = 9000 m
3.4 Ferry range R = 3500 km

4 Content of the settlement and explanatory note

4.1 Problem statement.
4.2 Analysis of statistical data.
4.3 Determination of geometric parameters of the aircraft.
4.4 Aerodynamic simulations.
4.5 Fuselage general layout design.
4.6 Definition of the wing loads and wing structure design.

5 List of graphic (illustrative) material (indicating mandatory drafters, posters, presentations, etc.):

5.1 Overview of Same-class Aircraft
5.2 Aircraft General View
5.2 Aircraft Aerodynamics
5.3 Fuselage Layout
5.4 Wing Loads and Structural Layout.

6. Date of issue of the assignment ______________________________

CALENDAR PLAN

№	The stage titles of the diploma project completion	The fulfilment term of project stages	Note
1	*Selection and analysis of literature*	*until 15.03.2023*	
2	*Analysis of the design methodology*	*until 29.03.2023*	
3	*Analysis of statistical data*	*until 12.04.2023*	
4	*Selection of general layout parameters and determination of geometric parameters of the aircraft*	*until 20.04.2023*	
5	*Aerodynamic simulations*	*until 04.30.2023*	
6	*Fuselage general layout design*	*until 05.05.2023*	
7	*Definition of the wing loads and wing structure design*	*until 15.05.2023*	
8	*Calculation of the main flight characteristics of the aircraft*	*until 27.05.2023*	
9	*Designing an explanatory note and graphic materials*	*until 07.06.2023*	
10	*Check for plagiarism*	*until 10.06.2023*	
11	*Defence*	*from 12.06.2023 to 16.06.2023*	

Student ____________ _Seungyon PARK_____
(signature) (initials, last name)

Project supervisor ____________ __Serhii POVAROV___
(signature) (initials, last name)

Explanatory note to the diploma project on the

topic: _______"Twin-engine Utility Aircraft"________

Kyiv 2023

Abstract

This paper presents a description of the process of conceptual design and creation of a technical proposal for a new twin-engine utility aircraft that will be effectively used for the transportation of passengers, their luggage and/or small cargo to the regional range (up to 3,500 km).

The work starts from an overview of the same class aircraft, were the statistical information about their flight characteristics and design features were collected. All collected statistical data were analyzed, and so the key technical and operational parameters of the future aircraft were determined. The project specifications for the aircraft were compiled as the result.

The next stages of the work were the calculations of mass and geometric parameters of the aircraft and a creation of the aircraft sketch basing on it.

The aerodynamic simulations based on numerical methods gave the general aerodynamic characteristics for the aircraft project. The calculation of the necessary power-to-weight ratio allowed selecting the engine for the aircraft powerplant. Also the calculation of the aircraft chassis, the layout of the cockpit and the passenger compartment have been completed.

Estimated values of the main flight characteristics for the aircraft project were obtained. Also, preliminary stress calculations of the aircraft main units were performed.

The paper consists of 74 pages.

Key words: *twin-engine multipurpose aircraft, aerodynamics, aircraft design, aerodynamic modeling, aircraft design.*

Анотація

В даній роботі представлене описання процесу концептуального проектування та створення технічної пропозиції на новий двомоторний багатоцільовий літак, який ефективно використовуватиметься для перевезень пасажирів, їх багажу та/або малогабаритних вантажів на регіональному рівні (на відстані до 3500 км).

Проведено огляд літаків-аналогів подібного класу, зібрана статистична інформація по їх льотно-технічних характеристиках та особливостях конструкції. Проведено аналіз зібраної статистичної інформації, визначено ключові технічні та експлуатаційні параметри майбутнього літака та складено технічне завдання на проект.

Виконано розрахунки основних масових та геометричних параметрів літака, створено попередній ескіз проекту, створено розрахункову модель та проведені аеродинамічні моделювання за допомогою чисельних методів. Розраховано потрібну енергооснащеність літака та підібрано двигун для силової установки. Проведено розрахунок шасі літака. Виконано компонування кабіни пілотів та пасажирського салону літака. Отримані розрахункові значення основних льотних характеристик літака. Також, виконано загальні силові розрахунки основних агрегатів літака.

Пояснювальна записка до дипломного проекту складається з 74 сторінок.

Ключові слова: *двомоторний багатоцільовий літак, аеродинаміка, проектування літака, аеродинамічне моделювання, проект літака.*

Contents

NOMENCLATURE

MTOW (m_0)	maximum take-off weight;
A_W	wing area;
λ_W	wing aspect ratio;
η_W	wing taper ratio;
$\chi_{0,25}$	wing sweep angle;
ψ	wing dihedral angle;
λ_F	fuselage aspect ratio;
D^e_{FUS}	fuselage equivalent diameter;
l_F	length of the fuselage;
λ_F	fuselage aspect ratio;
K_{STAB}	static momentum coefficient of the stabilizer;
L_{STAB}	lever arm of the stabilizer;
K_{FIN}	the static momentum coefficient of the fin;
L_{FIN}	lever arm of the fin;
AoA	angle of attack;
CL	lift coefficient;
CD	drag coefficient;
CL/CD	lift to drag ratio.

INTRODUCTION

Twin-engine utility aircraft play a vital role in the aviation industry, providing a diverse range of capabilities, these aircraft are essential for transporting both passengers and cargo, operating in remote or challenging environments, and supporting various industries, including emergency response. Additionally, twin-engine aircraft offer increased safety and reliability due to redundancy in their engine system. Therefore, the continued development and improvement of twin-engine utility aircraft is crucial for the growth and sustainability of the aviation industry.

The term “utility category aircraft” refers to aircraft that have a seating capacity of nine or less, without pilot seats, a maximum authorized take-off weight of 5,700 kg or less, and designed for performing acrobatic maneuvers within certain limitations.

Twin-engine utility aircraft are highly versatile and can be used for a variety of missions, including cargo transport, medical evacuation, and passenger flights. They are designed to take off and land in shorter runways and in smaller airports, which makes them ideal for accessing remote or challenging locations. In addition, they can be easily configured for different types of missions, such as adding cargo space or medical equipment, making them highly flexible.

Also twin-engine aircraft are known for their reliability. It makes them a popular choice for operators who prioritize safety and dependability. In addition, many twin-engine utility aircraft have a good safety records and are considered to be among the safest aircraft in their class.

Many twin-engine utility aircraft have spacious cabins and comfortable seating, making them an ideal choice for longer trips. They offer a quieter and smoother ride than many jet aircraft, thanks to their slower speed and advanced noise and vibration reduction technology. This makes them a popular choice for operators who want to provide a comfortable and enjoyable experience for their passengers.

Nevertheless twin-engine utility aircraft are generally slower than comparable jet aircraft, which can limit their range and make them less competitive for some missions. While twin-engine turboprops are still capable of flying long distances, they may require more time to complete a mission than a comparable jet aircraft.

Also twin-engine utility aircraft require regular maintenance and inspections, which can be time-consuming and costly. This is because they have complex systems that need to be maintained and inspected regularly to ensure their safety and reliability.

It must be added that twin-engine utility aircraft are generally not well-suited for flying in severe weather conditions, such as icing or turbulence. This can limit their availability for some missions. Operators may need to carefully consider weather conditions and plan their missions accordingly.

Overall, twin-engine utility aircraft are versatile, efficient, and reliable aircraft that are well-suited for a variety of missions. They offer a number of advantages, such as versatility, fuel efficiency, reliability, and comfort. However, they also have some limitations, such as speed, payload capacity, maintenance requirements, and weather limitations, which operators should carefully consider when choosing an aircraft for a particular mission.

1 OVERVIEW OF TWIN-ENGINE UTILITY AIRCRAFT

1.1 Beechcraft Super King Air.

1.1.1 History of creation.

In the early 1970s Beechcraft began development of a new version of its popular King Air twin-turboprop aircraft. The company's goal was to create an upgraded version that would provide better performance, improved comfort, and increased payload capacity. The resulting aircraft, the Beechcraft Super King Air, was introduced in 1974 as the Model 200T. it was based on the King Air 200, which had been introduced two years earlier, but featured a number of upgrades and enhancements. One of the key improvements was the installation of more powerful Pratt & Whitney PT6A-41 engines, which provided a 5% increase in power and improved fuel efficiency. The Super King Air also had a higher maximum takeoff weight, allowing it to carry more payload and fuel. Other upgrades included a redesigned interior with improved soundproofing and climate control, as well as upgrades avionics and navigation equipment. The Super King Air was also equipped with a new wing design that reduced drag and improved handling characteristics.

Fig. 1.1.1 Beechcraft Super King Air 250.

The Super King Air quickly became a popular choice among corporate and government customers, as well as air ambulance and air cargo operators. In the years that followed, Beechcraft continued to improve the aircraft, introducing new models and upgrades to keep it competitive in the marketplace.

In 1983, the Super King Air 300 was introduced, featuring more powerful engines and a longer range. in 1990, the Super King Air 350 was introduced, featuring an even larger cabin and improved avionics. Over the years, the Super King Air has undergone numerous upgrades and improvements, including the introduction of the Super King Air 360, which features advanced avionics and other modern amenities.

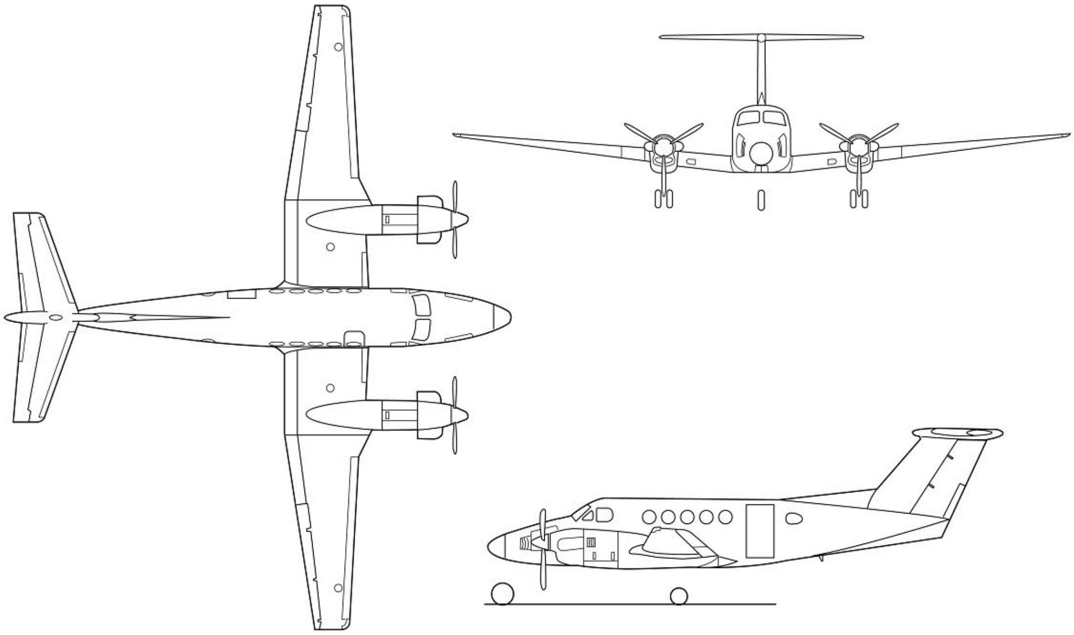


Fig. 1.1.2 Beechcraft Super King Air 250 – 3 view plans.

Today, the Super King Air remains a popular choice for a wide range of customers, for its versatility, reliability, and performance capabilities. It is one of the most successful aircraft in Beechcraft's long history and has played a significant role in shaping the turboprop aircraft market.

1.1.2 Operating experience.

Business and personal aviation: Many corporations and high-net-worth individuals use the Super Kina Air for executive travel. For example, in 2017, Walmart purchased four Super King Air 300ERs for executive transportation and emergency response missions.

Air ambulance services: The Super King Air is often used for air ambulance services, as it can be equipped with medical equipment and transport patients to hospitals quickly and efficiently. For example, in the UK, the East Anglian Air Ambulance service uses a Super King Air B200 for its operations.

Government and military applications: The Super King Air is used by many governments and militaries around the world for various missions. For example, the US Army uses the C-12 Huron, a military variant of the Super King Air, for personnel transport, intelligence gathering , and other missions.

Surveillance and reconnaissance: The Super King Air is also used for surveillance and reconnaissance missions, as it can be equipped with various sensors and cameras. For example, in 2018, the Australian government purchased three Super King Air 350s for maritime surveillance operations.

Cargo transport: The Super King Air is used for cargo transport, as it has a large cargo door and can carry up to 900 kg of cargo. For example, in 2019, FedEx announced that it would be adding 50 Super Kina Air 350s to its feeder aircraft fleet for package delivery.

1.2 Cessna 441 Conquest 2.

1.2.1 History of creation.

In the mid-1970s, Cessna Aircraft Company recognized a growing demand for a larger, more capable twin-engine turboprop aircraft to serve as a corporate and executive transport, as well as a regional airliner. Cessna began development of a new aircraft based on the existing Cessna 404 Titan, which was a successful twin-engine piston aircraft.

The new aircraft, designated the Cessna 441 conquest 2, featured a redesigned fuselage with a larger cabin and improved soundproofing, as well as more powerful Pratt & Whitney Canada PT6A-112 turboprop engines. The aircraft also had a new wing design with increased fuel capacity, which allowed for a range of up to 3,333 km.

The first prototype of the Cessna 441 Conquest 2 made its maiden flight on August 1977. Over the course of the next year, the prototype underwent a comprehensive testing program, including flight tests and ground tests, to ensure that the aircraft met all certification requirements.

In December 1977, the Cessna 441 Conquest 2 was certified by the FAA and the first production aircraft was delivered to a customer. The aircraft proved to be popular with corporate and executive customers, as well as regional airlines and charter operators.

Fig. 1.2.1 Cessna 441 Conquest 2.

Over the years, various improvements were made to the Cessna 441 Conquest 2, including the addition of winglets to reduce drag and increase fuel efficiency, and the introduction of a glass cockpit with digital displays. These improvements allowed the aircraft to remain competitive in the market, despite the introduction of newer, more advanced aircraft.

Production of the Cessna 441 Conquest 2 ended in 1986, with a total of 362 aircraft built. Today, many examples of the aircraft remain in service around the world, serving a variety of roles in the corporate and regional aviation markets.

1.2.2 Operating experience.

The Cessna 441 Conquest 2 has been widely used in a variety of operational roles, including as a corporate and executive transport, a regional airliner, and a cargo aircraft.

Corporate and Executive Transport: The Cessna 441 Conquest 2 has proven to be a popular choice for corporate and executive transport due to its spacious cabin, comfortable seating, and long-range capabilities. Many companies have used the aircraft to transport executives and their teams to business meetings and events across the country and around the world.

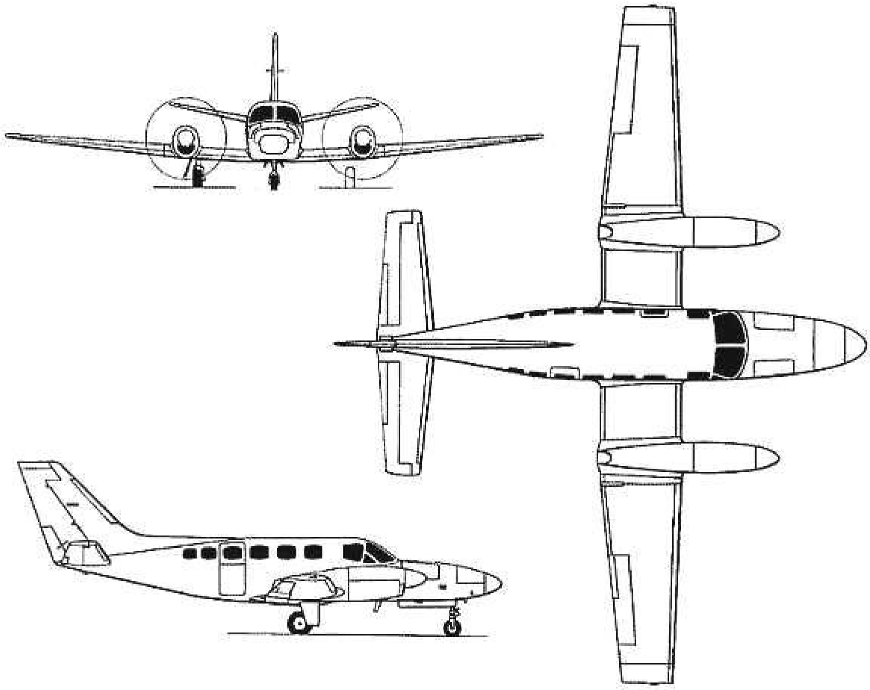


Fig. 1.2.2 Cessna 441 Conquest 2 – 3 view plans.

Regional Airliner: The Cessna 441 Conquest 2 has also been used by regional airlines for short-haul flights. With a range of up to 3,333 km, the aircraft can easily cover many regional routes. The aircraft’s pressurized cabin and comfortable seating also make it a popular choice for regional airline passengers.

Cargo Aircraft: The Cessna 441 Conquest 2 has been used as a cargo aircraft, particularly for short-haul cargo missions. The aircraft’s spacious cargo compartment and high-wing design make it well-suited for cargo transport. For example. FedEx used the aircraft to transport small packages and other cargo on short-haul routes.

In addition to these roles, the Cessna 441 Conquest 2 has also been used for other missions, such as air ambulance, military training, and surveillance. The aircraft’s reliability and versatility have made it a popular choice for many different types of operations. Overall, the Cessna 441 Conquest 2 has a long and successful operational history, and remains a popular choice for a. variety of missions. Many examples of the aircraft remain in service today, and are likely to continue to serve their operators well for many years to come.

1.3 Tecnam P2012 Traveller

1.3.1 History of creation

In 2012, Tecnam decided to develop a new aircraft that would address the needs of the general aviation market, which was looking for a modern, reliable, and cost-effective aircraft that could operate on short routes with a small number of passengers. Tecnam saw an opportunity to fill this gap in the market with an innovative aircraft that would incorporate the latest technology and design features.

Fig. 1.3.1 Tecnam P2012 Traveller.

The development of the P2012 Traveller began with a team of engineers form Tecnam and several other leading aerospace companies, who collaborated on the design and development of the aircraft. the team focused on creating an airplane that would be highly versatile, with a modular interior that could be easily configured to meet the needs of different operators.

The P2012 Traveller features a modern, all-metal airframe and is powered by two Lycoming TEO-540-C1A engine, which provides improved visibility and stability, and can seat up to 11 passengers in a spacious and comfortable cabin.

During the development process, Tecnam worked closely with aviation authorities to ensure that the P2012 Traveller would meet the strict safety and performance standards, required for certification. The aircraft underwent rigorous testing and evaluation, including extensive flight testing, before receiving certification form the European Aviation Safety Agency (EASA) in 2018 and the Federal Aviation Administration (FAA) in 2019.

Since then, the P2012 Traveller has been widely adopted by airlines, charter companies, and private individuals around the world, who appreciate its versatility, reliability, and affordability. The aircraft is used for a wide range of application, including commercial air transport, cargo operations, and special missions such as medical evacuation and aerial surveying.

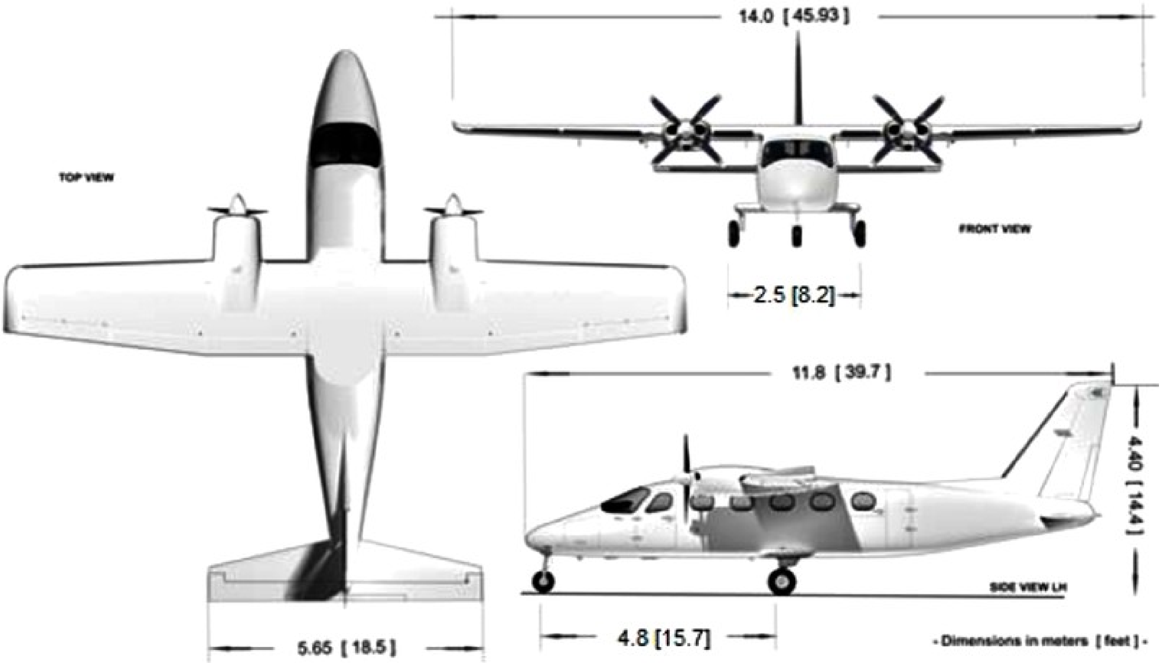


Fig. 1.3.2 Tecnam P2012 Traveller – 3 view plans.

1.3.2 Operating experience.

Passenger Transport: The P2012 Traveller has been used for passenger transport by a number of airlines and charter companies around the world. It can seat up to 11 passengers in a spacious and comfortable cabin, making it ideal for short-to-medium-haul flights. Its twin-engine design provides added safety and redundancy, while its advanced avionics and systems ensure reliable and efficient operation.

Cargo Operations: the P2012 Traveller's modular interior design allows it to be easily configured for cargo operations, with a large cargo door and ample space for cargo containers. It can transport up to 500 kg of cargo over a range of up to 950 nautical miles, making it ideal for small-package delivery and other cargo operations.

