МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Кафедра конструкції літальних апаратів

«ДОПУСТИТИ ДО ЗАХИСТУ»
Завідувач кафедри
д.т.н., проф.
_____________________Сергій ІГНАТОВИЧ
(підпис)
« _____»___________________ 2022 р.

ДИПЛОМНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ «БАКАЛАВР»
ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Аванпроект середньомагістрального пасажирського літака місткістю до 170 пасажирів»

Виконала: ____________ **Ден Шуан**

Керівник: канд.техн.наук ____________ **Володимир КРАСНОПОЛЬСЬКИЙ**

Нормоконтролер:
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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Department of Aircraft Design

PERMISSION TO DEFEND
Head of department
Dr.Sc., Professor
________ Sergiy IGNATOVYCH
«___» ___________ 2022

BACHELOR DEGREE THESIS
ON SPECIALTY
"AVIATION AND AEROSPACE TECHNOLOGIES"

Topic: "Preliminary design of the mid-range passenger aircraft with up to 170 seats capacity"

Prepared by:	__________	**Deng SHUANG**
Supervisor: PhD	__________	**Volodymyr KRASNOPOLSKII**
Standard controller: **PhD, associate professor**	__________	**Sergiy KHYZHNYAK**

Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет
Кафедра конструкції літальних апаратів
Освітній ступінь «Бакалавр»
Спеціальність 134 «Авіаційна та ракетно-космічна техніка»
Освітньо-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н., проф.
__________ Сергій ІГНАТОВИЧ
«___» __________ 2022 рік

ЗАВДАННЯ
на виконання дипломної роботи студентки

ДЕН ШУАН

1. Тема роботи: «Аванпроект середньомагістрального пасажирського літака місткістю до 170 пасажирів», затверджена наказом ректора №489/ст від 10 травня 2022 року.

2. Термін виконання проекту: з 23 травня 2022 р. по 19 червня 2022 р.

3. Вихідні дані до роботи: максимальна кількість пасажирів 170, крейсерська швидкість 871 км/год, дальність польоту 8000 км, крейсерська висота польоту 11 км.

4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить моделювання силових елементів фюзеляжу.

5. Перелік обов’язкового графічного матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), моделювання силових елементів фюзеляжу під навантаженням (А3×2).

6. Календарний план-графік:

№ пор	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	23.05.2022 – 26.05.2022	
2	Вибір та розрахунок параметрів проєктованого літака.	27.05.2022 – 30.05.2022	
3	Виконання компонування літака та розрахунок його центрування.	31.05.2022 – 03.06.2022	
4	Розробка креслень по основній частині дипломної роботу.	04.06.2022 – 06.06.2022	
5	Моделювання конструкції фюзеляжу та розробка креслень по спеціальній частині.	07.06.2022 – 11.06.2022	
6	Оформлення пояснювальної записки та графічної частини роботи.	12.06.2022 – 13.06.2022	
7	Захист дипломної роботи.	14.06.2022 – 19.06.2022	

7. Дата видачі завдання: 23 травня 2022 рік.

Керівник дипломної роботи ____________ Володимир КРАСНОПОЛЬСЬКИЙ

Завдання прийняв до виконання ____________ Ден ШУАН

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of Aircraft Design
Academic degree "Bachelor"
Specialty 134 "Aviation and aerospace technologies"
Educational poffesional program "Aircraft equipment"

APPROVED BY
Head of the Department Dr.Sc., Professor
__________ Sergiy IGNATOVYCH
«___» _________ 2022

TASK
for the bachelor degree thesis

DENG SHUANG

1. Topic: "Preliminary design of the mid-range passenger aircraft with up to 170 seats capacity" confirmed by Rector's order №489/ст 10.05.2022.

2. Thesis term: since 23.05.2022 till 19.06.2022.

3. Initial data: cruise speed 871 km/h, flight range 8000 km, operating altitude 11 km, 170 passengers.

4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part: stess-strain analysis of the fusrlage structure.

5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), modelling of the fuselage structure (A3×2).

6. Thesis schedule:

#	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	23.05.2022 – 26.05.2022	
2	Selection and calculation of the aircraft designed parameters.	27.05.2022 – 30.05.2022	
3	Performing of aircraft layout and centering calculation.	31.05.2022 – 03.06.2022	
4	Development of drawings on the thesis main part.	04.06.2022 – 06.06.2022	
5	Modelling of the fuselage structure and making drawings on a special part.	07.06.2022 – 11.06.2022	
6	Formatting an explanatory note and a graphic part of the diploma work.	12.06.2022 – 13.06.2022	
7	Defense of the diploma work.	14.06.2022 – 19.06.2022	

7. Date: 23.05.2022.

Supervisor ____________ Volodymyr KRASNOPOLSKII

Student ____________ Deng SHUANG

РЕФЕРАТ

Дипломна робота «Аванпроект середньомагістрального пасажирського літака місткістю до 170 пасажирів» містить:

52 сторінок, 16 рисунків, 21 таблиць, 8 літературних посилань

Цей проект спрямований на розробку великого реактивного магістрального авіалайнера, придатного для майбутнього розвитку, шляхом вивчення існуючої моделі A340 та прогнозування майбутнього ринку великих пасажирських літаків у моїй країні. Завдяки аналізу оригінального A340 компонування салону та кабіни було перероблено. Ширину коридору, відстань між передніми і задніми сидіннями, а також відстань від сидіння до стінки салону розраховували за формулою в посібнику. Обчислено кожен аеродинамічний профіль і обрано тип крила, щоб підвищити опір підйому. За допомогою аналізу шасі обрано модель, яка підходить до шини шасі. Збільшено тягу двигуна і зменшено витрату палива. Літак розрахований на 170 місць і має запас ходу 8000 кілометрів. Як силову установку він використовує 4 двигуни, які можна застосовувати на регіональних маршрутах і на далеких маршрутах, покращуючи універсальність між різними маршрутами. У промисловому ланцюжку сучасного виробництва великі літаки безперечно займають вершину, і цей випускний проект дає рекомендації щодо ескізного проектування великих пасажирських літаків.