Special Missions: The P2012 Traveller has also been used for a variety of special missions, including medical evacuation, aerial surveying, and military operations. Its versatile interior design allows it to be easily configured for different mission requirements, while its advanced systems and technology provide the reliability and performance needed for critical missions.

Maintenance and Support: Tecnam provides comprehensive maintenance and support services for the P2012 Traveller, including technical assistance, spare parts, and maintenance training. The company has a global network of authorized service centers and training facilities, ensuring that operators have access to the resources they need to keep their aircraft flying safely and efficiently.

Customer Feedback: Operators of the P2012 Traveller have generally been very positive about the aircraft's performance and reliability. They have praised its versatility, comfort, and efficiency, and have noted its ease of maintenance and low operating cost. Overall, the P2012 Traveller has demonstrated strong operational experience in a variety of applications, and is well-regarded by operators and pilots around the world.

1.4 Antonov An-28.

1.4.1 History of creation.

The Antonov An-28 is a light twin-engine turboprop aircraft that was designed and built by the Ukraine aircraft manufacturer Antonov. The history of creation dates back to the late 1960s when the Soviet Union began looking for a replacement for its aging fleet of An-2 biplanes.

In response to this need, Antonov started developing a new aircraft that would be more efficient, faster, and have a higher payload capacity then the An-2. The design process took several years, and the first prototype of the An-28 took in 1969.

The An-28 was designed to operate in remote areas with limited infrastructure, and its roust construction and high wing configuration made it well-suited for use in harsh environments. The aircraft was also designed to be easy to maintain and operated, making it a popular choice for regional airlines and air charter companies.

The An-28 entered service with Aeroflot, the Soviet Union's national airline , in 1978, and quickly became a popular aircraft for regional flights. The aircraft was also exported to other countries, including Cuba, Angola, and Mongolia.

Fig. 1.4.1 Antonov An-28.

Over the years, the An-28 has undergone several upgrades and improvements, including the installation of more powerful engines and advanced avionics. Today, the An-28 continues to be used by airlines and air charter companies around the world, and its reputation as a reliable and versatile aircraft remains strong.

1.4.2 Operating experience.

The An-28 has been primarily used in remote and rugged areas due to its short takeoff and landing capabilities and its ability to operate in a wide range of temperatures and weather conditions. It has been used for various purpose, including passenger and cargo transportation, medevac missions, aerial surveillance, and environmental monitoring.

Regional Transport: the An-28 is primarily used for regional transport in remote areas with limited infrastructure. It is often used to connect small towns and villages with larger cities and towns, and to transport goods and supplies to remote areas.

Popular in Russia and CIS countries: The An-28 is particularly popular in Russia and Cis countries, where it is used for passenger and cargo transport in remote regions. It is also used for arial surveillance, search and rescue, and other special missions.

The An-28 has had a few incidents and accidents over the years, including the 2010 crash in Siberia. However, it is important to note that the vast majority of An-28 flights have been completed safely, and its overall safety record is generally considered to be good.

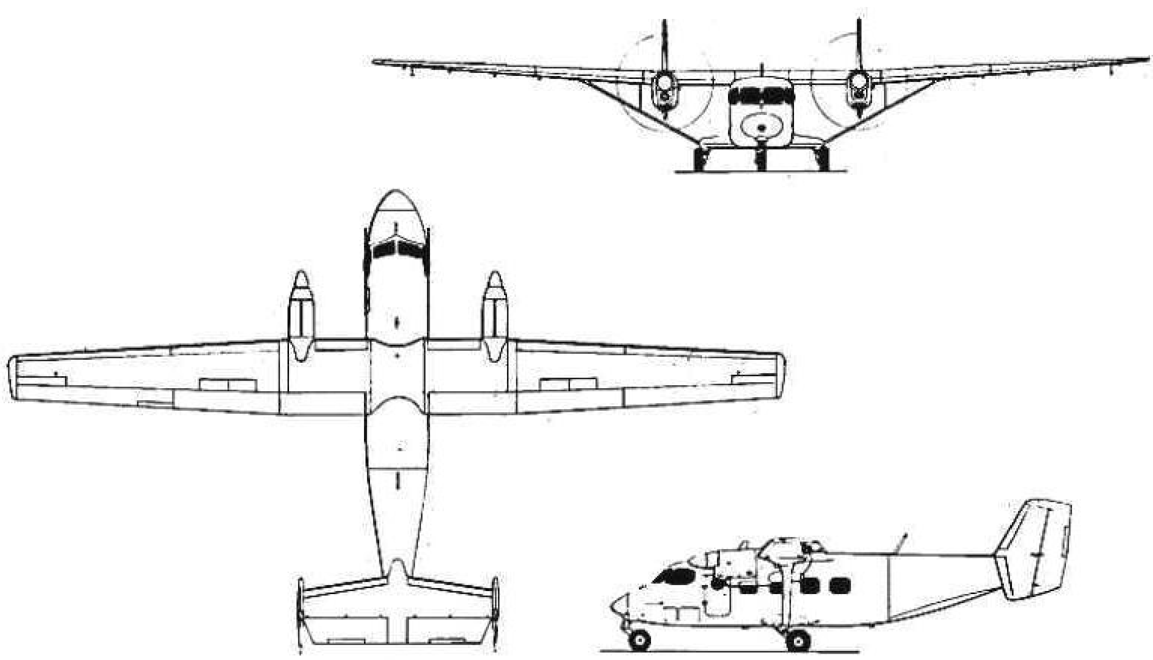


Fig. 1.4.2 Antonov An-28 – 3 view plans.

In recent years, there has been renewed interest in the An-28 due to its affordability, ease to maintenance, and its ability to operate in remote areas. Some operators have been even modified the aircraft to include modern avionics and other upgrades to extend its operational lifespan.

Overall, the Antonov An-28 has been a reliable and versatile aircraft, well-suited for use in remote and rugged areas. While it has had a few incidents and accidents over the years, its overall operational record is positive, and it continues to be used by various operators around the world.

1.5 Mitsubishi MU-2.

1.5.1 History of creation.

In the 1950s, the Japanese government issued a requirement for a light transport aircraft to replace aging piston-engine aircraft used by the Japan Air Self-Defense Force. Mitsubishi Heavy Industry (MHI) responded with a design for a twin-engine turboprop aircraft, which became known as the MU-2.

Fig. 1.5.1 Mitsubishi MU-2.

Development of the MU-2 began in 1956, and the first prototype, designated the MU-2A, flew for the first time on 1963. The MU-2A was powered by two Garrett TPE331-1 turboprop engines, each producing 665 horsepower, and had a maximum takeoff weight of 3,450 kg.

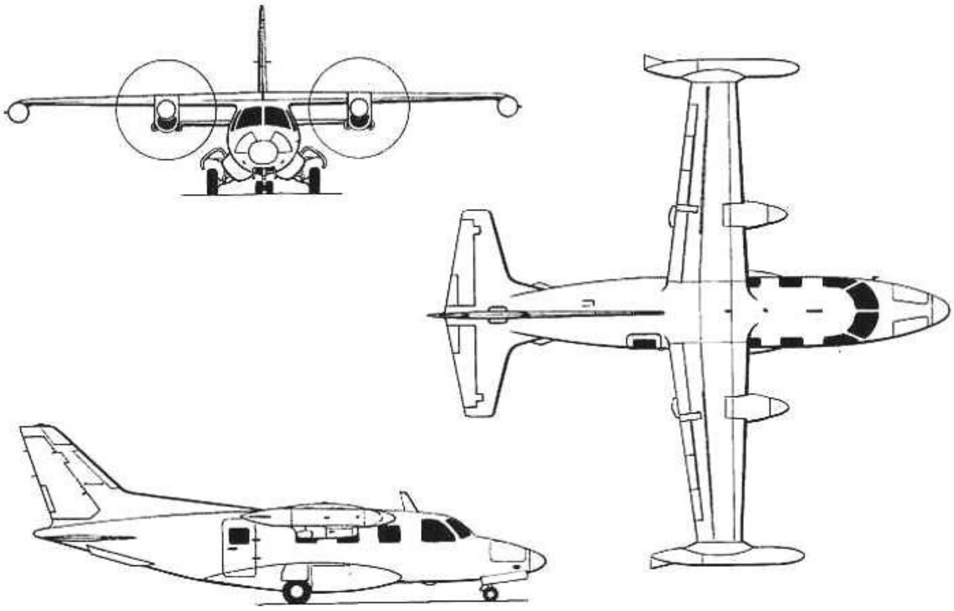


Fig. 1.5.2 Mitsubishi MU-2 – 3 view plans.

The MU-28, which was the production version of the aircraft, was introduced in 1965. It featured more powerful TPE331-5 engines, each producing 715 horsepower, and an increased maximum takeoff weight of 4,400 kg. The MU-2B also had an increased fuel capacity and longer range than the MU-2A.

The MU-2 proved to be a popular aircraft, particularly in Japan and the United States, where it was used for a variety of purposes, including passenger transport, cargo transport, and air ambulance services. However, the MU-2 also gained a reputation for being a difficult aircraft to fly, particularly in adverse weather conditions, due to its high wing loading and low airspeeds.

There have been a number of high-profile accidents involving the MU-2 over the years, including several incidents where the aircraft stalled and crashed during takeoff or landing. The safety record of the MU-2 led to increased security from regulatory authorities, and MHI implemented a number of safety enhancements over the years to address some of the issues with the aircraft.

Despite its reputation, the MU-2 remains in service with a number of operators around the world, and MHI continues to provide support and maintenance services for the aircraft. the MU-2 has also been used by various militaries for training, reconnaissance, and transport missions.

1.5.2 Operating experience.

The Mitsubishi MU-2 has been used in a variety of roles, including passenger transport, cargo transport, air ambulance services, and military operations.

Passenger Transport: the MU-2 has been used extensively as a regional airliner and corporate transport aircraft. it has been operated by numerous airlines and charter companies around the world, including Japan, the US, Australia, and Europe. The MU-2's high speed and short takeoff and landing capabilities have made it a popular choice for operators who need to serve smaller airports or remote locations.

Cargo Transport: The MU-2 has also been used for cargo transport, particularly in remote areas where access by road or larger aircraft is limited. The aircraft's large cargo door and high weight capacity make it well-suited for carrying cargo such as freight, supplies, or medical equipment.

Air Ambulance: the MU-2 has been used as an air ambulance aircraft due to its ability to operate from short runways and its high speed, which allows for rapid transportation of critically ill patients. The aircraft can be configured with medical equipment and staff to provide in-flight care to patients.

Military Operations: the Mu-2 has been used by various militaries around the world for a variety of roles, including training, reconnaissance, and transport missions. The aircraft's short takeoff and landing capabilities and high speed make it well-suited for military operations in remote or austere environments.

In addition to its operational roles, the MU-2 has also been used in various aviation research programs, including studies of icing conditions and wake turbulence. The aircraft's unique design and performance characteristics have made it a popular choice for research and testing purposes.

1.6 Piaggio P.180 Avanti.

1.6.1 History of creation.

The Piaggio P.180 Avanti is a twin-engine turboprop aircraft that was designed and manufactured by the Italian company Piaggio Aero. The development of the aircraft began in the late 1970s, and the first prototype flew on 1986.

The idea for the P.180 Avanti came from the Italian entrepreneur Rinaldo Piaggio, who founded Piaggio Aero in 1884 as a manufacturer of locomotives and rolling stock. After World War 2, the company shifted its focus to aircraft production, and in the 1960s it began to explore the idea of building a new type of aircraft that could offer superior performance and comfort compared to existing models.

Piaggio Aero formed a team of engineers and designers to work on the P.180 Avanti project, which was based on a unique configuration featuring three lifting surfaces a pair of forward-mounted winglet. This layout allowed for a larger wing area and more efficient lift production, resulting in better performance and fuel efficiency.

The P.180 Avanti was also notable for its use of innovative materials and construction techniques, including a composite fuselage and wing spars, as well as advanced avionics and flight control systems. The aircraft was designed to be operated by a single pilot and could carry up to nine passengers in a spacious and comfortable cabin.

After several years of development and testing, the P.180 Avanti received certification from the European Aviation Safety Agency in 1990, and it entered service later that year. Since then Piaggio Aero has continues to refine and improve the design of the P.180 Avanti, releasing several updated version of the aircraft with enhanced performance, range, and comfort features.

Fig. 1.6.1 Piaggio P.180 Avanti.

Operating experience

The P.180 Avanti has been in production since 1990, and over 220 units have been built to date. The aircraft has been operated by a variety of organizations, including corporations, private individuals, charter companies, and government agencies.

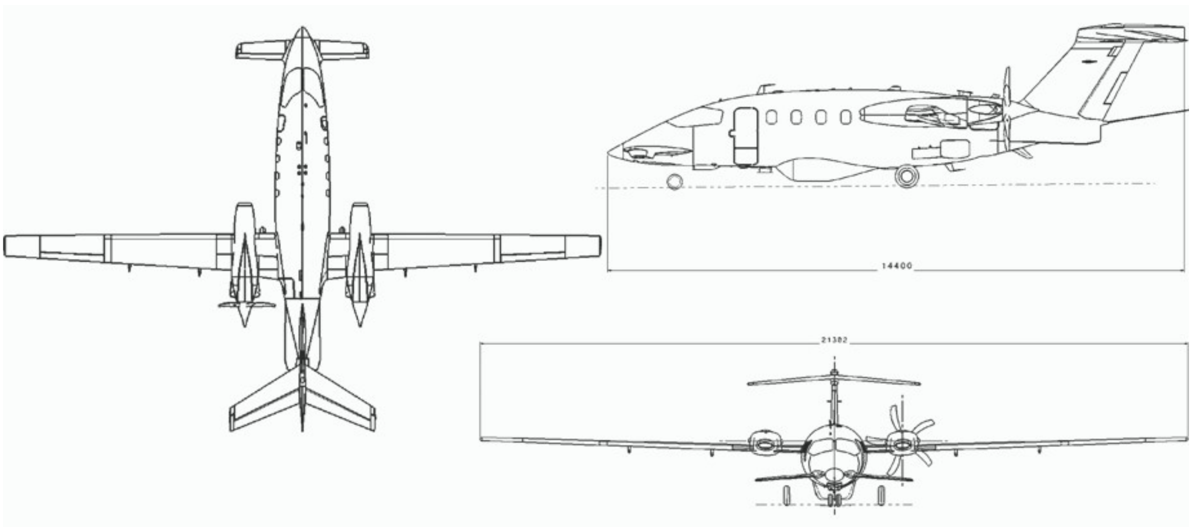


Fig. 1.6.2 Piaggio P.180 Avanti – 3 view plans.

The aircraft's speed and efficiency have been major selling points for the P.180 Avanti. The aircraft's maximum cruising speed of 460 mph is faster than most turboprop aircraft and comparable to many light jets, while its fuel efficiency is significantly better than most jet in its class.

The P.180 Avanti's unique design, featuring a forward wing and rear -mounted winglets, provides a number of operational benefits. The aircraft is able to fly at higher altitudes than most turboprops, up to 12.5 km, and can maintain its speed and range at high altitudes more efficiently than other aircraft.

The aircraft's spacious and comfortable cabin has also been a selling point for the P.180 Avanti. The cabin can accommodate up to nine passengers and has a stans-up height of 1.75 m, making it one of the largest cabins in its class. The cabin is also well-appointed, with a variety of amenities including a refreshment center, fully enclosed lavatory, and entertainment system.

The P.180 Avanti has been used for a variety of missions, including executive and corporate travel, air ambulance and medical transport, and government and military operations. The aircraft's speed, range, and short takeoff and landing capabilities make it well-suited for a variety of missions and operating environments.

In terms of maintenance and reliability, the P.180 Avanti has a good track record. The aircraft's composite construction and advanced avionic requires specialized maintenance procedures, but overall the aircraft is considered to be reliable and efficient to operate.

1.7 Technical specifications of the reviewed aircraft.

The technical specifications of the twin-engine aircraft discussed above are summarized in a single table for ease of use (Table 1.1).

Based on the analysis of the statistical data presented in Table 1.1, the approximate values of the main basic parameters for new design of a twin-engine utility aircraft were determined. The values of these basic parameters, as well as the main design and operational requirements, which were formed on the basis of a study of the history of creation and operating experience of the considered same class aircraft, determined the basis for drawing up Project Specifications for the new aircraft.

Table 1.1 Technical specifications of the twin-engine utility aircraft.

Variant	Beechcraft SuperKing Air 250	Cessna 441 Conquest 2	Tecnam P2012 Traveller	Antonov An-28	Mitsubishi MU-2L	Piaggio P.180 Avanti
Crew	1	2	1-2	2	1-2	1
Passenger	8-10	6	9	17	4-12	7-9
Height	4.52 m	4.01 m	4.4 m	4.5 m	4.17 m	4 m
Wingspan	17.65 m	15.04 m	14 m	22.06 m	11.94 m	14.3 m
Wing area	28.8 m^2	23.6 m^2	25.8 m^2	39.72 m^2	16.55 m^2	16 m^2
Length	13.36 m	11.89 m	11.8 m	12.95 m	12.01 m	14.4 m
Cabin H x W x L	1.45m x 1.37m x 5.08m	1.3m x 1.4m x 3.93m	1.35m x W x 4.27m	1.6m x 1.74m x 5.26m	1.3m x 1.5m x 4.87m	1.75m x 1.85m x 4.55m
Wing aspect ratio	9.4	9.6	7.7		7.71	12.3
MTOW	5,670 kg	4,470 kg	3,660 kg	6,500 kg	5,250 kg	5,488 kg
Max. landing weight	5,670 kg	4,245 kg	3,660 kg	6,500 kg	5,000 kg	5,216 kg
Empty weight	4,990 kg	2,588 kg	2,286 kg	3,900 kg	3,433 kg	3,799 kg
Fuel capacity	1,653 kg	1,798 kg	750 kg	1,530 kg	1,389 kg	1,271 kg
Max. payload	1,007 kg	1,043 kg	1,390 kg	1,750 kg	1,726 kg	1,066 kg
Max. range	3,185 km	3,700 km	1,760 km	1,370 km	2,334 km	2,759 km
Cruise speed	574 km/h	480 km/h	320 km/h	352 km/h	547 km/h	589 km/h
Service ceiling	10,668 m	10,668 m	5,900 m	6,000 m	9,020 m	12,000 m
Takeoff distance	643 m	544 m	791 m	270 m	661 m	972 m
Landing distance	867 m	890 m	743 m	197 m	573 m	1,000 m
Max. speed	480 km/h	545 km/h	359 km/h	355 km/h	546 km/h	745 km/h
Power plant (x2)	Pratt & Whitney Canada PT6A-52	Honeywell TPE 331-8	Lycoming TEO-540C1A	Glushenkov TVD-10B Or PT6A-65B	AiResearch TPE 331-6-251M	Pratt & Whitney Canada PT6A-66B
Power	625 kW	474 kW	280 kW	720 kW	579 kW	634 kW
Propellers		4-bladed McCauley	4-bladed MT-propeller	3-bladed AW-24AN	3-bladed Hartzell HC-B3TN-5/ T10178HB-11	Hartzell ve-scimitar blades low noise Propellers

1.8 Conclusion to the section.

In this section I reviewed and analyzed the technical data of some different twin-engine utility aircraft models. These aircraft represent a diverse selection of options suitable for various utility operations. I analyzed the main characteristics such as payload capacity, passenger capacity, cruise speed and range for each aircraft, which is important factors to consider selecting an aircraft for utility purposes, since these factors directly impacts the aircraft’s efficiency and suitability for different missions.

Reviewing the specification analysis, it is clear that variations in payload capacity can be observed with some aircraft capable of carrying heavier loads compared to others. Similarly, the passenger capacity rages from smaller aircraft capable to accommodate around 6-8 passengers to larger ones accommodating up to approximately 20 passengers.

Cruise speed is crucial factor to consider for specific mission requirements, which vary across the aircraft with some models offering higher speeds for more rapid transportation, such as **Beechcraft SuperKing Air 250** and **P.180 Avanti**, indicating cruise speed of over 500 km/h.

Range is another important aspect to consider, as it determines the aircraft’s ability to cover distance without requiring frequent refuelling stops. The flight range of the listed aircraft is within from shorter distances suitable for regional operations, such as **Antonov An-28**, to longer ranges suitable for intercontinental flights, such as **Beechcraft Super King Air 250** and **Cessna 441 Conquest 2**.

Therefore, by analyzing these characteristic data, we can conclude: the choice of a twin-engine utility aircraft depends on the specific needs and requirements of the intended missions. Factors such as payload capacity, passenger capacity, cruise speed and range need to be evaluated according to the operational goals. There for, all basic necessary requirements and characteristics should be defined in Project Specifications for the new aircraft yet before design process will start.

2 CONCEPTUAL SKETCH CREATION

2.1 Airframe layout definition.

The fuselage shape: conventional.

Type and number of the engines, their placement on the aircraft: twin turboprop engines mounted on the wings.

The empennage configuration: conventional/ H-tail/ T-tail.

The landing gear type and configuration: tricycle landing gear.

2.1.1 Justification of the design decisions.

Conventional fuselage is expected to provide a spacious cabin and it allows dedicated cargo compartments, enhancing utility and transport capabilities. A tricycle landing gear offers better ground stability and easier handling.

2.1.2 Airframe layout configuration variants.

2.1.2.1 Variant A.

Wing: high-wing.

Empennage: conventional.

A high wing configuration is expected to provide good stability, short takeoff and landing capabilities, increased payload capacity and easy access to cabin, which is suitable for passenger transportation.

The conventional empennage offers stability and expected to be aerodynamically efficient.

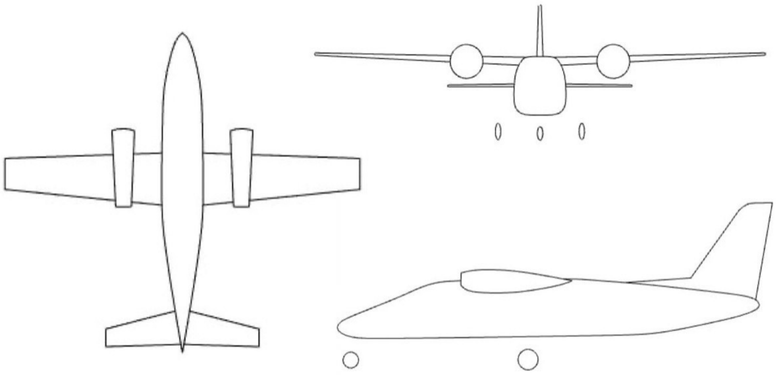


Fig. 2.1.1 Airframe layout - Variant A.