Пасижарський літак, аваніпроект літака, центрування літака, компанування пасажирської кабіни, розрахунок на міцність, аналіз напружено деформованого стану

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Performed	Dena			ABSTRACT	Letter	Sheet	Sheets
Supervisor	Krasnopolskii						
Adviser					402 ASF 134		
Stand.cont.	Khizhnuak S.						
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ABSTRACT

Explanatory note to the diploma work "Preliminary design of the mid-range passenger aircraft with up to 170 seats capacity" contains:

52 pages, 16figures, 21 tables, 8 references

This project aims to design a large jet trunk airliner suitable for future development by studying the existing model A340 and forecasting according to the future large passenger aircraft market in my country. Through the analysis of the original A340, the layout of the cabin and cab was redesigned. The width of the corridor, the distance between the front and rear seats, and the distance from the seat to the cabin wall were calculated using the formula in the manual. Calculate each airfoil and select the type of wing to make the lift resistance higher. Through the analysis of the landing gear, choose the model suitable for the tire of the landing gear.Increase engine thrust and reduce fuel consumption. The aircraft has 170 seats and has a range of 8000 kilometers. It uses 4 engines as the power plant, which can be applied to regional routes and long-distance routes, improving the versatility between different routes. Compared to twin-engine airliners, which offer the highest yield and lower operating costs on extended-haul routes from regional routes to twin-engine ETOPS, quad-engine airliners have the distinct advantage of providing a variety of capabilities on long- and ultra-long-haul routes. In the industrial chain of modern manufacturing, large aircraft are indisputably at the top, and this graduation project provides guidance for the preliminary design of large passenger aircraft.

Passenger aircraft, preliminary design, center of gravity calculation, passenger cabin layout, strength calculation, stress-strain analysis

Forma	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 22 11S 00 00 00 04 TW	Task for work	1	
	2	NAU 22 11S 00 00 00 04	mid-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
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Done by	Den Shuan		
Supervisor	Krasnopolskii		
St control	Khuzhniak S.V		
Head of	anatovich S.R		

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Supervisor	Krasnopolskii						
Adviser					402 ASF 134		
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Head of	Ignatovych S.						

LIST OF ABBREVIATIONS

RPK	Revenue passenger-kilometres
LG	Landing gear
APU	Auxiliary power unit
LP	Low pressure
HP	High pressure
IATA	International aviation transport association
ICAO	International civil aviation organization
FAR	Federal aviation regulation
CS	Certification specification
CCAR	Chinese civil aviation regulation
CM	The center of the mass

Introduction

With the development of China's economy, the improvement of transportation network and the rapid improvement of people's living standards, the proportion of aviation in public transport is becoming larger and larger. It can be said that the civil aircraft industry is in an unprecedented period of development. Its development environment is the growing demand for civil aircraft. Its development direction is to focus on large aircraft, taking into account regional lines, civil helicopters, general aircraft, etc. However, with the growing civil aviation market, the requirements for development technology and quality are becoming higher and higher, and China's civil aviation is facing greater and greater challenges. Civil aircraft development has high technical content, complex system, long development cycle, and high requirements for development and management. As far as the current situation is concerned, this is an urgent problem to be solved.

The purpose of this Diploma work is to design an aircraft for transporting 240 passengers and luggage at long ranges routes.

PART 1. PRELIMINARY DESIGN OF THE AIRCRAFT

1.1. Choices of the projected data

In order to present a promising aircraft, the selection of the best design parameters of the aircraft is a multidimensional optimization task. In the shape of the aircraft, complex flight technology, weight, geometry, start-up and economic characteristics are equally important. In the first stage of designing aircraft appearance, our method is transfer, approximate aerodynamics and statistical correlation. In the second stage, calculate the center of gravity of the aircraft and draw the general view and layout of the aircraft[1].

The prototypes of the aircraft, which taking for my design were in class 240 passengers. Statistic data of prototypes are presented in table 1.1.

Table 1.1 – Operational-technical data of prototypes

INITIAL DATA AND SELECTED PARAMETERS			
Passenger number	240	Fuel-to-weight ratio	0.43
Flight crew number	2	Aspect ratio	9.26
Filight attendant or load master number	6	Taper ratio	3.98
Mass of operational items	2851.09kg	Mean thickness ratio	0.12
Payload mass	25080kg	Wing sweepback at quarter of chord	34°

Continuation of the table. 1.1.

Cruising speed	871km/h	High-lift device coefficient	1.1
Cruising mach number	0.81	Relative area of wing extensions	0.01
Design altitude	11km	Wing airfoil type	Supercritical
Flight range with maximum payload	8000km	Winglets	No
Runway length for the base aerodrome	2.55km	spoilers	Yes
Engine number	4	Fuselage diameter	5.64m
Thrust-to-weight ratio in N/kg	2.8	Fineness ratio of the fuselage	9.00
Pressure ratio	37.4	Horizontal tail sweep angle	35°
Accepted bypass ratio	5	Vertical tail sweep angle	40°
Optimal bypass ratio	5		

This choice is determined by the relative position and shape of each part of the aircraft. The aerodynamic and operational characteristics depend on the aircraft layout and the aerodynamic scheme of the aircraft. The selected scheme is more conducive to high flight performance, aircraft safety and economic efficiency.

1.2. Brief description of the aircraft

This aircraft is an airliner manufactured by Airbus, mainly including the fuselage, wings, tail wings, landing gear, kitchen, bathroom, etc. The plane has four engines and uses the front three-point landing gear. The wings are supercritical airfoils with spoilers and no winglets. There are 30 seats in business class and 210 seats in economy class. The aircraft kitchen has both separate kitchens and centralized distributed kitchens, which can make the space utilization in the cabin high and facilitate communication and coordination. The toilets on the aircraft use centralized toilets to save water and meet sanitary conditions. In addition, the rudder and elevator of the aircraft are equipped with aerodynamic balancing devices.

Fuselage. The fuselage is located in the middle of the aircraft. Its function is to accommodate personnel, cargo, other loads or equipment, and other parts are connected to the fuselage. The main power components of the fuselage are the frame, double beam wings, longitudinal beams and skin. On low-level gliders and ultralight aircraft, in order to reduce flight resistance, it has been developed into a streamlined fuselage, which can accommodate more cargo, personnel and equipment. If an aircraft is large enough to accommodate all personnel, cargo and fuel, its fuselage can be cancelled and turned into a flying wing aircraft, that is, the so-called "flying wing".