2.1.2.2 Variant B.

Wing: high-wing.

Empennage: H-tail.

A H-tail empennage provides the restoring yawing moment and also increases the efficiency of the horizontal tail through endplate effects.

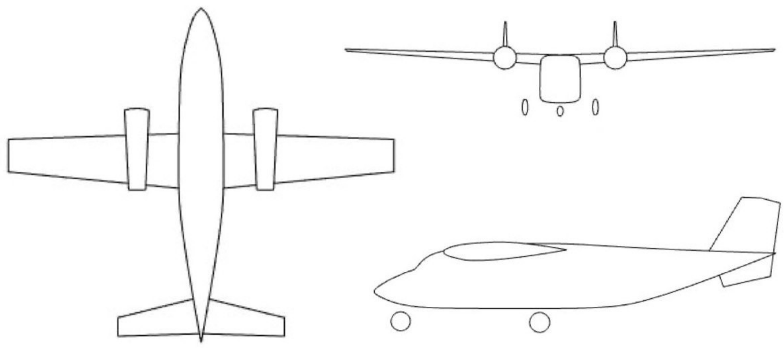


Fig. 2.1.2 Airframe layout - Variant B.

2.1.2.3 Variant C.

Wing: low-wing.

Empennage: T-tail.

A low-wing configuration allows for fuel storage in the wings, enhancing fuel efficiency, also typically have superior aerodynamic efficiency due to reduced drag.

The T-tail empennage configuration enhances stability and pitch control, reducing the risk of tail strikes.

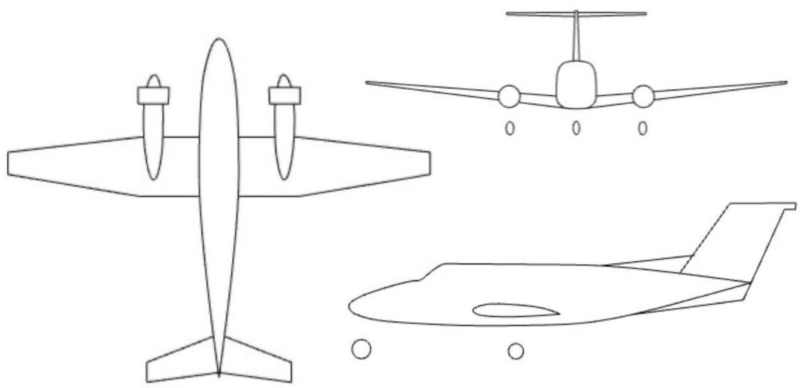


Fig. 2.1.3 Airframe layout - Variant B.

2.1.2.3 Variant chosen for conceptual sketch.

Wing: low-wing.

Empennage: conventional.

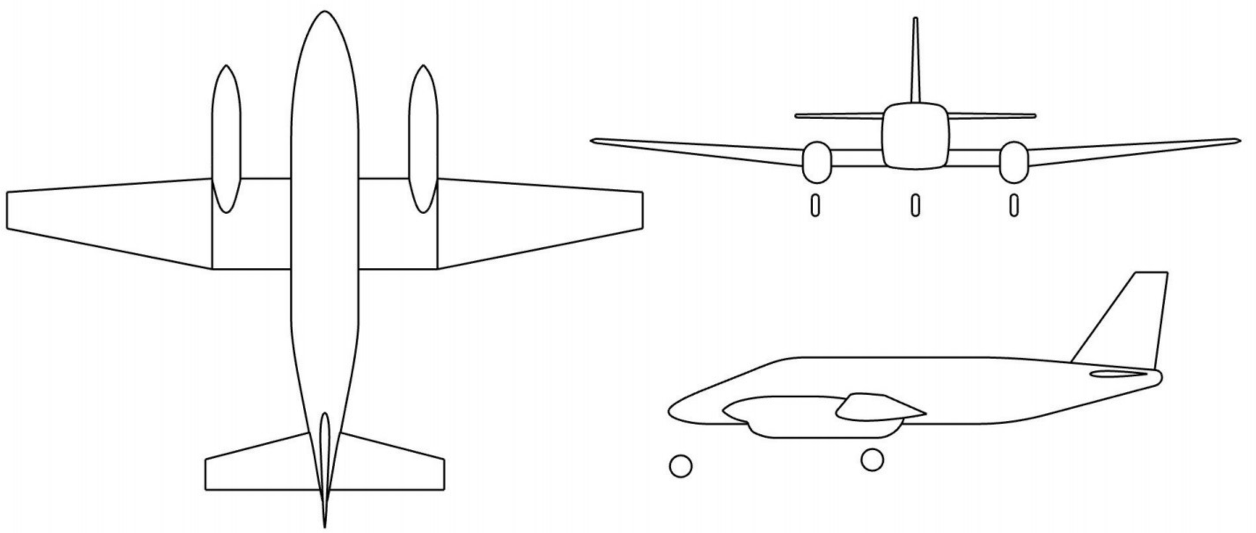


Fig. 2.1.4 Conceptual sketch airframe layout.

A low-wing configuration typically have superior aerodynamic efficiency due to reduced drag, easier to maintain engines, the wing design does not take up space in the passenger cabin - the wing spar goes under the cabin floor

2.2 Take-off weight calculation.

Maximum takeoff weight (MTOW):

$$(m_{MTOW})_I = \frac{m_{UL} + m_{SERV}}{1 - (\overline{m}_{AF} + \overline{m}_{PU} + \overline{m}_{SYS} + \overline{m}_{FUEL})};$$

m_{UL} - useful load weight [kg] = 2000 kg;

$\overline{m}_{AF}$ - airframe weight coefficient (mAF/mMTOW) – (0,24..0,26) = 0.25;

$\overline{m}_{PU}$ - power unit (engines and systems) weight coefficient – (0,10..0,12) = 0.11;

$\overline{m}_{SYS}$ - aircraft systems weight coefficient – (0,06..0,08) = 0.07;

$\overline{m}_{FUEL}$ - fuel weight coefficient – (0,12..0,18) = 0.15;

m_{SERV} - service load weight:

$$m_{SERV} = m_{CREW} + m_{EQUIP} + m_{ADE} = 150 + 155.19 + 200 = 505.19 \text{ kg}$$

n_{CREW} – crew number = 2;

$$m_{CREW} = 75 \cdot n_{CREW} = 75 \cdot 2 = 150 \text{ kg}$$

Aircraft equipment weight:

$$m_{0stat} = (m_{01} + m_{02} + m_{03} + m_{04} + m_{05} + m_{06})/6;$$

m_{01}, m_{02}, m_{03}, m_{04} – same-class aircraft MTOW statistical values;

m_{01}= 5670 kg,

m_{02}= 4470 kg,

m_{03}= 3660 kg,

m_{04}= 6500 kg,

m_{05}= 5250 kg,

m_{06}= 5488 kg.

$$m_{0stat} = (5670 + 4470 + 3660 + 6500 + 5250 + 5488)/6 = 5173 \text{ kg.}$$

$m_{EQUIP} = (0.03..0.05) \cdot m_{0stat}$ - for the aircraft with MTOW: $m_{0stat} < 6000$ kg;

$$m_{EQUIP} = 0.03 \cdot 5.173 = 155.19$$

Aircraft equipment consists of:

- Instrument Panels;
- Pilot seats;
- Flight controls;
- Navigating systems;
- Electrical system;
- Radio;
- Hydro/Pneumatic systems;
- Firefighting system;
- Anti-icing system;
- Soundproofing and thermal insulation;
- Passenger compartment equipment.

Additional equipment weight:

$$m_{ADE} = k \cdot n_{pass} = 20 \cdot 10 = 200 \text{ kg.}$$

n_{pass} – passengers number = 10,

k = 20 for aircraft with flight endurance more than 5 hours.

Additional equipment include:

- Cabin amenities;
- Maintenance and safety equipment;
- Emergency equipment;
- Cargo and baggage handling equipment.

Maximum takeoff weight:

$$(m_{MTOW})_I = \frac{2000 + 505{,}19}{1 - (0.25 + 0.11 + 0.07 + 0.15)} = 5965 \text{ kg;}$$

2.3 Determination of the main parameters of the wing

2.3.1 Airfoils selection.

For the wing of the aircraft were chosen NACA 23018 (wing root) and NACA 23012 (wing tip).

NACA 23018 airfoil series is the airfoils with a thickness-to-chord ratio of 18%, which provides a good balance between lift and drag, which can be important for maximizing the aircraft's payload and range. Close to the symmetric nature of the airfoil can contribute to predictable stall behavior and overall stability.

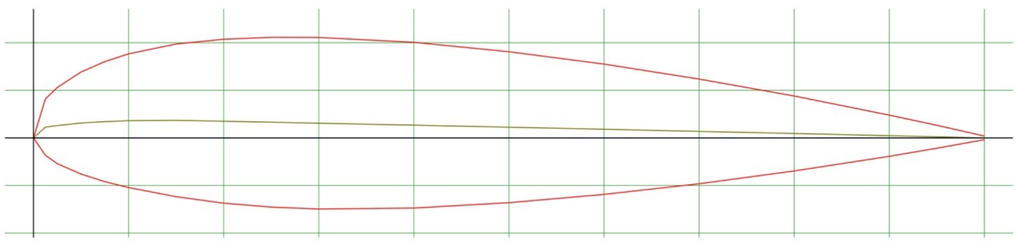


Fig. 2.3.1 NACA 23018 airfoil.

NACA 23012 airfoil with a smaller thickness was chosen for the wing tips in order to provide an optimal lift distribution along the wing span.

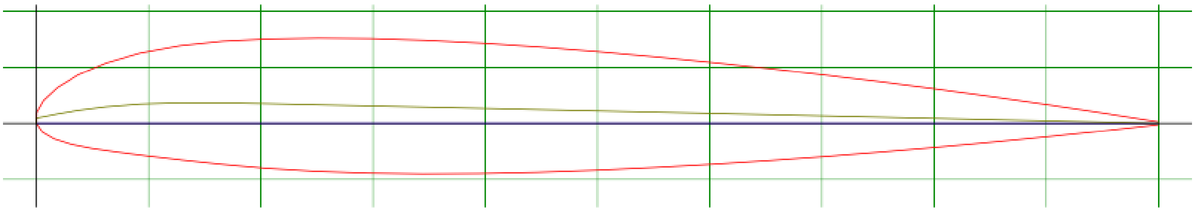


Fig. 2.3.2 NACA 23012 airfoil.

2.4 Wing geometry and dimensions.

2.4.1 Wing area:

$$A_W = \frac{m_0}{\overline{p}_0};$$

m_0 = 5965 kg – maximum takeoff weight (MTOW);

$\overline{p}_0$ – average value of the MTOW-to-wing area ratio:

$$\overline{p}_0 = \frac{p_{0_1} + p_{0_2} + p_{0_3} + p_{0_4} + p_{0_5} + p_{0_6}}{6}$$

$p_{0_1}, p_{0_2}, p_{0_3}, p_{0_4}, p_{0_6}, p_{0_6}$ - MTOW-to-wing area ratio value for each of the same-class aircraft from statistics data;

p_{01} = 196.9 kg/m²;

p_{02} = 189.4 kg/m²;

p_{03} = 141.9 kg/m²;

p_{04} = 163.6 kg/m²;

p_{05} = 317.2 kg/m²;

p_{06} = 343 kg/m²;

$$\overline{p}_0 = \frac{196.9 + 189.4 + 141.9 + 163.6 + 317.2 + 343}{6} = 225 \text{ kg/m}^2.$$

Wing area:

$$A_W = \frac{m_0}{\overline{p}_0} = \frac{5965}{225} = 26.5 \text{ m}^2.$$

2.4.2 Based on the same-class aircraft statistics and depending on chosen design configuration, should be determined:

- wing aspect ratio $\lambda_W = 10.0$;
- wing taper ratio $\eta_W = 2.5$;
- wing sweep angle $\chi_{0,25} = 0$;
- wing dihedral angle $\psi = 5°$.

2.4.3 Wing span:

$$S_W = \sqrt{\lambda_W \cdot A_W} = \sqrt{10 \cdot 26.5} = 16.28 \text{ m.}$$

2.4.4 Wing tip chord:

$$c_t = \frac{2 \cdot A_W}{S_W \cdot (1+\eta_W)} = \frac{2 \cdot 26.5}{16.28 \cdot (1+2.5)} = 0.93 \text{ m.}$$

2.4.5 Wing root chord:

$$c_r = \eta_W \cdot c_t = 2.5 \cdot 0.93 = 2.325 \text{ m.}$$

2.4.6 Mean Aerodynamic Chord (MAC).

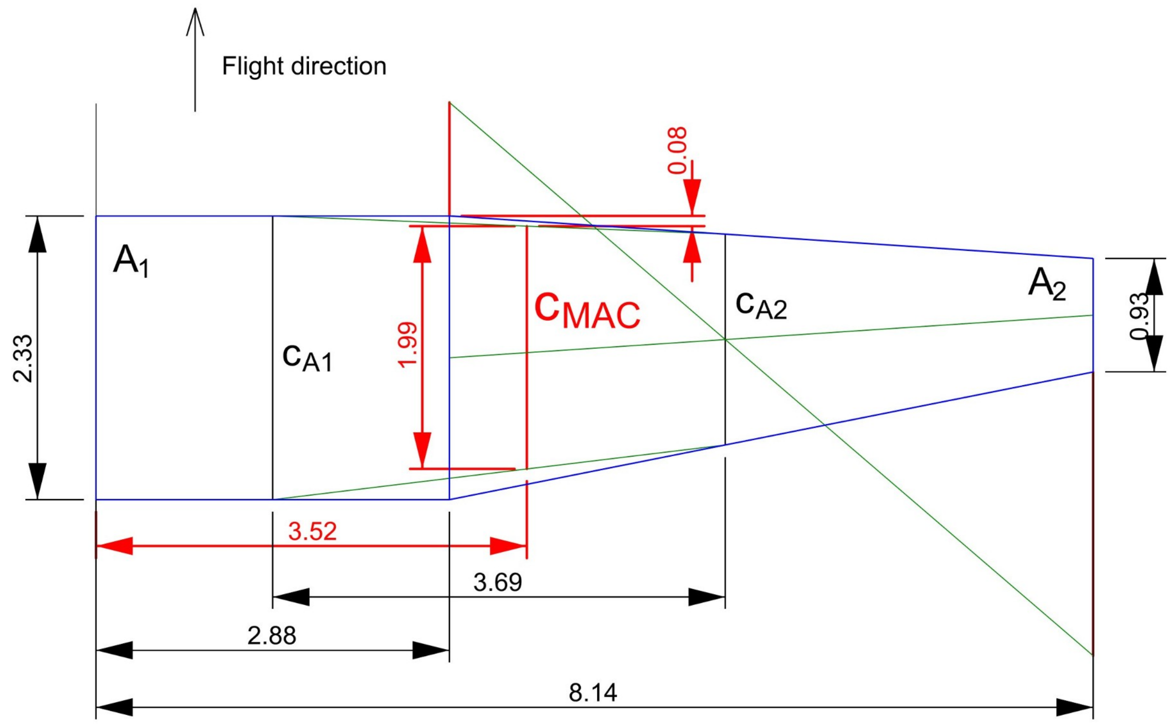


Fig. 2.4.1 Graphical determination of the Mean Aerodynamic Chord (MAC).

Due to complicate wing shape, z-coordinate for wing MAC position can be calculated as:

$$z_{MAC} = z_{CA2} - (z_{CA2} - z_{CA1}) \cdot \frac{A_1}{A_1 + A_2} = 5.13 - (5.13 - 1.44)\frac{6.71}{6.71 + 8.56} = 3.52 \text{ m.}$$

2.4.7 Geometric parameters of the flight control surfaces on the wing.

Aileron span (on one half of the wing):

$$S_{alr} = 0.3\cdot(0.5\cdot S_W) = 0.31\cdot(0.5\cdot 16.28) = 2.63 \text{ m}.$$

Aileron average chord:

$$c_{alr1} = 0.25\cdot c_{W1} = 0.25\cdot 1.6 = 0.4 \text{ m}; \quad c_{alr2} = 0.25\cdot c_{W2} = 0.25\cdot 0.93 = 0.23 \text{ m};$$

Flaps span (on one half of the wing):

$$S_{flp} = 0.55\cdot(0.5\cdot S_W) = 0.55\cdot(0.5\cdot 16.28) = 4.46 \text{ m}.$$

Flaps average chord:

$$c_{flp1} = 0{,}3\cdot c_{W1} = 0.3\cdot 2.32 = 0.69 \text{ m}; \quad c_{flp2} = 0{,}3\cdot c_{W2} = 0.3\cdot 1.6 = 0.48 \text{ m};$$

2.4.8 The wing sketch that was made based on the calculated geometrical parameters.

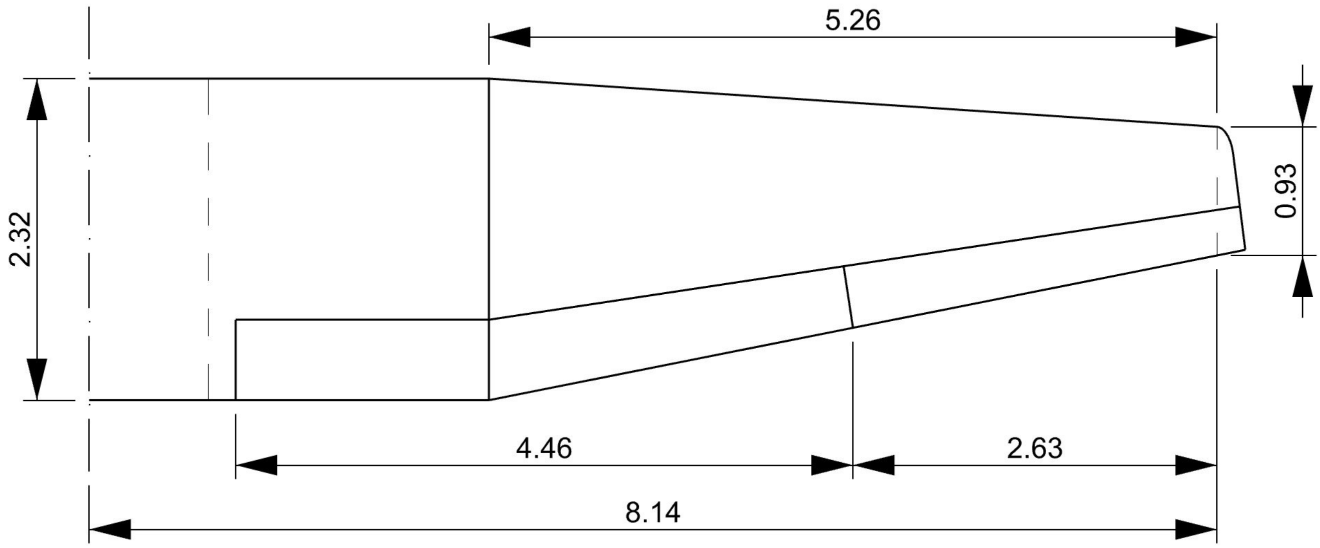


Fig. 2.4.2 Wing sketch.

2.5 Fuselage basic geometry determination.

Rectangular cross sectional design can maximize internal volume and allows for efficient utilization of space for passenger, cargo, and systems.

2.5.1 General dimensions of the fuselage.

Calculate the area of the fuselage midsection depending on sketch drawing you made:

$$A_{MID} = 2.64\ m^2.$$

As the cross section is different from round shape, fuselage equivalent diameter should be calculated:

$$D^{e}_{FUS} = 2 \cdot \sqrt{\frac{A_{MID}}{\pi}} = 2 \cdot \sqrt{\frac{2.64}{\pi}} = 1.83\ m^2.$$

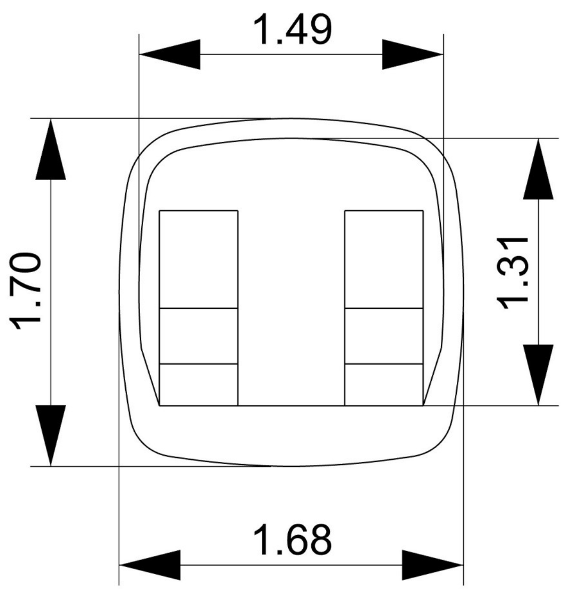


Fig. 2.5.1 Fuselage middle section.

2.5.2 The lengths of the nose and tail sections of the fuselage in the first approximation are determined using statistics.

Length of the nose section of the fuselage:

$$l_{Fn} = 3.5\ m.$$

Length of the tail section of the fuselage:

$$l_{Ft} = 4.7\ m.$$

2.5.3 Length of the central section of the fuselage for the passenger aircraft can be determined basing on accommodation of a given number of passengers:

n = 10 (5 armchairs in two rows).