The cockpit designed in this graduation project can accommodate two pilots. During flight, the main pilot is on the left, the co pilot is on the right, and there is a side plate for the main pilot and the co pilot on the left side of the fuselage. In front of the two pilots' seats, there is a steering wheel that controls the landing gear and ailerons and a pedal that controls the rudder[2].

There are windows and emergency exits on the left and right sides of the cabin, and luggage racks are set above both sides of the cabin to store passengers' personal belongings. The service panel is equipped with a ventilation nozzle, a light, a button to turn on the light, and a button to call the flight attendant. In the middle of the cabin roof, there are lights for cabin lighting, and the side and lower part of the luggage rack are also arranged.

Wing. A wing is a component that generates lift. Ailerons and spoilers are generally installed on both sides of the wing. Different flaps and slats are also provided at the front and rear edges to improve lift and change the lift distribution of the wing surface during takeoff and landing. The structural elements of the wing include spars, ribs, skin and stringers.

Compared with the high wing structure, the low wing aircraft has better lateral control, because the aircraft has less lateral static stability, which is due to the influence of the fuselage on the wing effect: (1) the friction between the wing and the tail is small, so the tail will produce a better effect; (2) Compared with high wing structure aircraft, the tail of low wing aircraft is lighter; (3) The wing drag produces a head down pitching moment, so the low wing is longitudinally stable, because the position of the wing drag line relative to the aircraft center of gravity is low.

Tail unit. The tail wing is generally located at the tail of the aircraft and has the functions of stability and control. It can generally be divided into two parts: one is the horizontal tail wing, and the other is the vertical tail wing. The tail of individual aircraft is V-shaped, which has the functions of horizontal tail and vertical tail, and is called V-shaped tail. An ordinary horizontal tail includes a horizontal stabilizer and elevator, while a vertical tail includes a vertical stabilizer and rudder. In supersonic aircraft, in order to improve the longitudinal control effect of the aircraft, the horizontal tail (regardless of the horizontal stabilizer and elevator) can be used for steering, that is, the so-called full motion flat tail. Some aircrafts mainly use variable sweep wings and also use full motion horizontal tail wings to make them have differential deflection, that is, the left and right wing surfaces of the flat tail can not only deflect at the same time, but also deflect in the opposite direction. At this time, lateral control can be carried out. This form is called differential flat tail. Because the vertical tail is equipped with rudder, which can adapt to the course control of supersonic navigation, the full acting vertical tail is rarely used. In some aircraft, the horizontal tail is moved forward of the wing, which is called the front wing or canard wing.

The aircraft tail of this graduation project consists of two horizontal tails and one vertical tail. The vertical tail includes rudder, and the horizontal tail includes stabilizer and elevator. The vertical and horizontal tail sweep angles are larger than the wing sweep angle, so the aerodynamic characteristics of the tail element will not exceed the wing characteristics with the increase of Mach number. The efficiency of the horizontal stabilizer can be improved by increasing its height, and a larger vertical tail angle can be selected.

The vertical and horizontal tail profiles are symmetrical. When the rudder rotates in different directions, the symmetrical section maintains the same properties of aerodynamic load and the resistance is smaller. The vertical tail has more relative contour thickness than the horizontal tail to reduce the weight transferred to the aileron by the vertical tail and the horizontal tail.

Crew cabin. Any structure of the aircraft provides the pilot with safe flight conditions. The stability and controllability of the aircraft, the structure, characteristics and automation of flight navigation equipment and airborne systems, and the structure and configuration of display equipment can enable the pilot to successfully perform his duties without exceeding the existing loading specifications.

In order to provide pilots with good overview conditions, the application of cabin cone windshield meets the requirements of aircraft operation under the expected working conditions. The pilot can control the aircraft manually or automatically in the cockpit[3].

According to the requirements of flight airworthiness standards: (1) equipment and optical signal devices are placed on the pilot's control panel, and the control panel of quick-use command radio and automatic control system is placed on the top of the control panel within the optimal range.(2) The top control panel of the airborne system is equipped with the start button, fire switch and alarm system board for fuel, hydraulic, power, anti ice, air conditioning, engine and auxiliary power unit.(3) In the center of the pilot panel, not only the traditional control rod engine, but also the panel of navigation and landing equipment are placed.

Passenger furnishing. Passenger transport facilities on the aircraft provide necessary convenience for crew and passengers, including adjustable pilot seat, flight attendant seat and passenger seat, filter, anti light shutter and toilet.

A toilet and kitchen are arranged between the cockpit and the cabin (the toilet is on the left of the cabin and the kitchen is on the right of the cabin). Each toilet covers an area of 1.1 square meters. A vacuum toilet is built in the bathroom, and there is a water tank with water and special liquid.

The emergency equipment on the aircraft includes ropes, oxygen masks, smoke masks, oxygen devices, manual fire extinguishers, first aid kits, axes, emergency radio stations, radio stations and radio beacons, light signs of evacuation methods, emergency lighting "exit" boards near each emergency exit, life jackets for crew and observers, and life rafts for pilots and passengers. There are also three first aid kits on board (in the cockpit, fuselage and tail of the aircraft).

Control system. The control system is used to operate and control the aircraft. It is mainly divided into manual control system and automatic flight control system. The early manual operation system consists of central operating mechanism (driving lever / plate, pedal), auxiliary system (hydraulic and electric), transmission mechanism (pull rod, rocker arm or steel cable, pulley, etc.). Automatic control system has been widely used in modern aircraft, mainly including central control, autopilot, fly by wire control, etc.

Airborne equipment. Airborne equipment includes flight instruments, communication, navigation, environmental control, life support, energy supply, etc., as well as various airborne equipment related to aircraft, such as weapons and fire control of fighter aircraft, cabin life services of civil aircraft, etc. A340 adopts a new generation of aircraft electronic system, such as the air data inertial system with strong anti-interference ability. The system is mainly composed of ADIRS backup navigation system, landing navigation equipment system, relevant positioning system, independent positioning system, etc.

Landing gear. Landing gear is the support for aircraft taxiing, taking off, landing and taxiing and parking on the ground. It usually includes bearing support, shock absorber, brake wheel (or skid, buoy) and retractor. In order to reduce the weight of low-speed aircraft, the fixed landing gear that cannot be retracted is generally used, and fairing is installed on the strut and wheel to reduce the resistance. For aircraft wheels used for taking off and landing on the ground or on ships, when taking off and landing on ice or snow, skids replace the wheels, and pontoons replace pontoons for floating seaplanes[4].