Distance between passengers chairs rows: s = 0.87 m.

$$l_{Fc} = 5 \cdot 0.87 = 4.39\ m.$$

2.5.4 Full length of the fuselage:

$$l_F = l_{Fn} + l_{Fc} + l_{Fn} = 3.52 + 4.39 + 4.72 = 12.64\ m.$$

2.5.5 Fuselage aspect ratio:

$$\lambda_F = l_F / D^e_{FUS} = 12.64 / 1.52 = 8.32.$$

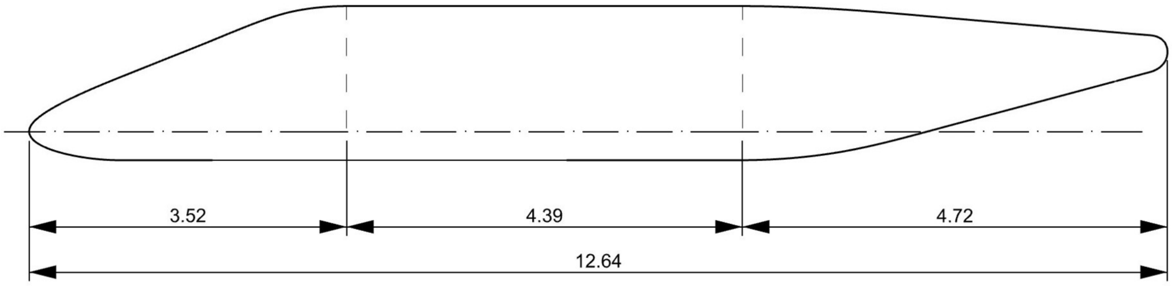


Fig. 2.5.2 Fuselage side view sketch.

2.6 Tail geometry and arrangement.

2.6.1 Horizontal stabilizer.

Airfoil for the horizontal stabilizer.

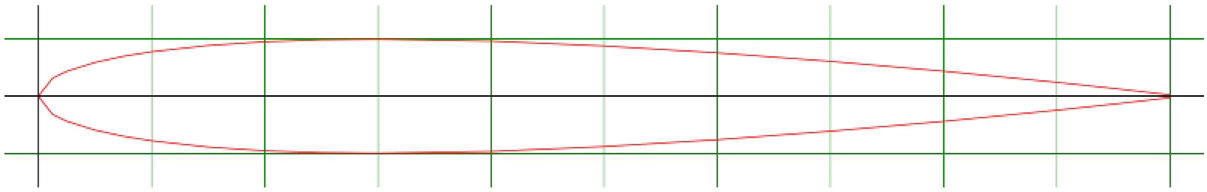


Fig. 2.6.1 NACA 0010 airfoil.

NACA 0010 is the symmetrical airfoil which is designed for balanced lift and drag characteristics with overall stability.

Pitch stability and controllability of the aircraft is provided by the efficiency of the horizontal stabilizer (STAB) and elevator, which is achieved by the corresponding lever arm L_{STAB} and the horizontal stabilizer area A_{STAB}.

The area of the horizontal stabilizer in the first approximation:

$$A_{STAB} = \frac{K_{STAB}}{\bar{L}_{STAB}} \cdot A_W = \frac{0.68}{2.5} \cdot 26.5 = 7.2 \text{ m}^2.$$

K_{STAB} – the static momentum coefficient of the stabilizer;

L_{STAB} – lever arm of the stabilizer (relative value to Mean Aerodynamic Chord);

A_W – wing area.

Stabilizer aspect ratio $\lambda_{STAB} = 5.2$

Stabilizer taper ratio $\eta_{STAB} = 2.0$

Stabilizer span: $l_{STAB} = \sqrt{\lambda_{STAB} \cdot A_{STAB}} = \sqrt{5.2 \cdot 7.2} =$ 6.12 m.

Stabilizer tip chord: $c_{STAB}^{tip} = \dfrac{2 \cdot A_{STAB}}{l_{STAB} \cdot (1+\eta_{STAB})} = \dfrac{2 \cdot 7.2}{6.12 \cdot (1+2.0)} =$ 0.78 m.

Stabilizer root chord: $c_{STAB}^{root} = \eta_{STAB} \cdot c_{STAB}^{tip} = 2.0 \cdot 0.78 = 1.57$ m.

The elevator area can be approximately determined as:

$$A_{ELEV} = 0.35 \cdot A_{STAB} = 0.35 \cdot 7.2 = 2.52 \text{ m}^2.$$

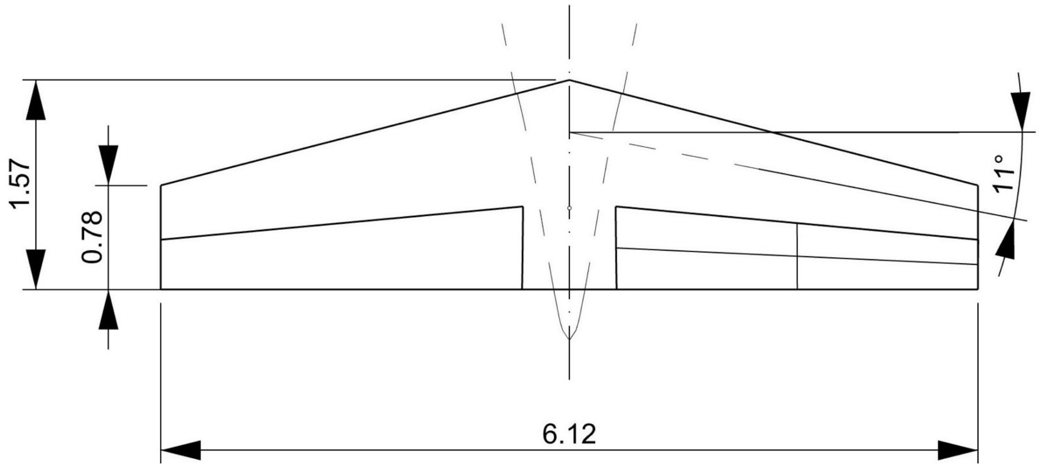


Fig. 2.6.2 Horizontal stabilizer sketch.

2.6.2 Vertical stabilizer.

Yaw stability and controllability of the aircraft is provided by the efficiency of the vertical stabilizer or fin (FIN) and rudder, which is achieved by the corresponding lever arm L_{FIN} and the fin area A_{FIN}.

Airfoil for the vertical stabilizer.

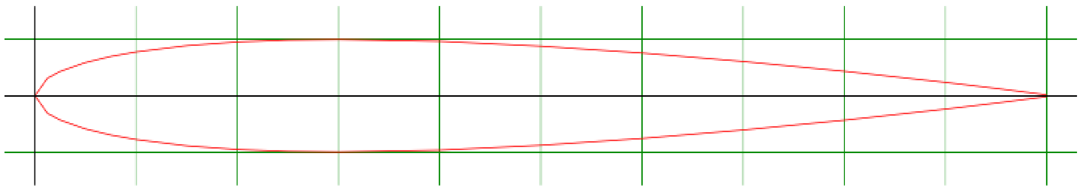


Fig. 2.6.1 NACA 0012 airfoil.

NACA 0012 is the symmetrical airfoil which is designed for balanced lift and drag characteristics with overall stability.

The area of the vertical stabilizer (fin) in the first approximation:

The area of the vertical stabilizer (fin) in the first approximation:

$$A_{STAB} = \frac{K_{FIN}}{\overline{L}_{FIN}} \cdot A_{WING} = \frac{0.05}{0.335} \cdot 26.5 = 3.95 \text{ m}^2.$$

K_{FIN} – the static momentum coefficient of the fin;

L_{FIN} – lever arm of the fin (relative value to Mean Aerodynamic Chord);

A_{WING} – wing area.

Fin aspect ratio $\lambda_{FIN} = 1.6$

Fin taper ratio $\eta_{FIN} = 2.8$

Fin height: $h_{FIN} = \sqrt{\lambda_{FIN} \cdot A_{FIN}} = \sqrt{1.6 \cdot 3.95} = 2.5$ m.

The tip chord of the fin: $c_{FIN}^{tip} = \frac{2 \cdot A_{FIN}}{h_{FIN} \cdot (1 + \eta_{FIN})} = \frac{2 \cdot 3.95}{2.5 \cdot (1 + 1.6)} = 0.83$ m.

The root chord of the fin: $c_{FIN}^{root} = \eta_{FIN} \cdot c_{FIN}^{tip} = 2.8 \cdot 0.83 = 2.32$ m.

The rudder area can be approximately determined as:

$$A_{RUD} = 0.35 \cdot A_{FIN} = 0.35 \cdot 3.95 = 1.38 \text{ m}^2.$$

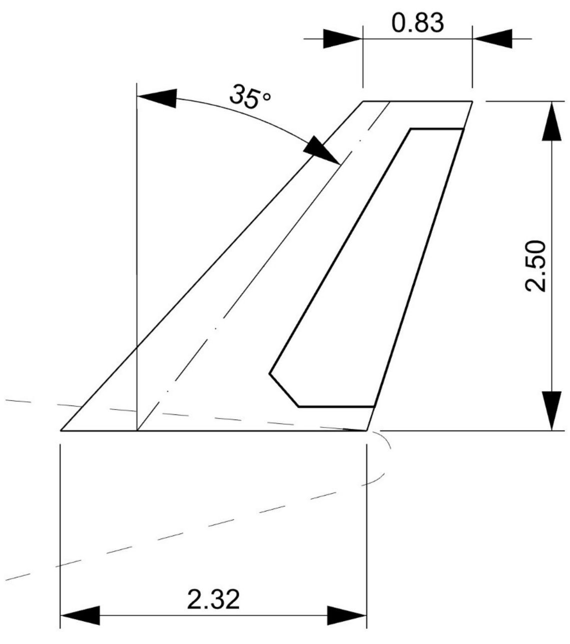


Fig. 2.6.3 Vertical stabilizer (fin) sketch.

2.7 Sketch design.

Based on all the above definitions and calculations, a conceptual sketch of the aircraft was formed. The layout of the main parts of the aircraft is made taking into account the provision of the necessary centering, as well as taking into account the values of the levers of the horizontal (L_{STAB}) and vertical (L_{FIN}) stabilizers.

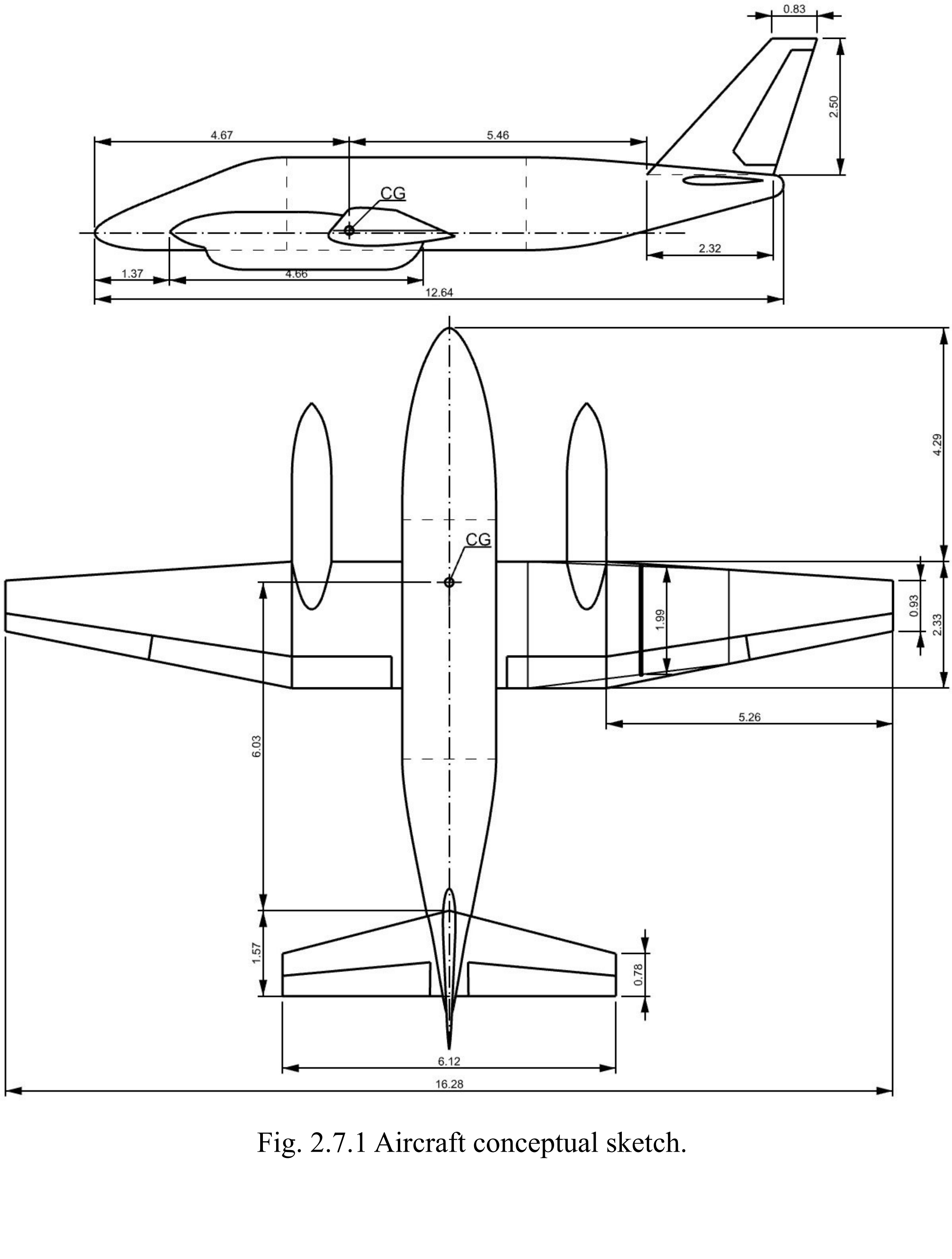


Fig. 2.7.1 Aircraft conceptual sketch.

2.8 Conclusion to the section.

In this section, the analysis and calculation of the aircraft configuration for a twin-engine utility aircraft have been undertaken to determine the optimal design parameters. This includes considerations for the MTOW, wing design, fuselage and stabilizers configuration. To accomplish this, extensive research was conducted to gather relevant information on similar class aircraft, focusing on design principles, performance requirements, and operational needs. Based on the analysis, the calculations were performed and detailed sketches were created to determine the more suitable values and dimensions for the aircraft configuration.

Overall, the objective of this section was to develop a comprehensive understanding of the twin-engine utility aircraft's configuration and ensure that the design aligns with the intended utility and performance requirement.

3 AERODYNAMIC SIMULATIONS

Aerodynamic simulations is crucial for the design and optimization of aircraft, which analyze flow characteristics and to develop aerodynamic design. By using computational tools like the PANSYM, it is possible to gain insights into the flow phenomena which leads to an aircraft's performance and behavior. Moreover, aerodynamic simulations allows for a understanding of the aerodynamic characteristics under different flight conditions. The provide information about lift and drag coefficients, pressure distribution and flow distribution enables to improve stability and aerodynamic efficiency.

3.1 Model for simulations.

For the aerodynamic simulations, a 3d numerical model of the aircraft was developed within the PANSYM program. To represent aircraft geometry, the model included the fuselage, wing (airfoil, wing root, wing center plane, wing console), empennage (airfoil, stabilizer, fin) and engine nacelles. The model was based on conceptual sketch, specification, and dimensions of the aircraft which were determined in section 2.

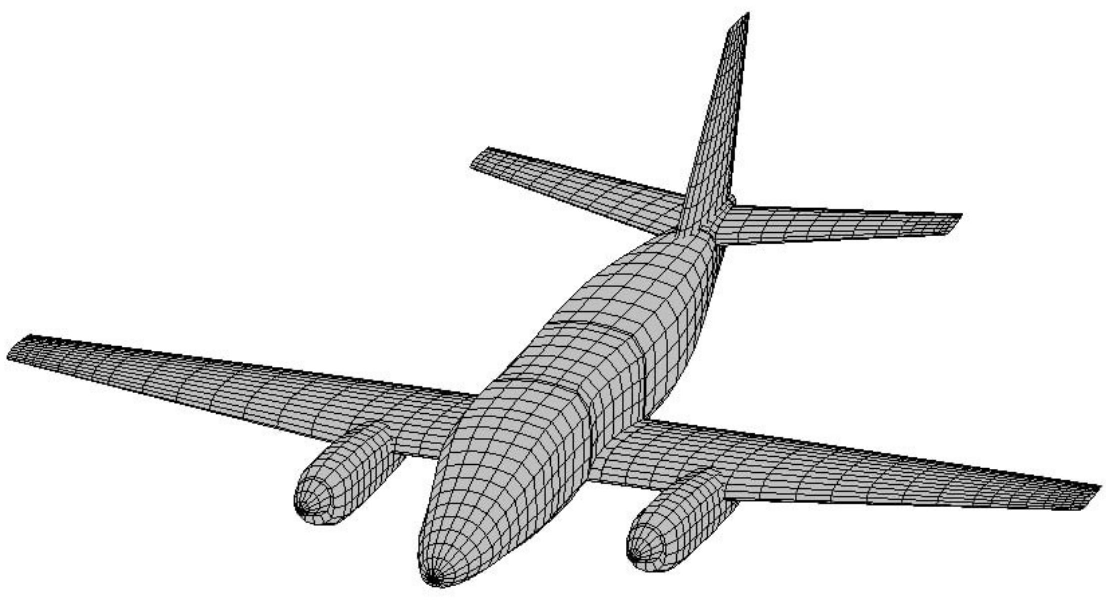


Fig. 3.1.1 Aerodynamic simulation model.

3.2 Simulation mode conditions.

To create realistic aerodynamic simulation, specific simulation mode conditions have to be defined. Flight conditions such as, Mach number, altitude, and Reynolds number were calculated.

In the process of working on the project, aerodynamic simulation was carried out for the two most important aircraft flight modes:

1) aircraft cruise flight mode;
2) aircraft takeoff and landing mode.

3.2.1 Cruise flight mode conditions.

Altitude H = 9000 m;

Speed of sound at a given height c = 304 m/s (at H = 9000 m);

Aircraft cruise speed at a given height V = 153 m/s;

Mean aerodynamic chord b = 1.99 m;

Kinematics air viscosity coefficient at a given height $\nu = 3.2 \cdot 10^{-5}$ m^2/s;

Mach number:

$$M = V/c = 153/304 = 0.5;$$

Reynolds number:

$$Re = V \cdot b / \nu = 153 \cdot 1.99 / (3.2 \cdot 10^{-5}) = 9\ 514\ 687.$$

3.2.2 Takeoff and landing mode conditions.

Altitude H = 0 m;

Speed of sound at a given height c = 340 m/s (at H = 0 m);

Aircraft minimum speed (approximate, H = 0 m) V = 56 m/s;

Mean aerodynamic chord b = 1.99 m;

Kinematics air viscosity coefficient at a given height $\nu = 1.46 \cdot 10^{-5}$ m^2/s;

Mach number:

$$M = V/c = 56/340 = 0.16;$$

Reynolds number:

$$Re = V \cdot b / \nu = 56 \cdot 1.99 / (1.46 \cdot 10^{-5}) = 7\ 632\ 876.$$

3.3 Aircraft cruise flight mode conditions simulation.

In order to simulate the aircraft cruise flight mode conditions, the simulation was performed with Mach number M=0.5 and Reynolds number Re=$9.5 \cdot 10^5$.

Using the program, the simulation provides detailed aerodynamic information including the lift and drag coefficients, and pitching moment for various angles of attack. The pressure distribution visualization allows for a better understanding of flow behavior.

By conducting aerodynamic simulations under the specified conditions, key parameters such as angle of attack (AoA), lift coefficient (CL), drag coefficient (CD), pitching moment (Mz), and lift-to-drag ratio (CL/CD) were obtained. These values provide insights into the aerodynamic performance of the aircraft.

Using the obtained data, graphs were plotted to illustrate the lift coefficient, aerodynamic efficiency, and pitching moment characteristics across the range of angle of attack values.

On the Fig.3.2.1 darker blue section above the wing indicates the low pressure zones, whereas yellow/orange section under the wing indicates high pressure zones. Aerodynamic force, consists of lift and drag, is generated by the pressure difference.

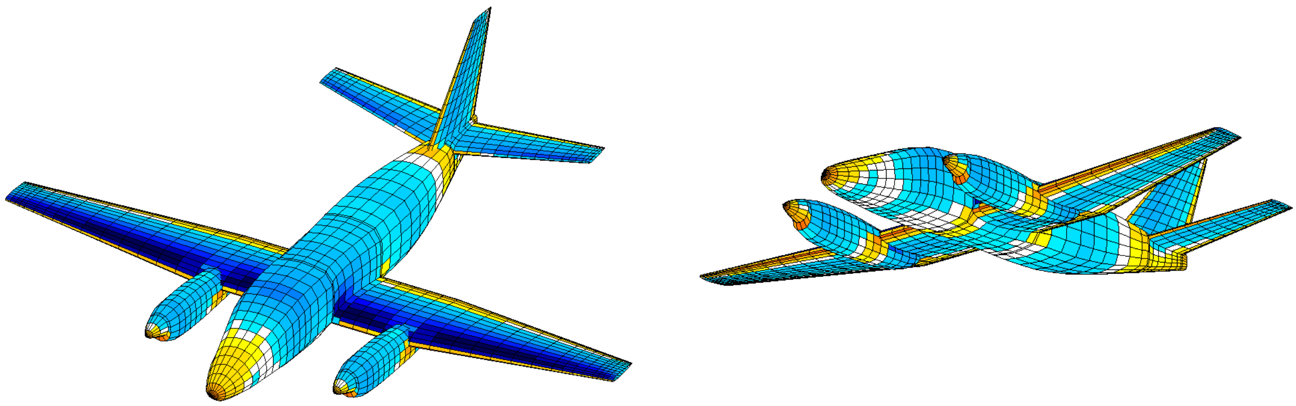


Fig . 3.3.1 Pressure distribution (cruise mode: M=0.5; Re=$9.5 \cdot 10^5$; AoA=5°).

Fig.3.3.2 describes the flow distribution at a 4-degree angle of attack (AoA). The vortex of the flow is clearly appears due to two flows acting on the model, which is one flow from the front of the aircraft and the another from generated by the pressure difference between the upper and under the wing.

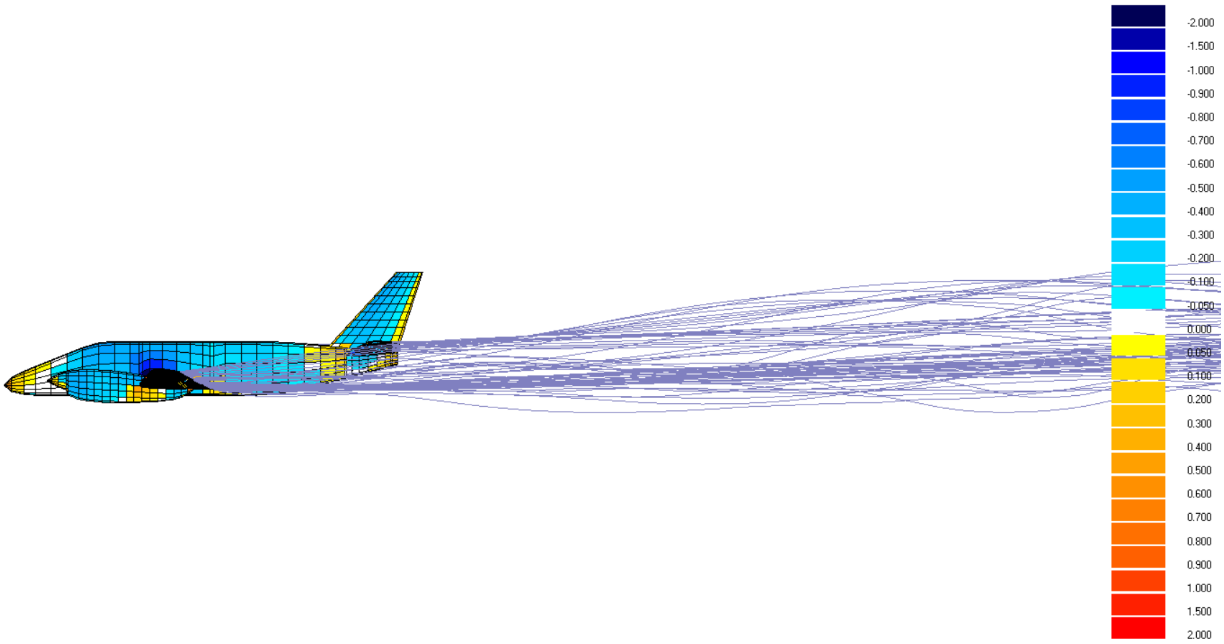


Fig. 3.3.2 Air flows behind the wing, tip vortices visualization
(cruise mode: M=0.5; Re=9.5·10^5; AoA=5°).

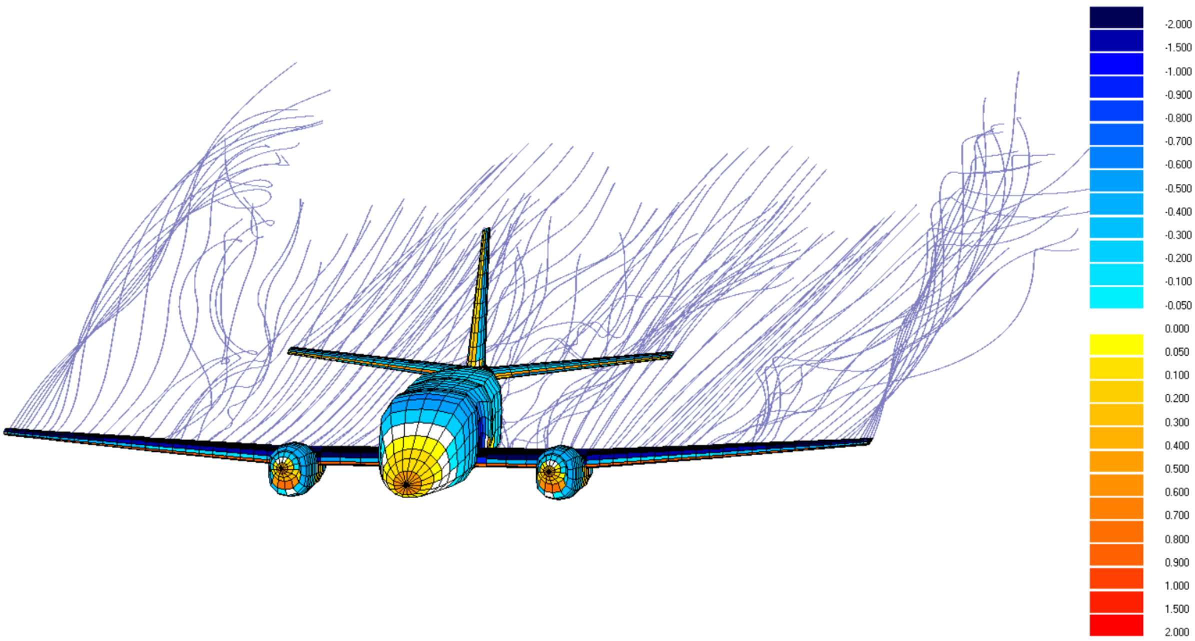


Fig. 3.3.3 Air flows behind the wing, tip vortices visualization
(cruise mode: M=0.5; Re=9.5·10^5; AoA=5°).

Based on the data obtained from the simulation results, the main aerodynamic characteristics of the model are shown in the form of graphs:

- CL(AoA) – the dependence of the lift force coefficient CL on the angle of attack;
- CL(CD) – aircraft drag polar - dependence of the lifting force coefficient CL on the aerodynamic drag coefficient CD;
- CL/CD(AoA) – the dependence of the aircraft lift-to-drag ratio (aerodynamic efficiency);
- m_z(AoA) – the dependence of the pitch moment coefficient m_z on the angle of attack.

From the analysis of the graphs (Fig. 3.3.4 – 3.3.7), the maximum value of the lift-to-drag ratio (best aerodynamic efficiency) is achieved at approximately 5-degree angle of attack. This indicates that the aircraft operates most efficiently and generates the highest amount of lift relative to drag at this specific angle of attack. Furthermore, the graph reveals that the pitching moment of the aircraft is approximately zero around the 5-degree angle of attack. Indicating that the aircraft achieves a balanced state, with no tendency to pitch up or down, resulting improved stability. Therefore, it can be concluded that the optimal performance and balance of the aircraft are achieved at a 5-degree angle of attack.

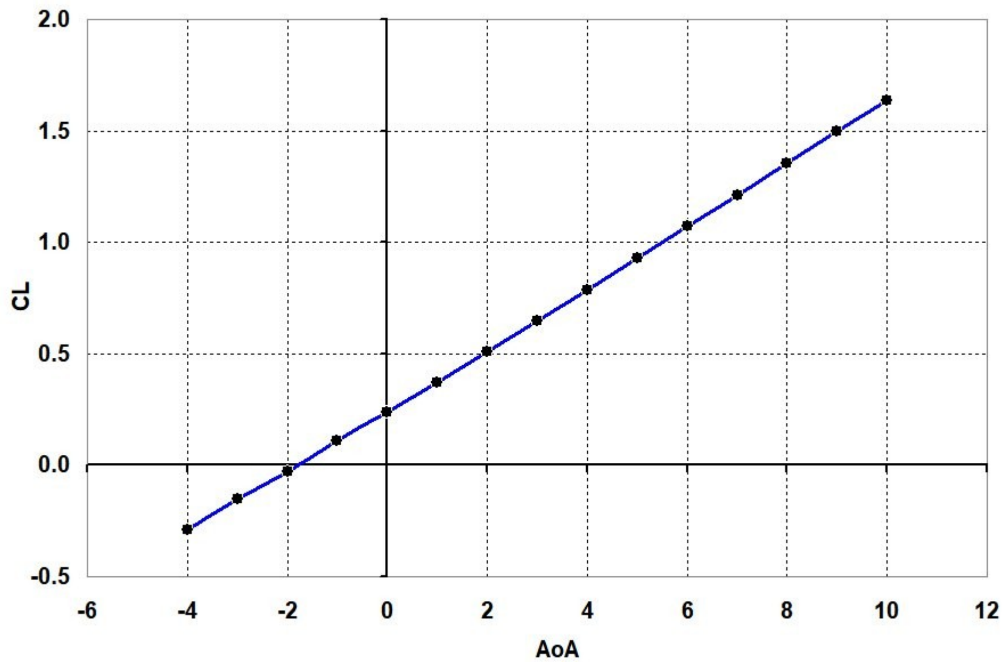


Fig. 3.3.4 Lift coefficient diagram (cruise mode: M=0.5; Re=$9.5 \cdot 10^5$).

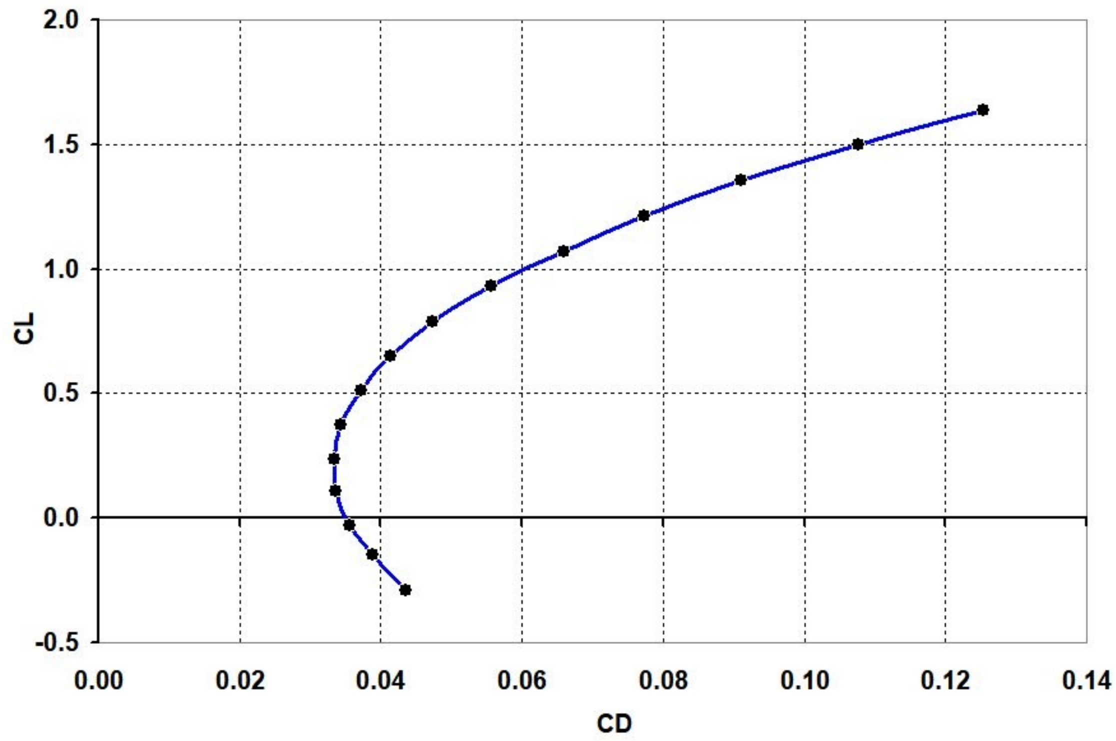


Fig. 3.3.5 Aircraft drag polar (cruise mode: M=0.5; Re=9.5·10^5).

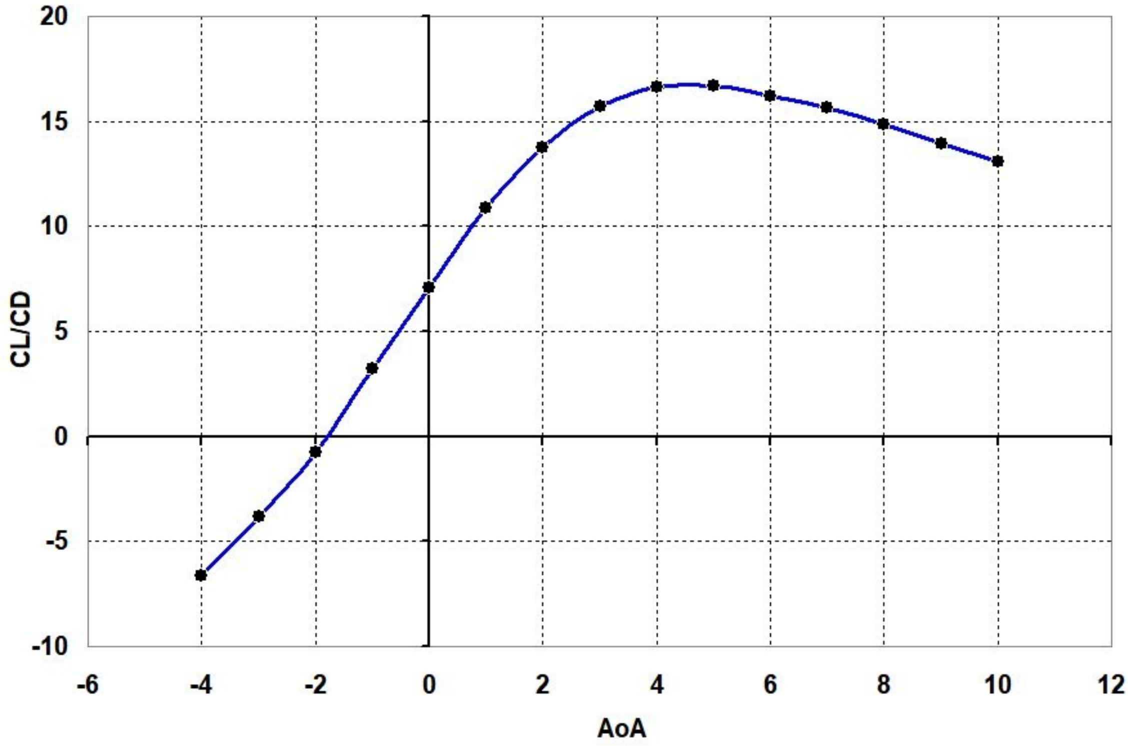


Fig. 3.3.6 Aircraft lift-to-drag ratio (cruise mode: M=0.5; Re=9.5·10^5).

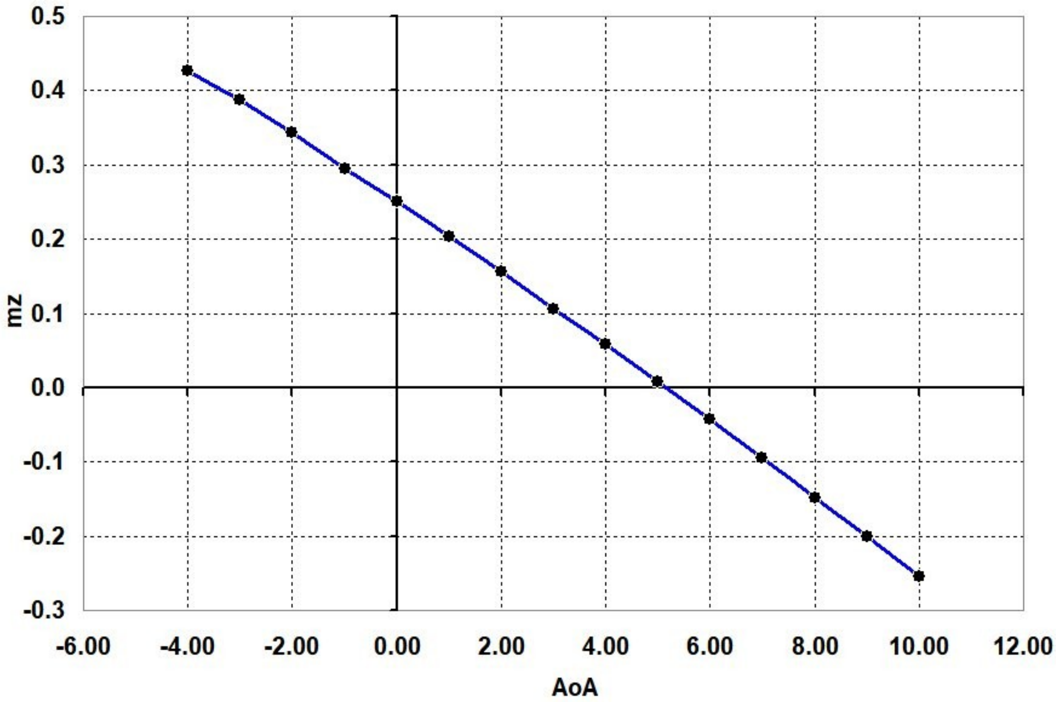


Fig. 3.3.7 Aircraft pitch moment coefficient (cruise mode: M=0.5; Re=9.5·10[5]).

3.4 Aircraft takeoff and landing mode conditions simulations.

Determining the aerodynamic characteristics of an aircraft using numerical simulation for take-off and landing modes and configurations makes it possible to analize the efficiency and optimality of the selected wing mechanization (flaps), as well as to calculate the main aircraft speed parameters for these modes.

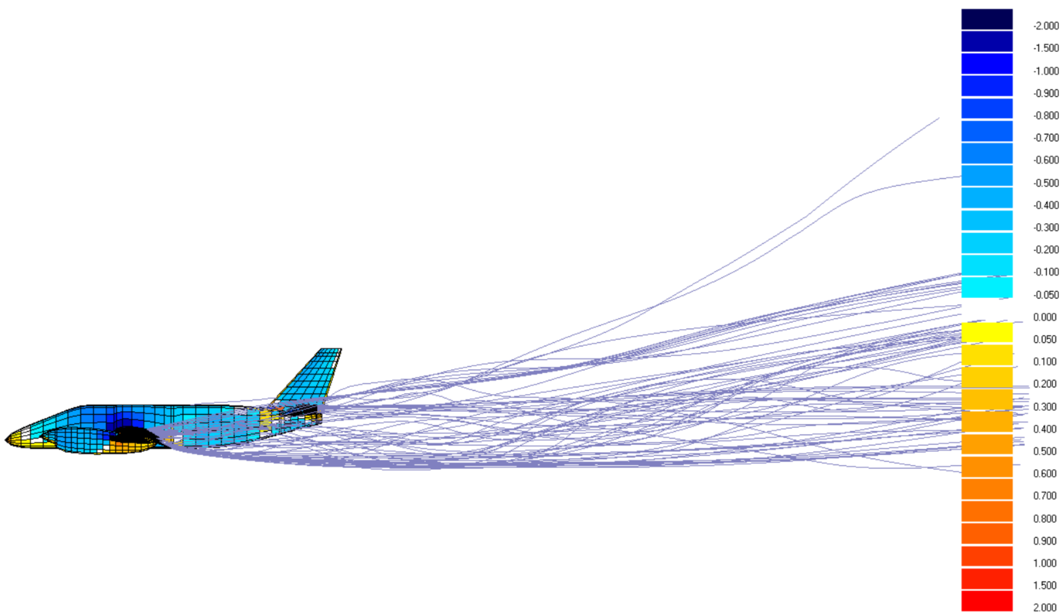


Fig. 3.4.1 Air flows behind the wing and stabilizer, visualization
(Takeoff mode: δ_{flaps} = 20°; M=0.16; Re=7.63·10[5]; AoA=8°).

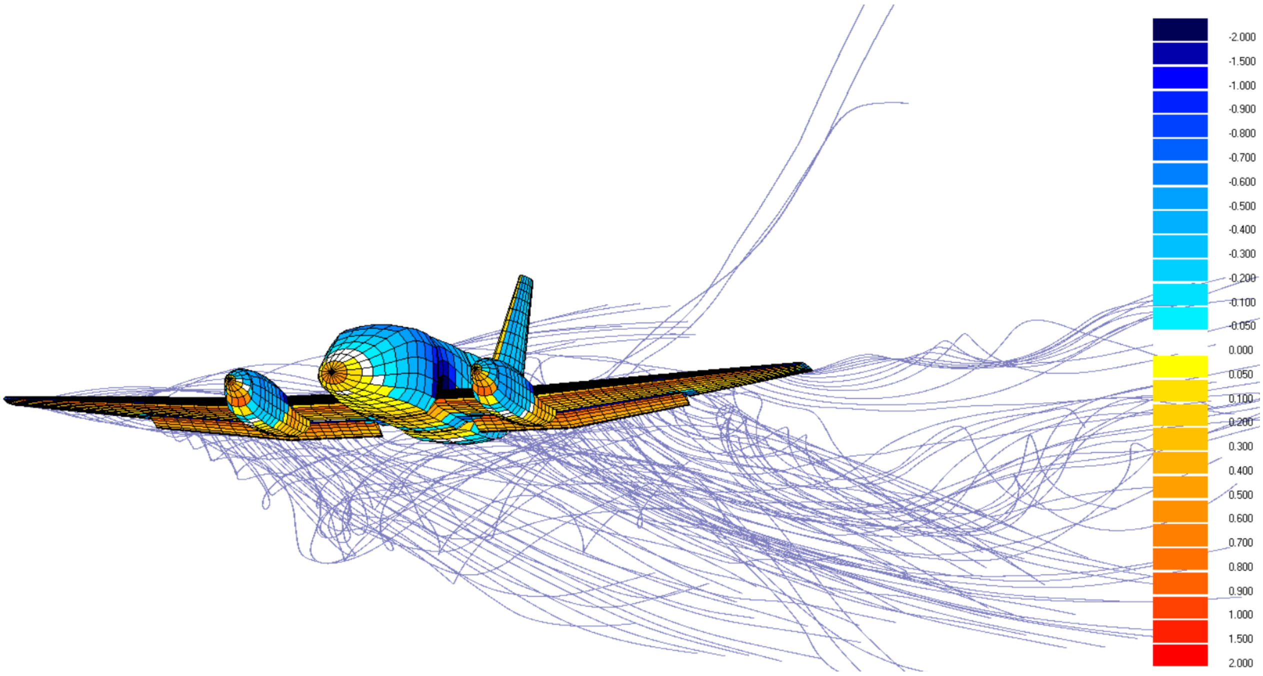


Fig. 3.4.2 Air flows behind the wing and stabilizer, wingtip vortices visualization (Takeoff mode: δ_{flaps} = 20°; M=0.16; Re=$7.63\cdot10^5$; AoA=8°).