On this aircraft, the landing gear is manufactured according to the three bearing scheme and can be retracted after takeoff. The rotation control of the front wheels, the horizontal position when stationary and moving, this design can obtain stable aircraft movement and effective mobility through the airport. The nose landing gear allows the aircraft to take off and land in strong crosswind and to move in a straight line during the flight and take-off of the aircraft.

The front landing gear is located in front of the center of gravity to avoid overturning and effectively brake the wheels to reduce sliding. The main landing gear is located behind the center of gravity of the aircraft. The front landing gear has 2 wheels, and each main support has 1 bogie and 2 pairs of wheels. The pneumatic device of the wheel bears the load and transmits it to the landing gear during landing and moving on the ground.

1.3. Main parts of the aircraft calculations

Based on the key design parameters of the aircraft determined in the previous chapter, this section first determines the aircraft aspect ratio, taper ratio, swept angle at 1/4 chord, relative load on the wing, takeoff weight and other parameters, so as to facilitate the later calculation of wing area, wing span and other parameters.

1.3.1. Wing geometry calculation

Some initial data of the prototype are presented in the table 1.2.

Aspect ratio, λ	9.26
Taper ratio, η	3.98
Sweep back angle on 1/4 chord, $\chi_{1/4}$	34°
Relative load on the wing, P_0 [Pa]	6567
MTOW, m_0 [kg]	168708

The geometry of the wing is determined by the weight and specific wing loads..

Wing area is:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{168708 \times 9.8}{6567} = 251 m^2$$

Wing span is:

$$l_w = \sqrt{S_w \cdot \lambda} = \sqrt{251 \times 9.26} = 48m$$

Root chord is:

$$b_{root} = \frac{2 \cdot S_w \cdot \eta}{l_w \cdot (1+\eta)} = \frac{2 \times 251 \times 3.98}{48 \times (1+3.98)} = 5.5m$$

Tip chord is:

$$b_{tip} = \frac{b_{root}}{\eta} = \frac{5.5}{3.98} = 1.4m$$

On board chord for trapezoidal shaped wing is:

$$b_{ob} = b_{root} \cdot \left(1 - \frac{(\eta-1)\cdot D_{fuselage}}{\eta \cdot l_w}\right) = 5.5 \times \left(1 - \frac{(3.98-1)\times 5.64}{3.98\times 48}\right) = 5.01m$$

I use the geometrical method of mean aerodynamic chord determination (figure 1.1). Mean aerodynamic chord is equal:

$$b_{mac} = 3.87$$

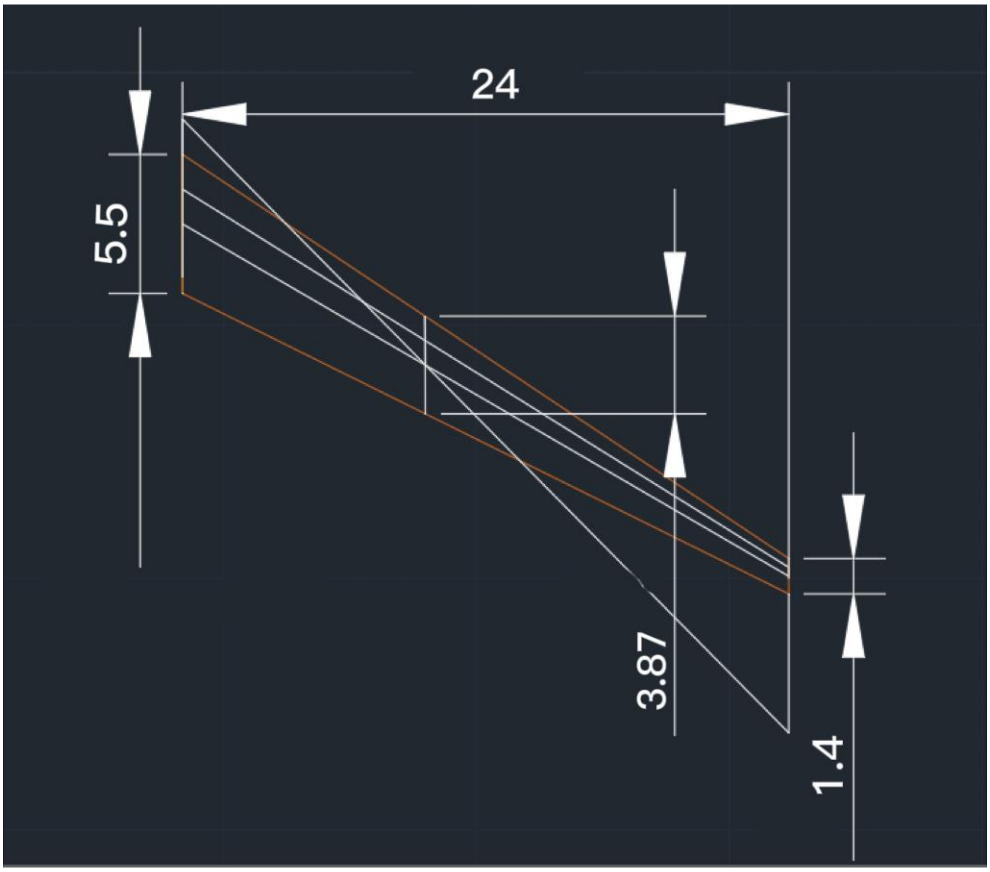


Figure 1.1 – Determination of mean aerodynamic chord

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ail} = 0.375 \cdot \frac{l_w}{2} = 0.375 \times \frac{48}{2} = 9m$$

Aileron area:

$$S_{ail} = 0.065 \cdot \frac{S_w}{2} = 0.065 \times \frac{251}{2} = 8.1575m^2$$

Range of aileron deflection for upward $\delta_{up} = 25°$;

for downward $\delta_{down} = 15°$.

The sketch of the wing is shown as figure 1.1. As shown, the length of mean aerodynamic chord $b_{MAC} = 3.87m$.

1.3.2. Fuselage layout

For an aircraft with a capacity of 240 passengers, economy class can be designed with two channels. Three seats are arranged on both sides of the aisle of economy class, and two seats are arranged in the middle space. In business class, there are three seats on each side. There are 30 passengers in business class and 210 passengers in economy class.