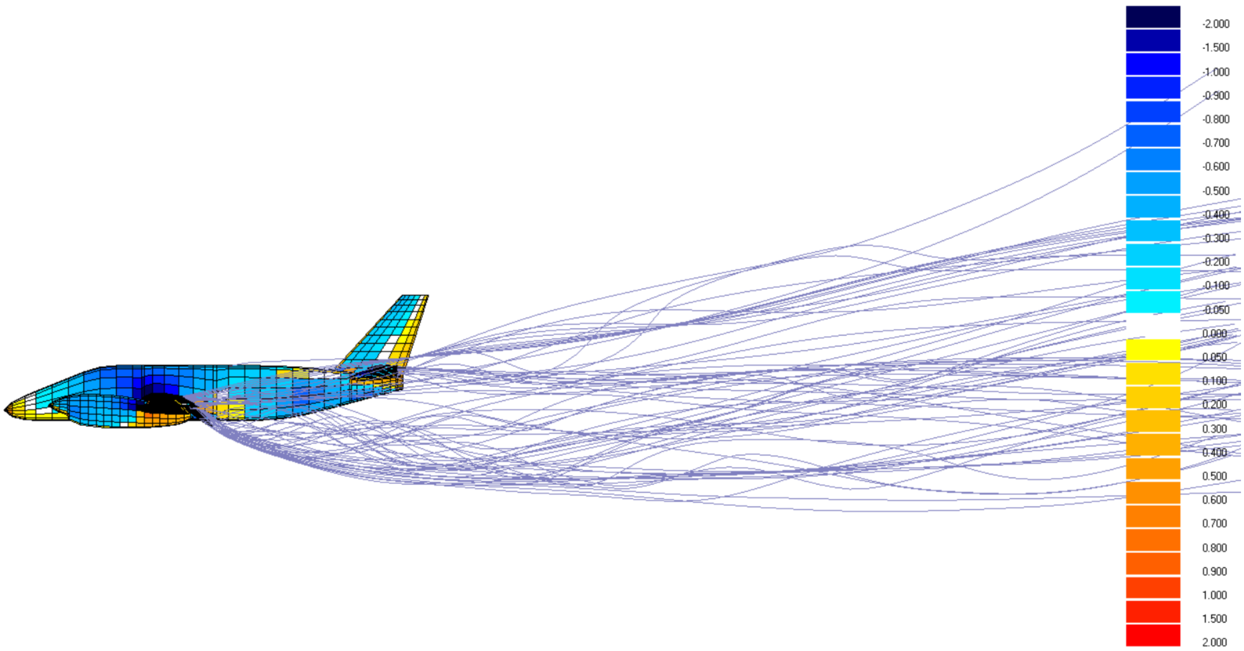


Fig. 3.4.3 Air flows behind the wing and stabilizer, wingtip vortices visualization (Landing mode: δ_{flaps} = 40°; M=0.16; Re=$7.63\cdot10^5$; AoA=8°).

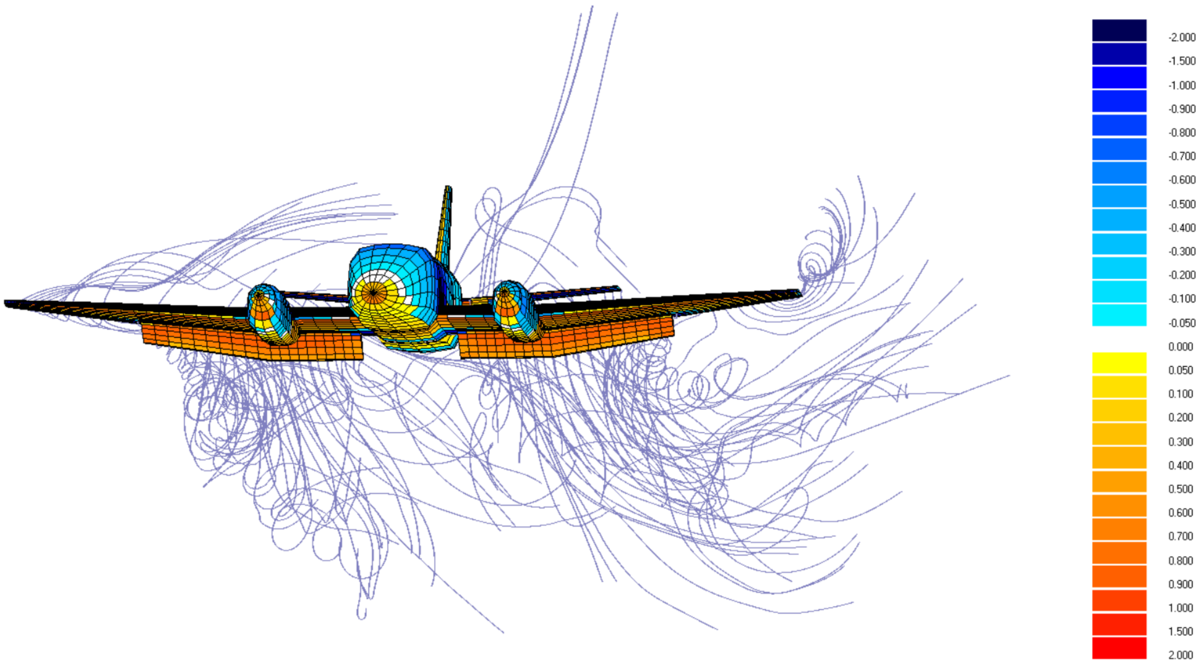


Fig. 3.4.4 Air flows behind the wing and stabilizer, wingtip vortices visualization (Landing mode: δ_{flaps} = 40°; M=0.16; Re=7.63·10^5; AoA=8°).

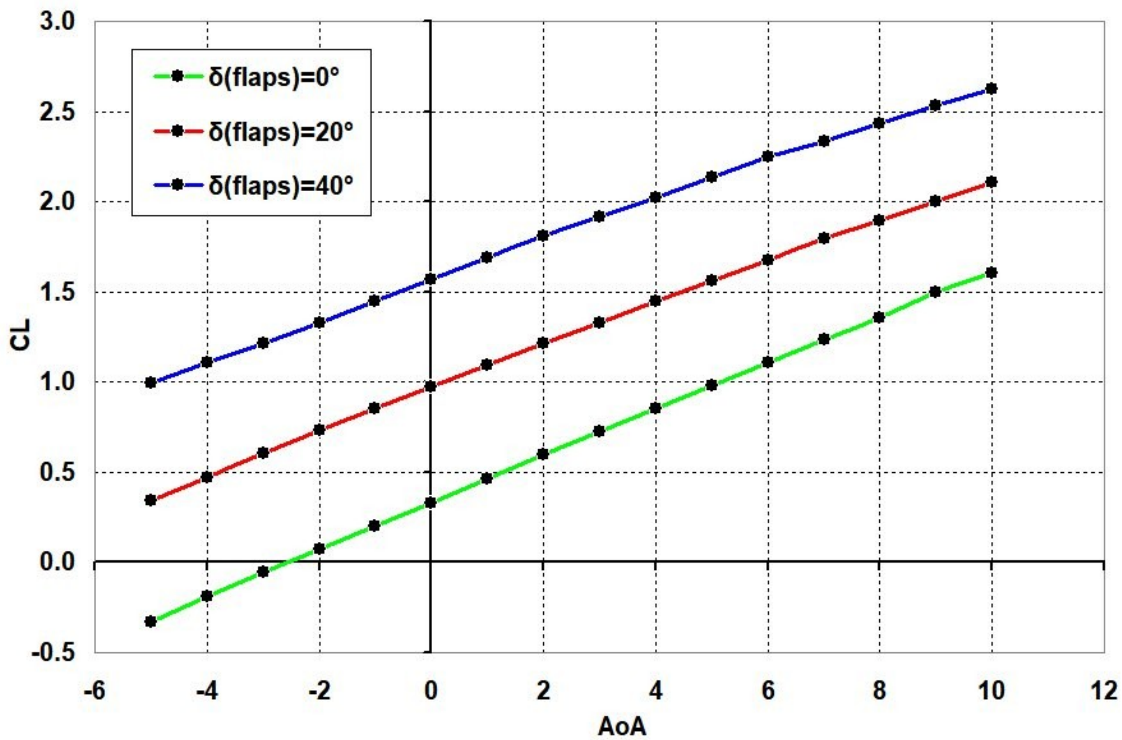


Fig. 3.4.5 Lift coefficient diagram (M=0.16; Re=7.63·10^5).

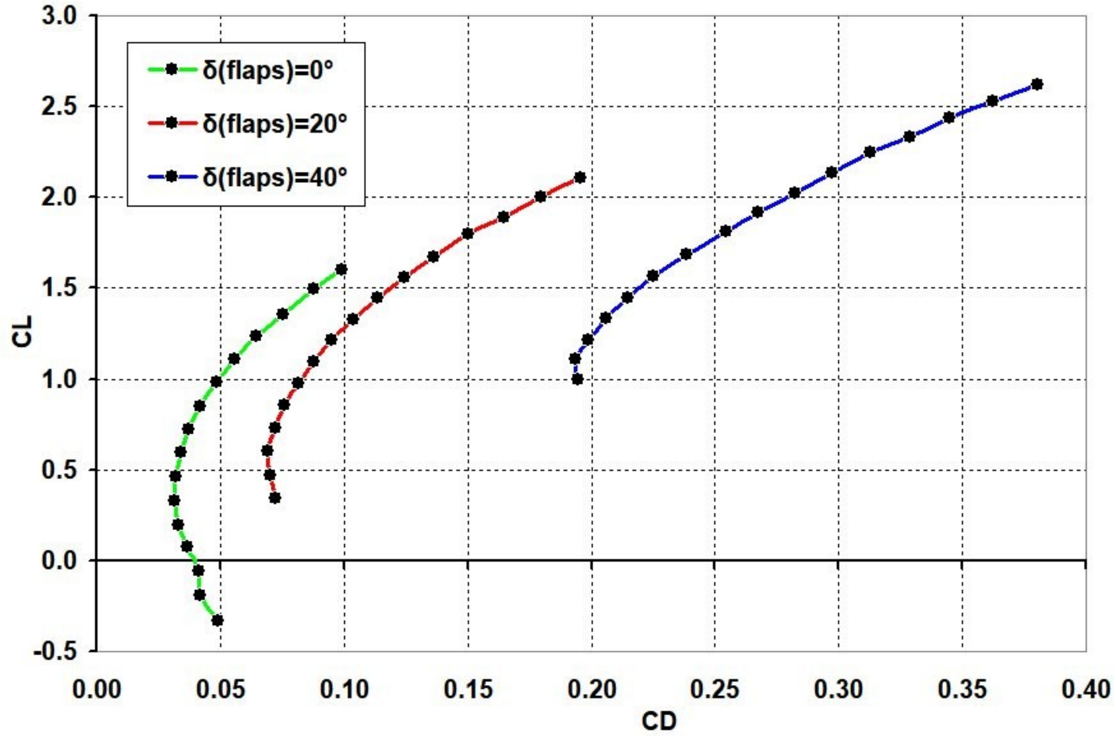


Fig. 3.4.6 Aircraft drag polar (M=0.16; Re=7.63·10^5).

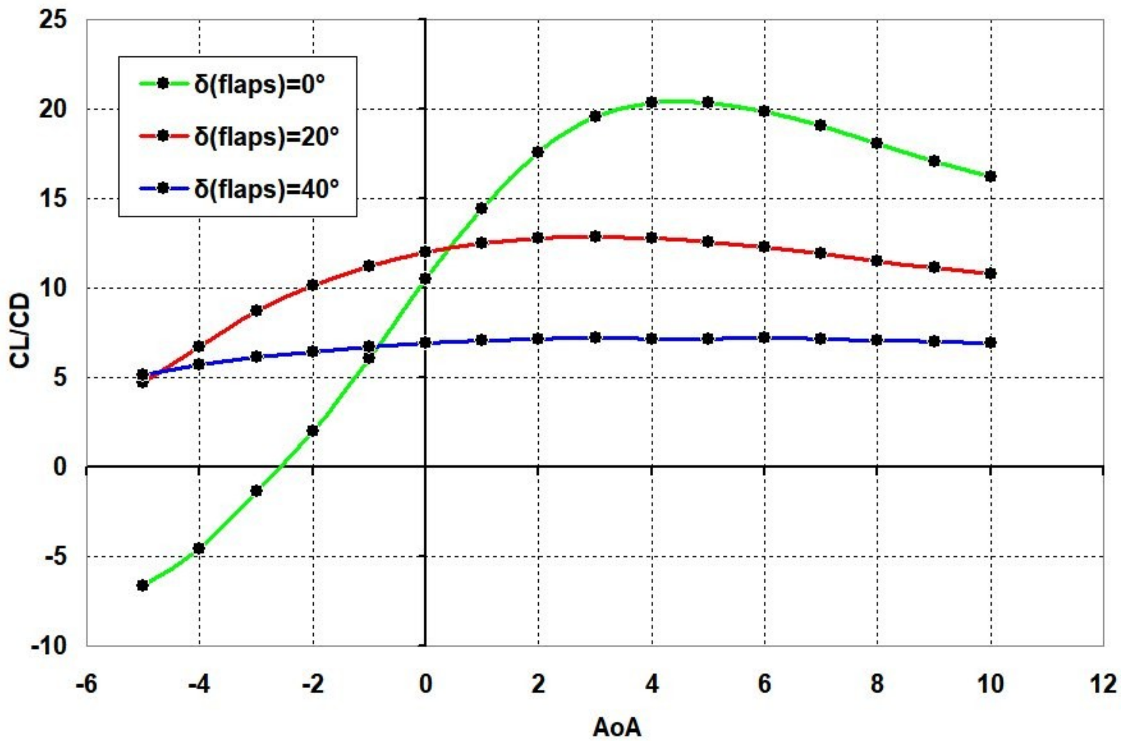


Fig. 3.4.7 Aircraft lift-to-drag ratio (M=0.16; Re=7.63·10^5).

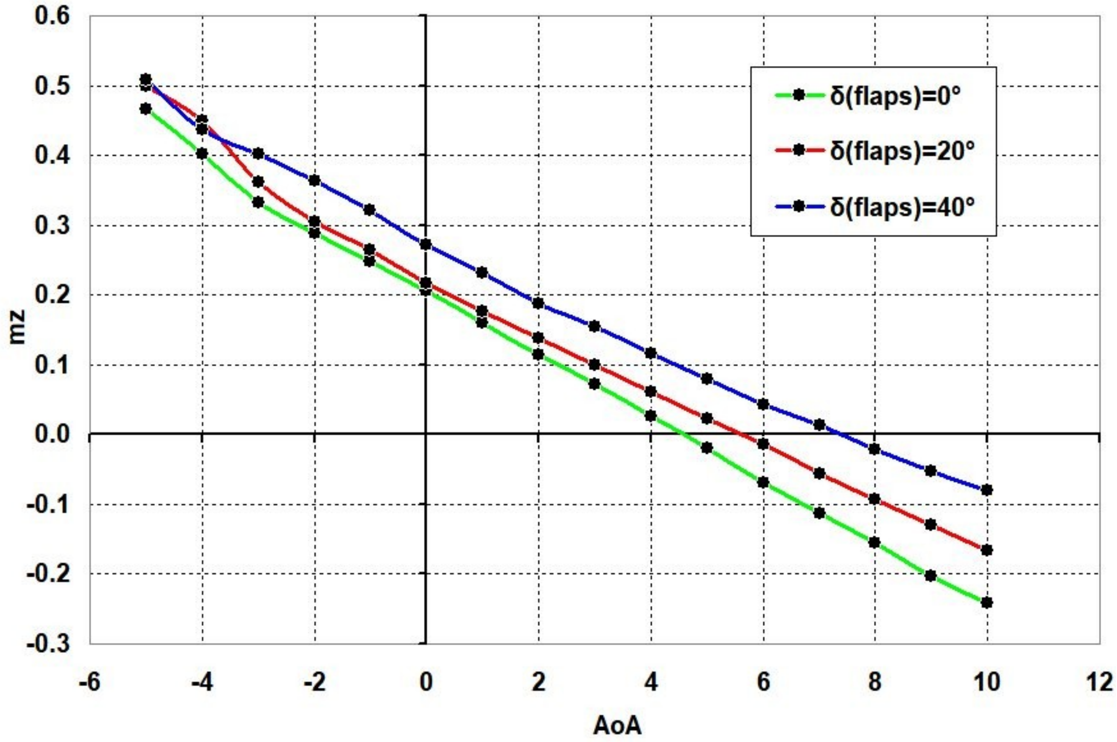


Fig. 3.4.8 Aircraft pitch moment coefficient (M=0.16; Re=$7.63 \cdot 10^5$).

Analyzing the obtained results, it is necessary to note some characteristic features.

1) Deflection of flaps at angles of 20 and 40 degrees leads to a significant increase in the lift force of the aircraft wing, which is very important for reducing takeoff and landing speeds.

2) The deflection of the wing flaps by 20 and 40 degrees leads to a significant decrease in the lift-to-drag value due to a large increase in wing drag, both due to an increase in the frontal projection area of the wing and due to vortex formation at the ends of the flaps.

3.5 Conceptual sketch geometry optimization based on simulation results.

The angle of installation for both the wing and the stabilizer was carefully considered to achieve the optimal characteristics for balancing the aircraft. By varying the installation angles within specific ranges, and iterative process was undertaken to achieve the ideal aircraft's geometry based on the simulation results.

The angle of installation for the wing was set from 0 to 3 degrees, and with this adjusting, the lift distribution and overall balance of the aircraft was optimized.

Similarly, the angle of horizontal stabilizer was varied form o to -2 degrees, which affected the aircraft's longitudinal stability to achieve optimal balance of the aircraft.

By considering the range of wing and horizontal stabilizer installation angles, it was possible to identify the optimal configuration that is essential for balance and aerodynamic efficiency for the aircraft.

3.6 Conclusion to the section.

In conclusion, the aerodynamic simulations conducted using the PANSYM program provide insights into the aircraft's behavior during cruise. The simulations represented the aircraft's geometry and considered realistic simulation with specific mode conditions. The results revealed the aerodynamic characteristics, including lift and drag coefficients, pitching moment, and pressure distribution. Based on these findings, the optimization process successfully refined the initial conceptual sketch geometry, leading to improve aerodynamic performance. The optimized geometry demonstrated enhanced efficiency and stability, indicating the effectiveness of the simulation-based design approach.

4 AIRCRAFT POWERPLANT DESIGN

4.1 Power-to-weight ratio calculations

4.1.1 The necessary power-to-weight ratio under the condition of ensuring a safe take-off with one failed engine:

$$N^{I}_{TO} = 1.5 \cdot \frac{6.67 \cdot V_{TO}}{\eta^{prop}_{TO}} \cdot \left(\frac{n_{eng}}{n_{eng}-1}\right) \cdot \left(\frac{1}{(CL/CD)^{\max}_{TO}} + tg\theta_{TO}\right) \quad \text{[W/kg]}$$

$V_{TO.} \approx 55.6$ m/s – climb speed during the take-off phase;

$\eta^{prop}{}_{TO} = 0.55$ – coefficient of performance for the propeller in take-off mode;

$n_{eng} = 2$ – number of engines;

$(CL/CD)^{max}{}_{TO} = 20$ – maximum lift-to-drag ratio of the aircraft during take-off phase;

$tg\theta_{TO} = 0.025$– aircraft climb gradient if $n_{eng} = 2$.

$$N^{I}_{TO} = 1.5 \; \frac{6.67 \;\; 55.6}{0.55} \left(\frac{2}{2-1}\right)\left(\frac{1}{20} + 0.025\right) = 151.7 \quad \text{[W/kg]}$$

4.1.2 The necessary power-to-weight ratio under the condition of ensuring that the required cruising speed is reached at the final stage of reaching the estimated flight height:

$$N^{II}_{TO} = \frac{g \cdot V_{CR}}{(CL/CD)^{\max}_{CR} \cdot \eta^{\max}_{CR} \cdot \sqrt{\Delta}} \quad \text{[W/kg]}$$

g = 9,81 kg·m/s^2;

$V_{CR} = 152.8$ m/s – aircraft approximate cruise speed;

$(CL/CD)^{\max}_{CR} = 17$ – maximum aircraft lift-to-drag ratio for cruise flight conditions;

$\eta^{\max}_{CR} = 0.75$ – coefficient of performance for the propeller in cruise mode;

$\Delta = \rho_H/\rho_0 = 0.38$ – relative air density at cruising altitude (cruise altitude to sea level air density ratio).

$$N^{II}_{TO} = \frac{9.81 \;\; 152.8}{17 \;\; 0.75 \;\; \sqrt{0.38}} = 190.7 \quad \text{[W/kg]}$$

4.1.3 The necessary power-to-weight ratio under the condition of ensuring the specified take-off runs distance:

$$N_{TO}^{III} = \frac{g \cdot V_{TO\min}}{\eta_{TO}^{prop}} \cdot \left[\frac{V^{2}{}_{TO\min}}{2 \cdot g \cdot L_{TO}} + \frac{1}{3} \cdot \left(2 \cdot f_{TO} + \frac{1}{(CL/CD)_{TO}^{\max}} \right) \right] \quad [W/kg]$$

g = 9,81 kg·m/s^2;

$V_{TO\min}$ – minimum take-off speed of the aircraft;

$$V_{TO\min} = 1.28 \cdot \sqrt{\frac{\overline{p}_0 \cdot g}{CL_{TO}}}$$

$$V_{TOmin} = 1.28 \sqrt{\frac{225 \cdot 9.81}{1.4}} = 50.8 \text{ m/s}$$

$\overline{p}_0$ = 225 kg/m^2 – average value of the MTOW-to-wing area ratio;

CL_{TO} = 1.4 – lift coefficient for the take-off configuration;

$\eta^{prop}{}_{TO}$ = 0.55 – coefficient of performance for the propeller in take-off mode;

L_{TO} = 650 m – approximate value for take-off distance;

f_{TO} – coefficient of friction for the landing gear wheels on the runway during take-off;

f_{TO} = 0.02 – for a concrete runway;

$(CL/CD)^{max}{}_{TO}$ = 20 – maximum lift-to-drag ratio of the aircraft during take-off phase;

$$N_{TO}^{III} = \frac{9.81 \cdot 50.8}{0.55} \left[\frac{50.8^2}{2 \cdot 9.81 \cdot 650} + \frac{1}{3} \left(2 \cdot 0.02 + \frac{1}{20} \right) \right] = 210.2 \quad W/kg$$

4.1.4 The largest value of the aircraft's power-to-weight ratio among those calculated above should be selected:

$$N_{TO} = \max \ (N_{TO}^{I}, N_{TO}^{II}, N_{TO}^{III})$$

$$N_{TO} = max(151.7,\ 190.7,\ 210.2);$$

$$N_{TO} = 210.2 \quad W/kg;$$

4.1.5 Calculation of the required take-off power of one engine:

$$N_0 = \frac{N_{TO} \cdot m_0}{n_{eng}} \quad [W]$$

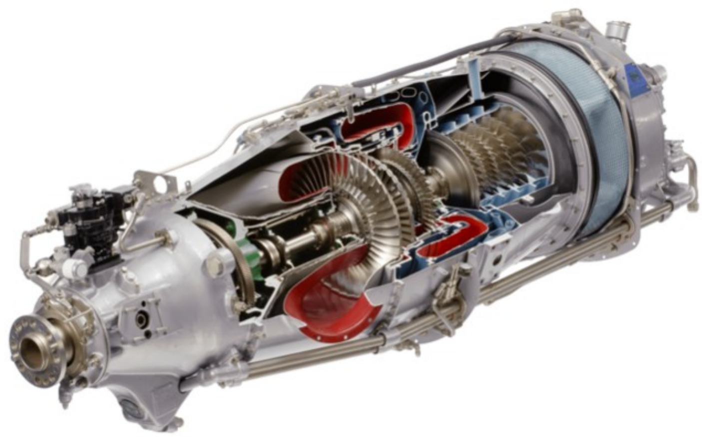
$$N_0 = \frac{210.2 \cdot 5965}{2} = 626\,921 \text{ W} = 627 \text{ kW};$$

m_0 – maximum take-off weight (MTOW) = 5965 kg;

n_{eng} = 2 – number of engines;

4.2 Engine selection

Pratt and Whitney PT6A-42 engine



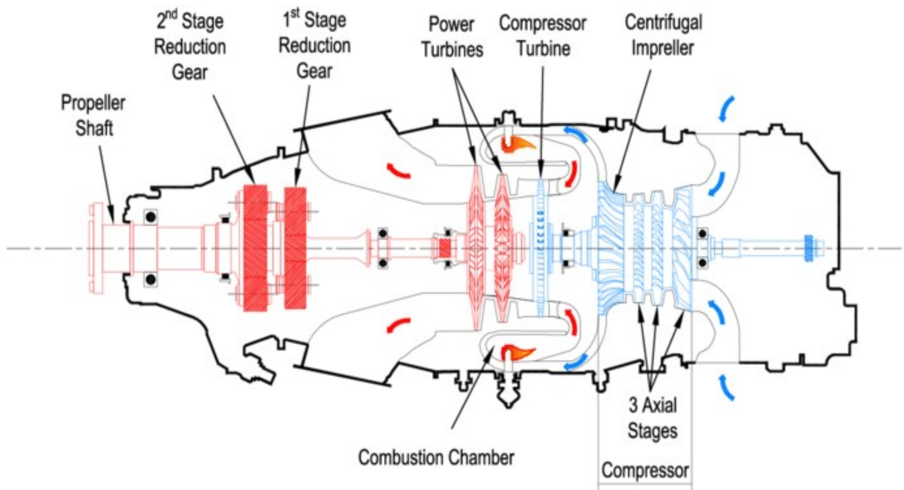


Table 4.2.1 Engine specifications

Manufacturer	Pratt & Whitney Canada	
Design	Compressor stages	4
	Gas generator stages	1
	Power turbine stages	1
	Control system	Hydromechanical
Dimensions	Length	1.7 m

	Width	0.48 m
	Height	0.48 m
Performance	Max. Continuous power	630 kW
	Max. takeoff power	630 kW
Rotation speeds	Ng RPM	37,468
	Output shaft RPM	2,200
Weights	Dry weight	183 kg

4.3 Conclusion to the section

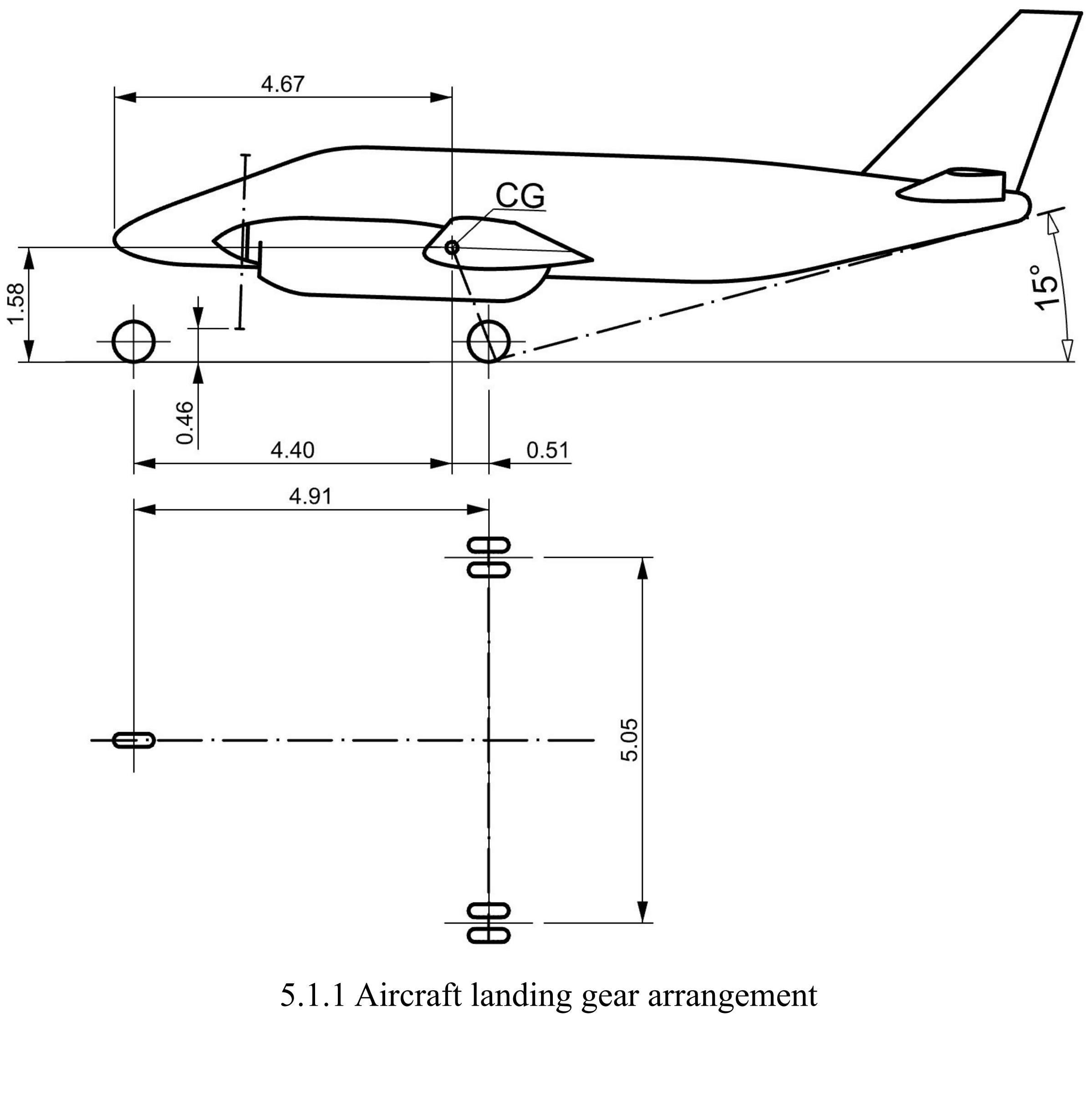
In this section of the thesis, the required ratio of the power to the weight of the aircraft was calculated according to various criteria, the largest value was chosen according to which the required engine power was calculated. According to the calculated value of the required power, the engine for the aircraft power plant was selected.

5 LANDING GEAR DESIGN

5.1 Landing gear arrangement

Tricycle landing gear, with two main wheels aft of the center of gravity and an auxiliary wheel forward of the center of gravity, will arranged.

By using tricycle landing gear, with the center of gravity is in front of the main wheels enables aircraft o achieve stability on the ground and makes it possible to be landed at a fairly large angle, where nose does not aligned with the runway. Also, this arrangement enhances forward visibility on the ground and allows a flat cabin floor for passenger and cargo loading.



5.1.1 Aircraft landing gear arrangement

5.2 Tire sizing

Choosing the number of wheels based on the aircraft parking weight:

$$W_p = m_0 \cdot g = 5965 \cdot 9.81 = 58.5 \text{ kN}.$$

To choose the landing gear wheels, we calculate the weight distribution:

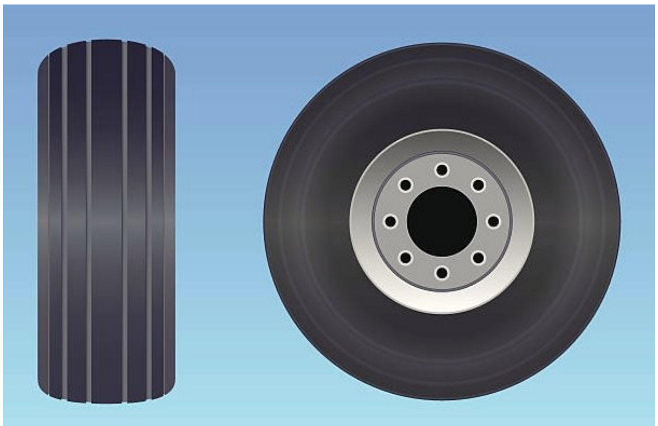
- at front gear leg – $W_{p\,fr}$ = (15%) W_p = 8.775 kN;
- at main gear legs – $W_{p\,main}$ = (85%) W_p = 49.725 kN.

The next step is to calculate the mass of the aircraft distributed on one separate wheel for the front $(W_{p\,fr})_1$ and main $(W_{p\,main})_1$ legs of the landing gear, depending on their number and the number of wheels on each of them:

$$(W_{p\,fr})_1 = W_{p\,fr} / 2 = 8.775 / 2 = 4{,}4 \text{ kN}.$$

$$(W_{p\,main})_1 = W_{p\,main} / (2 \cdot 2) = 49.725 / 4 = 12{,}4 \text{ kN}.$$

Based on the calculated distributed weight, we choose the type and size of wheels for the nose and main supports of the aircraft chassis.



5.2.1 The wheel for the main landing gear legs.

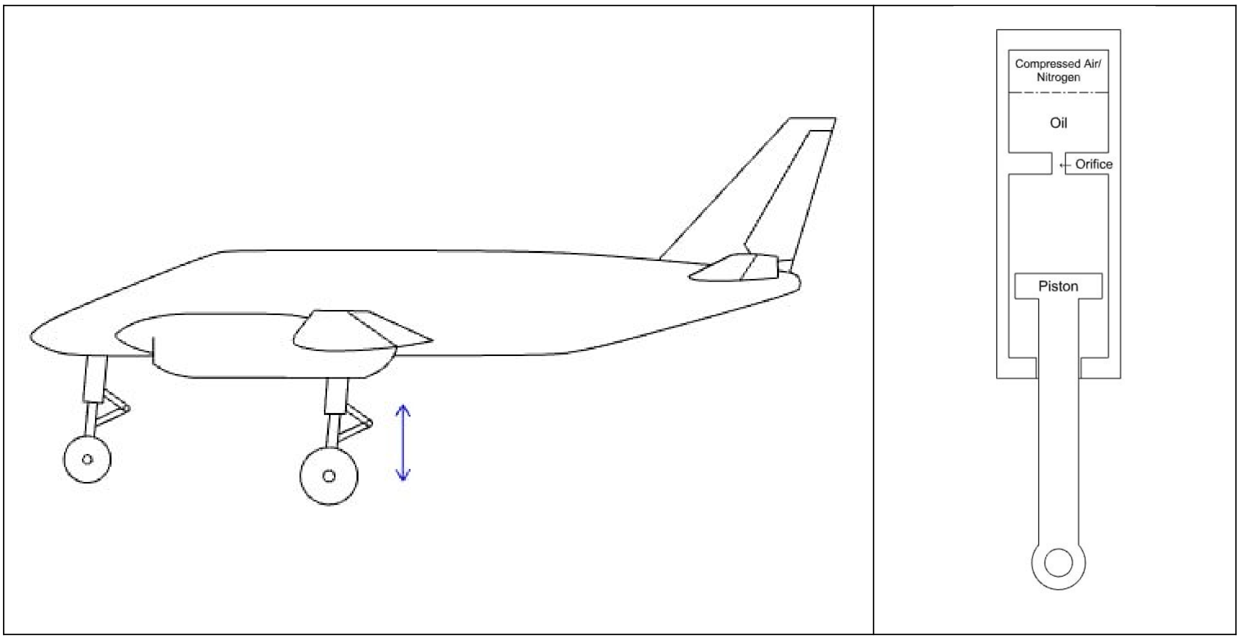
The characteristics of aviation wheels are shown in the table 5.2.1.

Table 5.2.1 The wheels for the landing gear.

Lending gear front leg wheels		Lending gear main legs wheels	
Dimensions	Maximum load at one wheel	Dimensions	Maximum load at one wheel
400x150 mm	9.25 kN	650x200 mm	14.5 kN

5.3 Shock-absorbers

Shock-absorber is essential to absorb shock of landing gear from a bad landing and smooth out ride when taxiing.



5.3.1 For Shock absorber, oleo shock-strut type will be used.

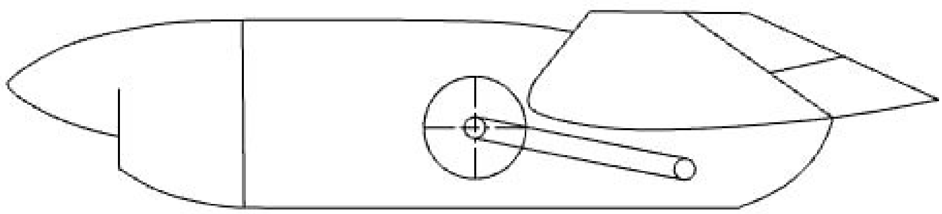
The oleo pneumatic shock-strut is a combination of a spring effect using compressed air with a damping effect using a piston which forces oil through a small orifice.

5.3.2 Landing gear main leg with the shock absorber.

By considering shock-strut, oleo must provide the full required amount of wheel deflection by itself, in order to lengthen the total landing gear height, and strong enough to deal with the lateral and braking loads of the wheels.

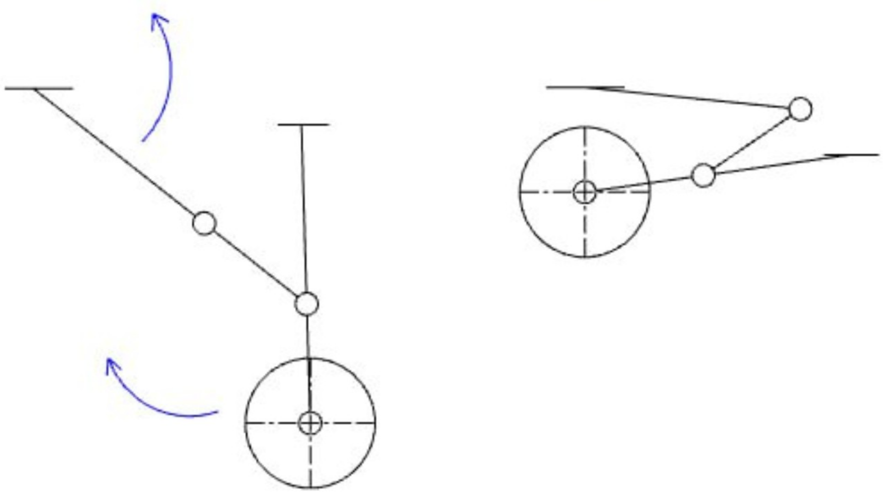
5.4 Gear-retraction kinematics

Aircraft retract the gear into the nacelle, reduces weight significantly because the wing and fuselage structure is uninterrupted.



5.4.1 The main landing gear layout inside the engine nacelle.

Landing gear retraction mechanism is based upon the four-bar linkage, which uses three bars connected by pivot, where the fourth bar being the aircraft structure. By loads passing through rigid bars and simple pivot, this mechanism of four-bar linkage offers a simpler and lightweight gear.



5.4.2 The main landing gear retraction kinematics.

From the mechanism above, the diagonal bar is called a “drag brace”, which withstands the aerodynamic loads and the braking loads. The drag brace is located in front of the wheel with gear retracting forward, which is beneficial for air loads to blow the gear down in a hydraulic failure situation, and it breaks at the middle of retraction.

Landing gear leg is positioned to the aircraft at the “pivot point”, which located along the perpendicular bisector to the line connecting the up and down position of the wheel.

5.5 Conclusion to the section

In this section of the thesis, the chassis for the aircraft was designed. The design was based on the analysis of the chassis schemes of aircraft of the same class and the determination of their main characteristics. The design scheme of the aircraft chassis was selected; the main geometric characteristics were calculated. The wheels for the landing gear legs were chosen based on calculations, taking into account the aircraft's stall weight. The design of the leg racks for the chassis was determined, and the type of shock absorbers was selected. The kinematics of main legs retraction, as well as their layout in the engine nacelles was calculated.

6 COCKPIT AND PASSENGER COMPARTMENT LAYOUT

6.1 Crew station layout

The crew station layout is crucial since it directly influences the effectiveness and efficiency of the crew, therefore it is important to provide optimal visibility, accessibility, and comfort for the pilot.

The primary consideration is the range of pilot sizes to accommodate. Since, the general utility aircraft's cockpits are designed by customers need, but it is preferred for those who are under 1.8 m tall. Moreover, seating arrangement is required with all necessary flight instruments and control systems, including primary flight display, engine instruments, communication and navigation equipment, which are easily accessible to operate without any excessive workload or distraction for the pilot. Therefore, the overall length of cockpit is suggested about 2.5 m for a two crew members with all the required devices contained.

In addition, to achieve suitable visibility, consideration of angles of visions from the location of pilot's eyes are important to ensure safety. Over-nose vision is crucial especially during landing. Optimal choice of the general utility aircraft is to have 5 to 10 degree of over-nose vision angle. Over-the side vision of 35-degree angle to look down without head movement of pilot is desirable. For vision angle upward needs to be at least 20 degree above the horizon to obtain unobstructed sight forward and upward.

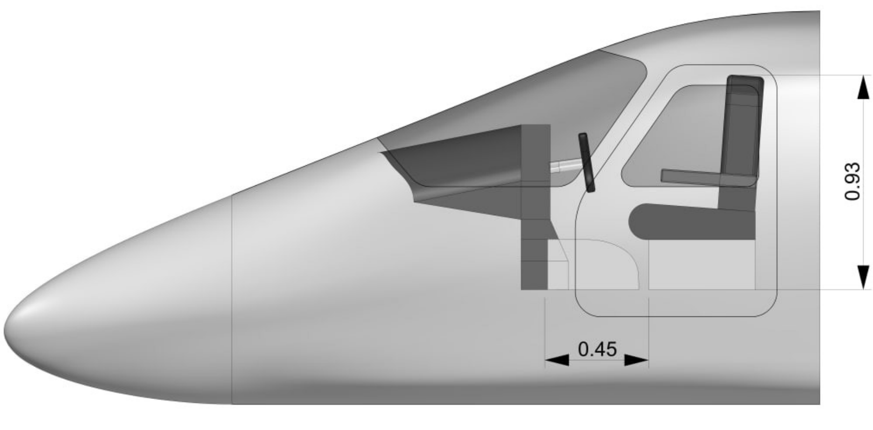


Fig. 6.1.1 Pilots cockpit layout - right view.

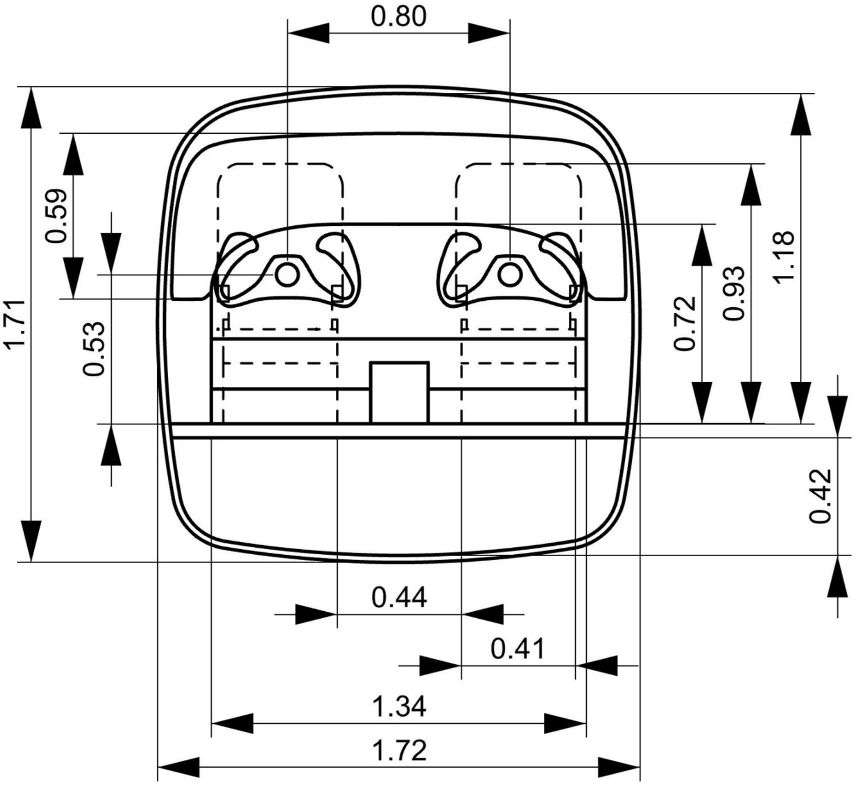


Fig. 6.1.2 Pilots cockpit layout - cross section view.