Fuselage length is equal:

$$L_{fuselage} = FR \cdot D_{fuselage} = 9 \times 5.64 = 50.76m$$

Fuselage nose part is equal:

$$L_{nose} = FR_{nose} \cdot L_{fuselage} = 0.104 \times 50.76 = 5.27m$$

Fuselage rear part is equal:

$$L_{rear} = FR_{rear} \cdot L_{fuselage} = \times\ 50.76 = 8.96m$$

Fuselage cabin is equal:

$$L_{cabin} = L_1 + (N-1) \cdot L_{seat\,pitch} + L_2$$

Where L_1 --- distance between the wall to the back of the seat in the first row;

L_2 --- distance between the back of the seat in the last row to the wall;

N --- number of rows.

Length of business class:

$$L_{business} = 1200 + (5-1) \times 960 + 250 = 5290mm$$

Length for economy class:

$$L_{economy} = 1200 + (27-1) \times 800 + 250 = 24070mm$$

Then total length of cabin:

$$L_{cabin} = L_{business} + L_{economy} = 5.29 + 24.07 = 29.36m$$

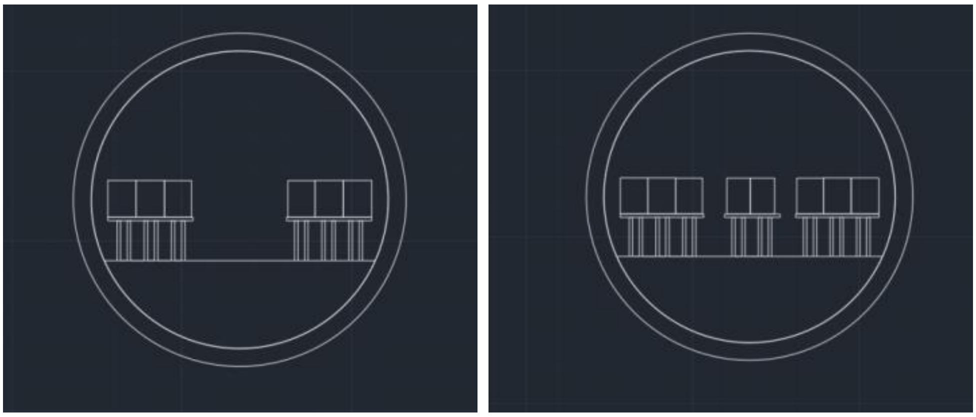
Width of economy class:

$$\begin{aligned} B_{cabin} &= 2\delta + 2\delta_{wall} + n_{block} \cdot b_{block} + n_{aisle} \cdot b_{aisle} \\ &= 2\cdot 50 + 2\cdot 120 + 2\cdot 450 + 2\cdot 1500 = 5240mm < 5640\text{mm} \end{aligned}$$

Width of business class:

$$B_{cabin} = 2\delta + 2\delta_{wall} + n_{block} \cdot b_{block} + n_{aisle} \cdot b_{aisle}$$
$$= 2{\cdot}50 + 2{\cdot}120 + 2{\cdot}1600 + 1{\cdot}500 = 4040mm < 5640\text{mm}$$

The cross section of the cabin is shown as figure 1.2.



Business class economy class

figure 1.2 Cross section cabin

1.3.3. Galleys and buffets

The civil aircraft kitchen is an area for storing and preparing food and beverages on the aircraft. The area is equipped with a full set of kitchen structures, such as utensils, ovens, coffee makers, refrigerators, water and electricity systems, and connectors connecting kitchen equipment and aircraft interface connectors. During the overall layout, the kitchen is required to set up a separate service door due to the access of drinks, food and sundries, and try to connect with the boarding gate to increase the use area and form a service area.

According to different aircraft needs, the kitchen can be centrally arranged, separately arranged or used at the same time. The basic principle is: clear service route and try to eliminate mutual interference between functions. The service line of the centralized kitchen is decentralized, with high space utilization and convenient communication and coordination; The separate kitchen can also be well arranged without any interference[5].

Volume of buffets(galleys) is equal:

$$V_{galley} = 0.1 \cdot N_{passenger} = 0.1 \times 240 = 24m^3$$

Height of cabin can be calculated as follow:

$$H_{cabin} = 0.296 + 0.383 \cdot 5640 = 2160mm$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cabin}} = \frac{24}{2.16} = 11.11m^2$$

Weight of meals for each passenger is 1.0kg, tea and water is 0.6kg. So, the total weight of meals and water is 384kg.

Galley design is similar to prototype.

1.3.4 Lavatories

The aircraft toilet is the sanitary equipment provided by the on-board toilet system for relevant passengers and flight attendants. The toilet system consists of three parts: the toilet components of the on-board part, the sewage tank and related components of the off-board part and the sewage discharge panel.

There are two types of toilets in the aircraft, one is the integrated toilet, and the other is the centralized toilet, also known as the "vacuum toilet". The aircraft toilet of this graduation project adopts a centralized toilet, which has good effect due to its "suction", saving water and meeting sanitary conditions at the same time. The schematic diagram of the toilet is as follows:

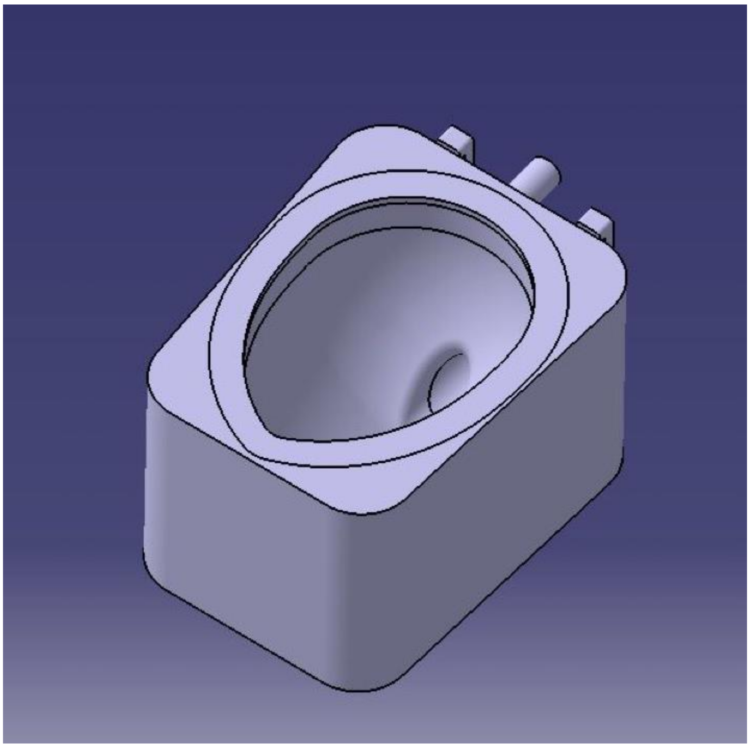


figure 1.3 closestool

The number of lavatories I choose according to the original airplane and it is equal:

$$N_{lav} = \frac{240}{40} = 6$$

Area of floor:

$$s = 0.036 \cdot 240 = 8.64 m^2$$

Area of one lavatory:

$$s_{lav} = 0.95 \cdot 1.15 = 1.1 m^2$$

Width of lavatory:1m. Toilets design will be similar with the prototype.