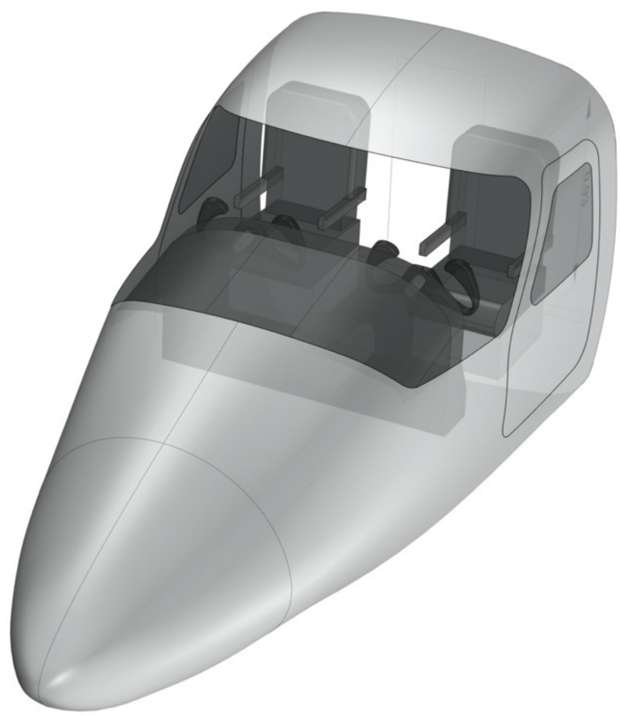


Fig. 6.1.3 Pilots cockpit general view.

6.2 Passenger or cargo compartment layout.

The layout of the passenger or cargo compartment allows aircraft to optimize versatility by accommodating different operational requirements.

The most priority of passenger transport is that the layout should satisfied passenger comfort and safety. It can be carried out by including appropriate sized and comfortable seat, proper headroom and seat pitch, sufficient legroom as well as the aisle width.

Additionally, the cabin should contain with necessary equipment such as laboratory, emergency equipment, and cabin amenities.

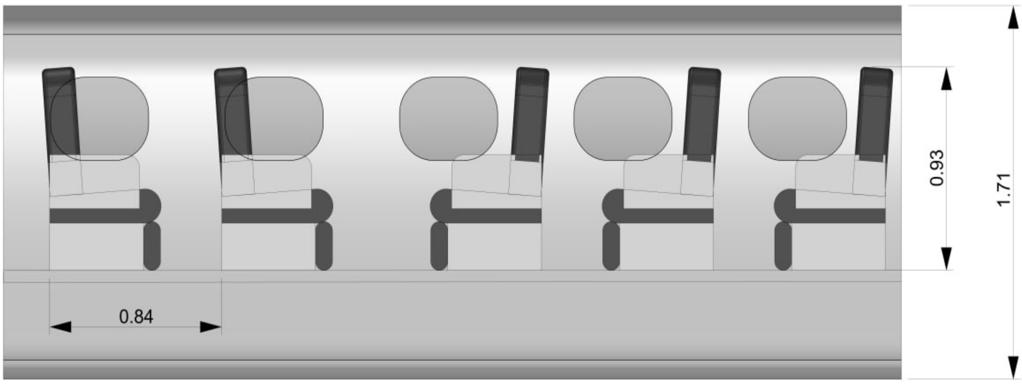


Fig. 6.2.1 Right view of passenger cabin layout.

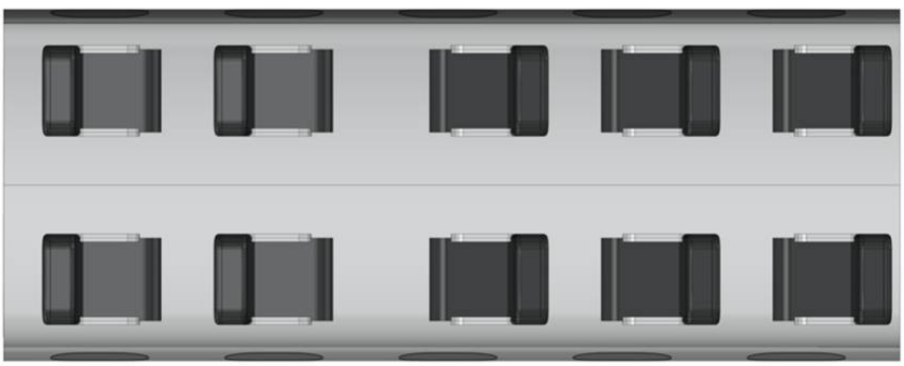


Fig. 6.2.2 Top view of passenger cabin layout.

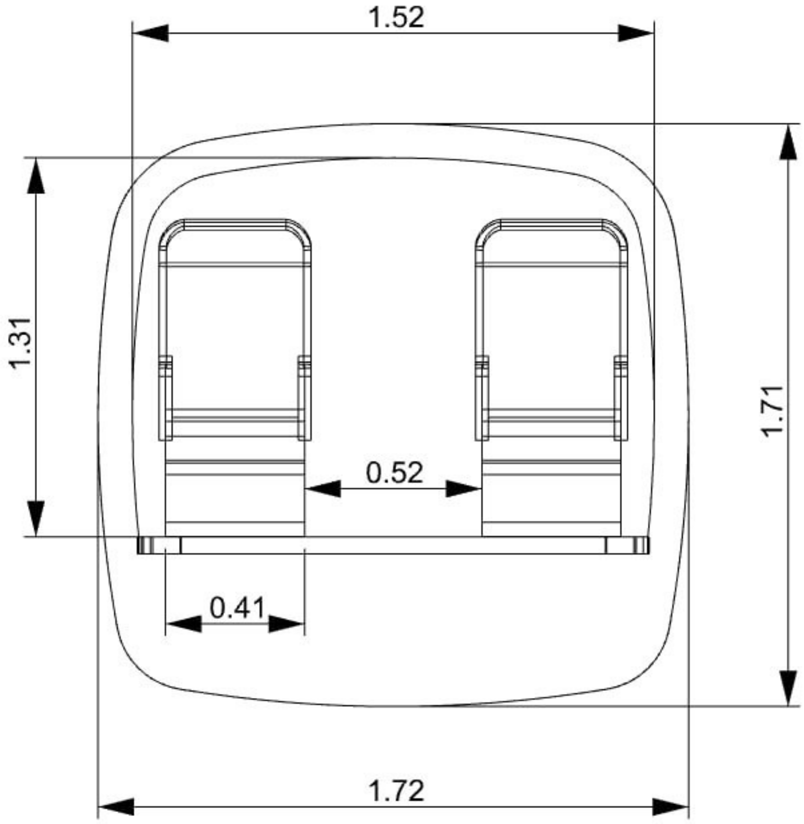


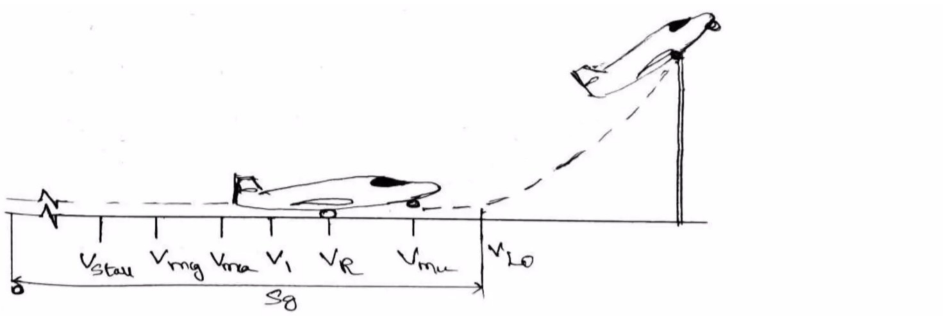
Fig. 6.2.1 Passenger cabin layout - cross section view.

6.3 Conclusion to the section

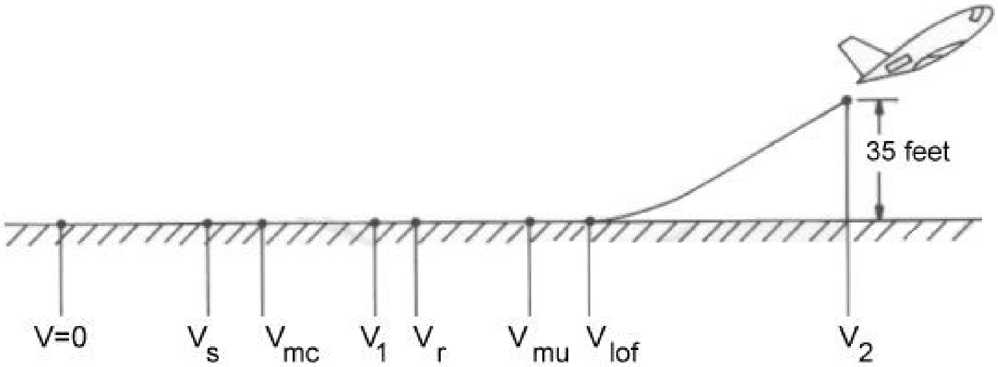
In conclusion, the cockpit and passenger or cargo compartment layouts are vital to increase utility for both pilots and passengers. The crew station layout should be regarded for suitable position and angle of the seat and ease accessibility to the operation, to perform stable flight. The passenger compartment layout should offer appropriate space and equipment (amenities) to the passenger achieving passenger comfort, which enhances the overall travel experience. Therefore, passenger needs should be considered to satisfy customers demand in various operating missions.

7 ESTIMATED AIRCRAFT FLIGHT PERFORMANCE

7.1 Aircraft takeoff characteristics



1. **V$_{stall}$:** Stalling velocity (L=W)
2. **V$_{mcg}$:** minimum control speed on the ground (Vertical Fin-Rudder)
3. **V$_{mca}$:** minimum control speed in the air
4. **V$_1$:** decision speed
5. **V$_R$:** takeoff rotational speed (Elevator)
6. **V$_{mu}$:** minimum unstick speed (AOA)
7. **V$_{LO}$:** lift-off speed (1.1 **V$_{stall}$**)



7.1.1 Minimum airspeed (with flaps in take-off configuration)

$$V_{stall}^{TO} = 1.28 \cdot \sqrt{\frac{m_0 \cdot g}{A_W \cdot CL_{TO}}}, \text{ [m/s]}$$

m_0 - maximum take-off weight (MTOW) = 5 965 [kg];

g = 9,81 [m/s^2];

A_W – wing area= 26.5 [m^2];

CL_{TO} – lift coefficient for the take-off configuration= 1.4;

$$V_{stall}^{TO} = 1.28 \sqrt{\frac{5965 \;\; 9.81}{26.5 \;\; 1.4}} = 50.8 \text{ m/s}$$

7.1.2 Operational take-off speed

$$V_{LO} \geq 1{,}1 \cdot V_{stall}^{TO}$$

$$V_{LO} \geq 1.1 \;\; 50.8 \quad V_{LO} \geq 55.9 \text{ m/s}$$

7.1.3 Speed at the end of the first stage of take-off (flaps in take-off configuration, landing gear extended)

$$V_2 \geq 1{,}2 \cdot V_{stall}^{TO}$$

$$V_2 \geq 1.2 \;\; 50.8 \quad V_2 \geq 61 \text{ m/s}$$

7.1.4 Calculated take-off distance

$$L_{TO} = \frac{V_{LO}^2}{2 \cdot g} \cdot \frac{1}{\dfrac{N_{eng} \cdot n_{eng} \cdot \eta_{TO}^{prop}}{V_{LO} \cdot m_0 \cdot g} - \dfrac{1}{3} \cdot \left(2 \cdot f_{TO} + \dfrac{1}{(CL/CD)_{TO}^{max}} \right)}, \quad [m]$$

N_{eng}^{max} = 630 000 W - take-off (maximum) power of one engine ;

n_{eng} – number of engines, $n_{eng} = 2$;

$\eta^{prop}{}_{TO}$ = 0,5..0,6 – coefficient of performance for the propeller in take-off mode = 0.55;

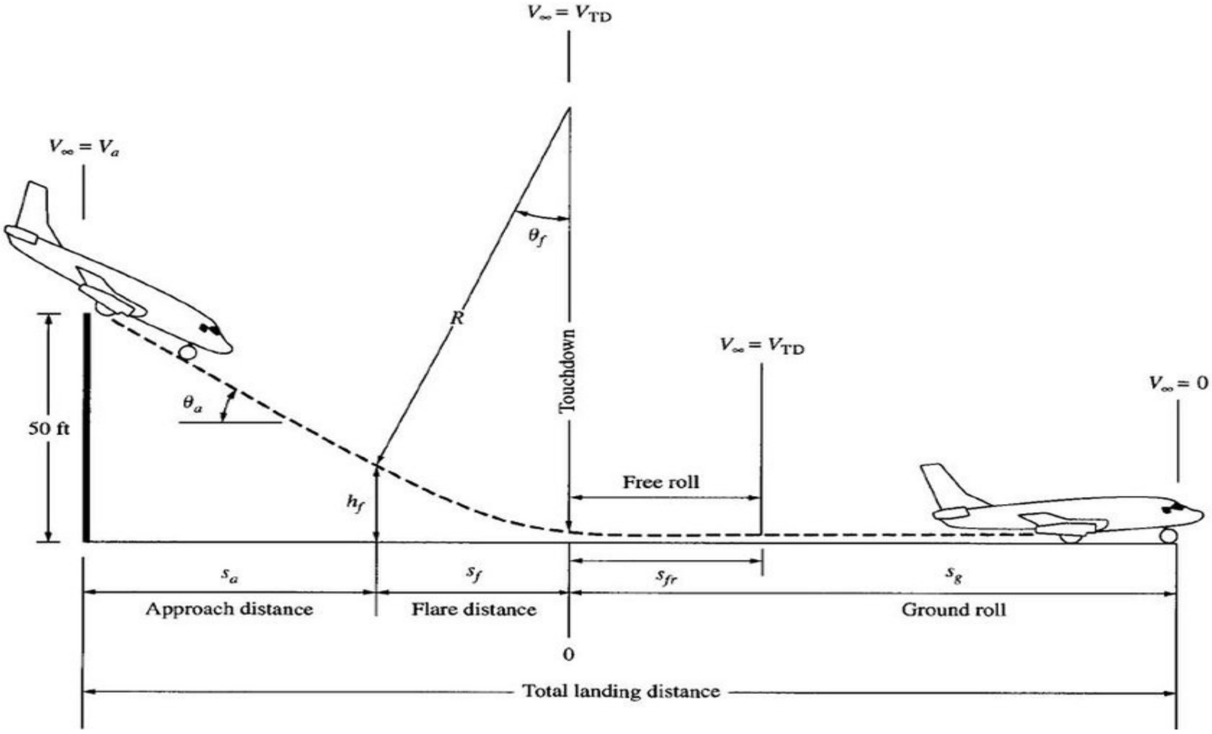
f_{TO} – friction coefficient for the landing gear wheels on the runway during take-off;

f_{TO} = 0,02 – for a concrete runway;

$(CL/CD)^{max}{}_{TO}$ = 12.9 – maximum lift-to-drag ratio of the aircraft during take-off phase

$$L_{TO} = \frac{56^2}{2 \;\; 9.81} \; \frac{1}{\dfrac{630000 \;\; 2 \;\; 0.55}{56 \;\; 5965 \;\; 9.81} - \dfrac{1}{3} \left(2 \;\; 0.02 + \dfrac{1}{12.9} \right)} = 880 \text{ m}$$

7.2 Aircraft landing characteristics



7.2.1 Minimum airspeed (with flaps in landing configuration)

$$V_{stall}^{LND} = 1.28 \cdot \sqrt{\frac{m_0 \cdot (1 - 0{,}985 \cdot \overline{m}_{FUEL}) \cdot g}{A_W \cdot CL_{LND}}}, \text{ [m/s]}$$

$\overline{m}_{FUEL}$ - fuel weight coefficient $\overline{m}_{FUEL}$ = 0.15;

CL_{LND} – lift coefficient for the landing configuration = 2.5;

A_W – wing area= 26.5 [m^2];

$$V_{stall}^{LND} = 1.28 \sqrt{\frac{5965 \ (1 - 0.985 \ 0.15) \ 9.81}{26.5 \ 2.5}} = 35 \text{ m/s}$$

7.2.2 Approach speed

$$V_{APP} \geq 1{,}3 \cdot V_{stall}^{LND}$$

$$V_{APP} \geq 1.3 \ 35 \qquad V_{APP} \geq 45.5 \text{ m/s}$$

7.2.3 Touchdown speed

$$V_{TD} \geq 1{,}1 \cdot V_{stall}^{LND}$$

$$V_{TD} \geq 1.1 \ 35 \qquad V_{TD} \geq 38.5 \text{ m/s}$$

7.2.4 Calculated landing distance

$$L_{LND} = \frac{0{,}94}{CL_{LND}} \cdot \frac{p_{LND}}{\frac{N_{eng}^{max} \cdot \overline{R}_{prop} \cdot n_{eng} \cdot \eta_{LND}^{prop}}{V_{TD} \cdot g \cdot m_0 \cdot (1 - 0{,}985 \cdot \overline{m}_{FUEL})} + \frac{1}{2} \cdot \left(3 \cdot f_{LND} + \frac{1}{(CL/CD)_{LND}^{max}}\right)}, \text{ [m]}$$

CL_{LND} – lift coefficient for the landing configuration = 2.5;

p_{LND} - weight-to-wing area ratio for the aircraft in landing configuration,

$$p_{noc} = \frac{m_0 \cdot (1 - 0{,}985 \cdot \overline{m}_{FUEL}) \cdot g}{A_W},$$

$$P_{LND} = \frac{5965 \ (1 - 0.985 \ 0.15) \ 9.81}{26.5} = 1882$$

$\overline{m}_{FUEL}$ - fuel weight coefficient $\overline{m}_{FUEL}$ = 0.15;

A_W - wing area [m] = 26.5;

N_{eng}^{max} - maximum power of one engine [W] = 452 445;

n_{eng} – number of engines, $n_{eng} = 2$;

$\overline{R}_{prop}$ - propeller reversal factor; $\overline{R}_{prop}$ ≈ 0,35..0,45 = 0.4;

η^{prop}_{LND} = 0,5..0,6 – coefficient of performance for the propeller in landing mode = 0.55;

f_{LND} = 0,5..0,6 – friction coefficient for the landing gear wheels on the runway during landing= 0.55;

$(CL/CD)_{LND}^{max}$ = 7.18 - maximum lift-to-drag ratio of the aircraft during landing phase.

$$L_{LND} = \frac{0.94}{2.5} \ \frac{1882}{\frac{630000 \ 0.4 \ 2 \ 0.55}{39 \ 9.81 \ 5965 \ (1 - 0.985 \ 0.15)} + \frac{1}{2}\left(3 \ 0.55 + \frac{1}{7.18}\right)} = 682 \text{ m}$$

7.3 Maximum speed in horizontal flight

$$V_{max} = 2.5 \cdot \sqrt[3]{\frac{N_{eng}^{max} \cdot n_{eng} \cdot \eta_{CR}^{prop}}{A_W \cdot \Delta}}, \text{ [m/s]}$$

N_{eng}^{max} = 630 000 W - maximum power of one engine;

n_{eng} – number of engines, $n_{eng} = 2$;

$\eta^{prop}{}_{CR}$ = 0,8..0,85 – coefficient of performance for the propeller in cruise mode = 0.8;

A_W – wing area [m] = 26.5;

$\Delta = \frac{\rho_H}{\rho_0}$ = 0.38 – relative air density at cruising altitude .

ρ_H - air density at cruising altitude [kg/m^3];

ρ_0 - air density at sea level [kg/m^3].

$$V_{MAX} = 2.5\ \sqrt[3]{\frac{630000\ \ 2\ \ 0.8}{26.5\ \ 0.38}} = 116.1 \text{ m/s}$$

7.4 Cruise airspeed

$$V_{CR} \approx (0{,}75..0{,}85) \cdot V_{max}$$

$$V_{CR} = 0.85\ \ 116.1 = 98.7 \text{ m/s}$$

7.5 Aircraft flight performance calculation results

Operational take-off speed [km/h]	201
Take-off distance [m]	880
Landing approach speed [km/h]	164
Landing touchdown speed [km/h]	139
Landing distance [m]	682
Max. speed in horizontal flight [km/h]	418
Cruise airspeed [km/h]	355

7.6 Conclusion to the section

This section of the thesis presents calculations of approximate values of the main flight parameters of an aircraft, such as takeoff and landing distances, as well as characteristic speeds for the main stages of flight. The obtained values of the parameters allow us to make an assessment of how effective and successful the aircraft project turned out to be.

CONCLUSION

In conclusion, this thesis has presented the comprehensive process of conceptual design and development a new twin-engine utility aircraft, aiming to achieve effective transportation of passengers, luggage, and small cargo within a regional range of up to 3,500 km. The research followed as a systematic approach by covering various stages and considerations crucial to aircraft design.

The initial phase involved a conducting overview of existing twin-engine utility aircraft, collecting statistical data on their flight characteristics and design features. Through this analysis, key technical and operational parameters were identified for the future calculations, resulting in the compilation of project specification.

Following stages focused on essential calculations and aerodynamic simulations. MTOW and geometric parameters were determined, leading to the creation of a detailed aircraft sketch. Aerodynamic simulations, utilizing numerical and visual methods, provided insights into the general aerodynamic characteristics of the aircraft.

The calculation of the power-to-weight ratio leads to the selection of an appropriate engine for the aircraft's powerplant, ensuring optimal performance. Furthermore, considerations were given to the design of the landing gear, cockpit, and passenger cabin arrangement to achieve functionality, comfort, and safety for both crew and passengers.

By utilizing the obtained data, calculation for the main flight characteristics of the aircraft project were conducted. These values provided a broad assessment of the aircraft's performance potential.

The results of this thesis present a successful development of a conceptual twin-engine utility aircraft, to meet the transportation requirements of passengers, luggage, and small cargo within a regional range. The intensive analysis, calculations, simulations and design considerations have contributed to the creation of a appropriate technical proposal.

Overall, this study demonstrates the importance of a systematic and comprehensive approach in conceptual aircraft design. The proposed aircraft holds great potential for addressing the transportation needs within its designated range, and it is expected that this research will inspire further advancements and contributes to the utility aircraft sector.

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