1.3.5. Layout and calculation of basic parameters of tail unit

In Span of horizontal tail unit and vertical tail unit can be calculated as:

$$l_{HTU} = (0.32...0.5) \cdot L_w = 0.4 \times 48 = 19.2m$$

$$h_{VTU} = (0.14...0.2) \cdot L_w = 0.18 \times 48 = 8.64m$$

Area of horizontal tail unit is equal:

$$S_{HTU} = \frac{A_{HTU} \cdot S_w \cdot b_{MAC}}{L_{HTU}} = \frac{0.65 \times 251 \times 3.87}{7.74} = 81.575m^2$$

Area of vertical tail unit is equal:

$$S_{VTU} = \frac{A_{VTU} \cdot l_w \cdot S_w}{L_{VTU}} = \frac{0.12 \times 48 \times 251}{13.54} = 106.7m^2$$

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{elevator} = (0.3...0.4) \cdot S_{HTU} = 0.35 \times 81.575 = 28.55m^2$$

Rudder area:

$$S_{rudder} = (0.35...0.45) \cdot S_{VTU} = 0.4 \times 106.7 = 42.68m^2$$

Elevator balance area is equal:

$$S_{aero\,ele} = (0.15...0.23) \cdot S_{elecator} = 0.2 \times 28.55 = 5.71m^2$$

Rudder balance area is equal:

$$S_{aero\,rud} = (0.15...0.23) \cdot S_{rudder} = 0.2 \times 42.68 = 8.536m^2$$

The area of altitude elevator trim tab:

$$S_{tbe} = (0.08...0.12) \cdot S_{elevator} = 0.1 \times 28.55 = 2.855m^2$$

Area of rudder trim tab is equal:

$$S_{tbr} = (0.04...0.06) \cdot S_{rudder} = 0.05 \times 42.68 = 2.134m^2$$

Tip chord of horizontal stabilizer is:

$$b_{tip\,HTU} = \frac{2S_{HTU}}{(\eta_{HTU}+1) \cdot l_{HTU}} = \frac{2 \times 81.575}{(3.98+1) \times 19.2} = 1.706m$$

Root chord of horizontal stabilizer is:

$$b_{root\,HTU} = \eta_{HTU} \cdot b_{tip\,HTU} = 3.98 \times 1.706 = 6.79m$$

Tip chord of vertical stabilizer is:

$$b_{tip\,VTU} = \frac{2S_{VTU}}{(\eta_{VTU}+1) \cdot h_{VTU}} = \frac{2 \times 106.7}{(9.26+1) \times 8.64} = 2.407m$$

Root chord of vertical stabilizer is:

$$b_{root\,VTU} = \eta_{VTU} \cdot b_{tip\,VTU} = 9.26 \times 2.407 = 22.29m$$

1.3.6. Landing gear design

Landing gear is one of the most commonly used landing gear, which is the main stress component of aircraft. The landing gear has a large bearing capacity and complex stress. It bears the reaction of landing, ground sliding, braking, turning and other actions on the ground, generally including the stress structure, buffer, wheel, retracting and releasing mechanism, upper lock, lower lock, turning control mechanism, brake, etc.

The landing gear has good floatability. The tire pressure and landing gear structure meet the predetermined runway load to ensure that the aircraft can take off and land smoothly on the designated runway. The connection between the landing gear and fuselage structure of the aircraft is reasonable and reliable, and the landing gear can be conveniently stowed into the fuselage, reducing the flight resistance of the aircraft and improving the flight performance of the aircraft. Therefore, the landing gear is small in size and has the functions of retraction, interlocking, orientation, signal display, front wheel correction, etc. The landing gear take-off and landing time should be as short as possible (no more than 10-20 seconds).

Landing gear is a take-off and landing device, which can ensure aircraft taxiing, take-off, landing, taxiing after landing and maneuvering taxiing on the airport. At this time, the landing gear will bear various loads on the aircraft, and its kinetic energy will dissipate during landing and taxiing. At present, there are four kinds of landing gears used in aircraft: rear three-point landing gear, front three-point landing gear, bicycle landing gear with fulcrum under the wing and multi fulcrum landing gear. The landing gear of this graduation project is the front three-point landing gear, and the main fulcrum contacts the runway first, which will not cause any adverse impact. At this time, the main fulcrum generates an oncoming force, the nose sinks down, and all the fulcrum are pushed. During this process, both the angle of attack and the lift of the airfoil will be reduced. If the shock absorber on the support can effectively absorb the energy of the aircraft, it will not leave the runway[6].

Therefore, aircraft with the three-point landing gear can greatly improve landing speed. When the aircraft lands and taxis, there may be piloting errors due to the increase of landing speed, but there will be no danger. A higher landing speed will increase the load of the landing gear, thus increasing the weight of the landing gear, but it is very cost-effective because it can increase the load per unit area of the aircraft and increase the speed of the aircraft.

The distance from center of gravity to main landing gear is calculated as:

$$B_m = (0.15...0.2) \cdot b_{MAC} = 0.18 \times 3.87 = 0.6966m$$

Wheel base:

$$B = (0.3...0.4) \cdot L_f = 0.35 \times 50.76 = 17.766m$$

The distance from the center of gravity to the nose:

$$B_n = B - B_m = 17.766 - 0.6966 = 17.0694m$$

Wheel track is:

$$T = (0.7...1.2) \cdot B = 0.7 \times 17.766 = 12.4362m$$

Wheels for the landing gear is chosen by the size and run loading on it from the take off weight; for the front support we consider dynamic loading also.

Then , we come to the determination of load on wheels. Dynamic coefficient(k_g) is 1.75.

Nose wheel load:

$$F_{nose} = \frac{9.81 \cdot B_m \cdot k_g \cdot m_0}{B \cdot n \cdot z} = \frac{9.81 \times 0.6966 \times 1.75 \times 168708}{17.766 \times 1 \times 2} = 56781.459N$$

Main wheel load:

$$F_{main} = \frac{9.81 \cdot B_n \cdot m_0}{B \cdot n \cdot z} = \frac{9.81 \times 17.0694 \times 168708}{17.766 \times 2 \times 4} = 198766.547N$$

As for brakes, we choose the disc brakes, there are superior performance, are lighter, and easier to maintain.

1.4. Center of gravity calculation

1.4.1. Trim-sheet of the equipped wing

The example list of the mass objects for the aircraft, where the engines are located under the wing, included the names given.The example list of the mass objects for the aircraft[7], where the engines are located in the wing, included the names given in the table 1.3. Coordinates of the center of power for the equipped wing are defined by the formulas:

$$X'_w = \frac{\Sigma m'_i x'_i}{\Sigma m'_i}$$

Table 1.3 - Trim sheet of equipped wing

N	Object name	Mass		C.G coordinates Xi,m	Mass moment, Xi*mi
		units	total mass m(i)		
1	Wing (structure)	0.0998	16847.18	0.38	6510.70
2	Fuel system	0.0119	2007.62	0.46	92.45
3	Airplane control, 30%	0.0013	222.69	0.0051	1.13
4	Electrical equipment, 10%	0.0028	477.44	0.01	5.22
5	Anti-ice system, 50%	0.0075	1275.43	0.029	37.31

Continuation of the table. 1.3.

N	**Object name**	**Mass**		**C.G coordinates Xi,m**	**Mass moment, Xi*mi**
		units	**total mass m(i)**		
6	Hydraulic system, 70%	0.0092	1558.86	0.035	55.74
7	Power plant 1,3	0.04	6748.32	-2.5	-16870.80
8	Power plant 2,4	0.04	6748.32	-2.50	-13496.64
9	Equipment wing without landing gear and fuel	0.21	35885.87	-0.65	-23664.82
10	Nose landing gear	0.006	1051.62	0.02	25.36
11	Main landing gear	0.028	4790.73	0.10	526.47
12	Fuel	0.33	55825.47	1.28	71489.15
13	Total	0.57	97554.00	0.25	24711.34

1.4.2. Trim-sheet of the equipped fuselage

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given[8]. The example list of the objects for the AC, which engines are mounted under the wing, is given in table 1.4.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}};$$

After we determined the C.G. of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively to the fuselage nose:

$$m_f x_f + m_w (x_{MAC} + x_w^{/}) = m_0 (x_{MAC} + C)$$

From here we determined the wing MAC leading edge position relative to fuselage, means X_{MAC} value by formula:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w},$$

where m_0 – aircraft takeoff mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; C – distance from MAC leading edge to the C.G. point, determined by the designer.

C = (0,22...0,25) B_{MAC} –low wing ;

Table 1.4 – Trim sheet of equipped fuselage

N	**Object names**	**Mass**		**C.G coordinates Xi,m**	**Mass moment, Xi*mi**
		units	**total mass m(i)**		
1	Fuselage	0.07	12256.97	25.00	306424.34
2	Horizontal tail	0.008	1349.66	-47.00	63434.20
3	Vertical tail	0.008	1455.95	48.50	70613.57
4	Radar	0.02	4386.40	0.50	2193.20
5	Radio equipment	0.001	320.54	0.80	256.43
6	Instrument panel	0.004	759.18	1.50	1138.77
7	Navigation equipment	0.003	641.09	2.00	1282.18
8	Flight control system 70%	0.003	519.62	25.38	13187.97
9	Hydraulic system 30%	0.003	668.08	35.53	23738.34
10	Electrical equipment 90%	0.02	3374.16	25.38	85636.18
11	Not typical equipment	0.002	421.77	5.00	2108.85
12	Lining and insulation	0.006	1147.21	25.00	28680.36

Continuation of the table. 1.4.

N	**Object names**	**Mass**		**C.G coordinates Xi,m**	**Mass moment, Xi*mi**
		units	**total mass m(i)**		
13	Anti-ice system 25%	0.003	637.716	40.60	25896.38
14	Airconditioning system 25%	0.007	1275.43	25.38	32370.47
15	Passenger seats (business class) 1 seat/block of 2/block of 3/ 8-10kg/14-18kg/20-25kg	0.007	1200.00	28.00	33600.00
	Passenger seats (economy class) 1 seat/block of 2/block of 3/ 6-8kg/12-15kg/18-20kg	0.001	200.00	9.00	1800.00
	Seats of flight attendances	0.00015	26.00	7.41	192.66
	Seats of pilots	0.00018	32.00	3.70	118.56
	Emergency equipment	0.00199	28.00	15.00	420.00
	Galley 1	0.00500	12.00	24.00	288.00
	Galley 2	0.00500	38.00	25.00	950.00
16	Additional items	0.00820	1383.40	4.00	5533.62
17	Operational equipment	0.01000	1687.08	4.00	6748.32
18	Passengers(economy)	0.08	15000.00	28.50	427500.00
19	Passengers(business)	0.01	2310.00	9.50	21945.00
20	On board meal	0.002	360.00	25.00	9000.00
21	Baggage	0.028	4800.00	10.37	49776.00
22	Cargo，mail	0.002	500.00	10.37	5185.00
23	Flight attendant	0.002	360.00	7.41	2667.60
24	Crew	0.0009	154.00	3.70	570.57
25	**TOTAL**	0.35	57304.30	33.67	1929869.08

According to the table 1.4:

$$X_{MAC} = \frac{mf\ xf + mw * x\prime w - moC}{mo - mw} = 25.1756$$

1.4.3. Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in table 1.5 and Center of gravity calculation options given in table 1.6, completes on the base of both previous tables.

Table 1.5 – Calculation of C.G. positioning variants

1	Name	Mass, Kg	Coordinate	Mass moment
2	Object	mi	C.G., M	Kg.m
3	equipped wing (without fuel and landing gear)	35885.87	24.51	879785.51
4	Nose landing gear (extended)	1051.62	7	7361.37
5	main landing gear (extended)	4790.73	25.64	122834.40
6	fuel reserve	6275.93	26.45	166037.67
7	fuel for flight	64208.57	26.45	1698717.13
8	equipped fuselage (without payload)	34329.79	22.18	761447.42
9	Passengers(economy)	15000	28.5	427500
10	Passengers(bussiness)	2310	9.5	21945
11	on board meal	360	26	9360
12	baggage	4800	10.37	49776
13	cargo, mail	500	10.37	5185
14	flight attend	360	7.41	2667.6
15	crew	154	3.70	570.57
16	Nose landing gear (retrected)	1051.62	6	6309.74
17	main landing gear (retrected)	4790.73	25.64	122834.40

Table 1.6 – Airplane C.G. position variants

No.	Variants of the loading	Mass, kg	Moment of the mass, kg*m	Center of mass, m	Center of gravity position
1	Take off mass (L.G. extended)	170026.55	4153187.69	24.42	0.19
2	Take off mass (L.G. retracted)	170026.55	4152136.07	24.42	0.19
3	Landing weight (L.G. extended)	111660.33	2583614.72	23.13	0.52
4	Ferry version (without payload, max fuel, LG retracted)	146696.55	3635702.47	24.78	0.10
5	Parking version (without payload, fuel for flight and LG extended)	82333.97	1937466.39	23.53	0.42

Conclusion to part 1

According to the development trend of China's future large passenger aircraft market, this graduation project has carried out the preliminary design of the aircraft and obtained the preliminary design results of the project. Using A340, one of the most popular aircraft at present, as a reference, a long-range civil aircraft with 240 seats is designed, and the selection and calculation of various parts of the aircraft and the drawing of 3D model are completed, including:

(1) A brief description of the main components of the aircraft is designed. The cabin of the aircraft meets the requirements of flight airworthiness standards. A double channel is set inside the fuselage to provide convenience for passengers and crew. There are windows, emergency exits, luggage racks and other necessary facilities on the left and right sides of the fuselage cabin.

(2) The geometry of the main components of the aircraft is designed. The low wing is used as the wing part. Compared with the high wing structure, the low wing can better control the aircraft laterally, and the tail is lighter. The tail wing is set as horizontal tail wing and vertical tail wing, which plays a role in stability and control, and can also prevent the aircraft from yaw and swing in high-altitude and high-speed flight.

(3) The cabin layout of the aircraft is designed. The number of toilets is 6. Centralized toilets are used to save water and meet sanitary conditions. There are four kitchens to provide meals for the personnel on board.

(4) The center of gravity position calculation and landing gear selection and calculation of the aircraft in different states. The use of the first three-point landing gear can greatly improve the landing speed of the aircraft.

(5) The three-dimensional modeling completes the aircraft appearance design, cabin design, etc.

Through the analysis of the calculation results, the parameters of the main components meet the design requirements. This aircraft is a long-range wide body aircraft, which also meets the requirements of the current passenger transport market.

PART 2 FUSELAGE DESIGN

2.1. Analysis of fuselage

The fuselage is the primary body to which all pieces are linked and should carry the cargo. It must withstand bending moments (due to the weight and lift from the tail), torsional stresses (due to the fin and rudder), and cabin pressurisation. The fuselage's structural strength and rigidity must be sufficient to sustain these stresses. Simultaneously, structural weight must be maintained to a bare minimum[9].

The majority of the fuselage of transport aircraft is cylindrical or nearly cylindrical, with tapering nose and tail portions. A stressed skin with extra stringers to avoid buckling is coupled to hoop-shaped frames in the semi-monocoque structure, which is almost conventional in all current aircraft. Members perpendicular to the skin support the fuselage and help it maintain its form. If the supports are open or ring-shaped, they are termed frames; if they are closed, they are called bulkheads[10]. Cutouts are irregularities in the ideal cylindrical shell, such as doors and windows.

Many of the loads that are present on the surrounding structure are typically improper for them. Because the direct load routes are disrupted, the structure surrounding the cut-out must be strengthened in order to retain the requisite strength. A cargo aircraft's door will be substantially bigger than a passenger plane's. As a result, part of the loads from the frames and stringers must be transmitted to them. Where doors are smaller, the surrounding structure is strengthened to handle the loads.

The fuselage volume above and below the floor is pressurised in aeroplanes with pressurised fuselages, therefore there are no pressurisation stresses on the floor. Because of the pressure differential, the floor will be loaded if the fuselage is rapidly de-pressurized. The load will remain in place until the pressure in the plane has been equalised, which is normally accomplished by floor-level side wall vents. Various portions of the fuselage have different radii at times.

A fuselage with two bubbles is known as a double-bubble fuselage. Depending on the design, pressurisation might cause tension or compression in the floor-supports. When the fuselage is subjected to bending stresses, frames give it its cross-sectional form and protect it from buckling. Stringers provide a significant improvement in skin stiffness under torsion and bending stresses while adding minimum weight[11]. The fuselage's fundamental structure is made up of frames and stringers.

The pressure chamber is closed at both ends of the fuselage by pressure bulkheads, which carry the weights imposed by pressurisation. They might be flat discs or curved bowls in shape.

2.2 The members of fuselage

Skin carries all loads in monocoque fuselages; stringers and frames are not present. Although such fuselage designs are uncommon, some structural parts, such as the aft fuselage structure and the front piece of the fuselage where an airborne radar is positioned, may be constructed as monocoques.

2.2.1. Stringers

Stringers run lengthwise (longitudinally) along an airplane's fuselage or span wise of a wing, and are commonly mistaken with or referred to interchangeably as longerons. Their function is to transfer loads and stresses from the aircraft's skin to the formers as structural components. They are usually attached between formers and bulkheads, and they are more numerous and spaced closer together than longerons. Individual strings are insufficient to withstand the massive stresses and pressures that an aircraft is subjected to. As a result, they are directly linked to formers and bulkheads and are spaced much closer together than their longeron counterpart. The role of stringers and longerons is similar, which is why they are sometimes mistaken. Both connect to the formers (also known as frames) of a fuselage and transfer the aircraft's skin stresses to the entire structure. Stringers are increasingly often utilised in commercial aircraft, despite the fact that they take longer to install during the production process[12]. The 3D model may be seen below.

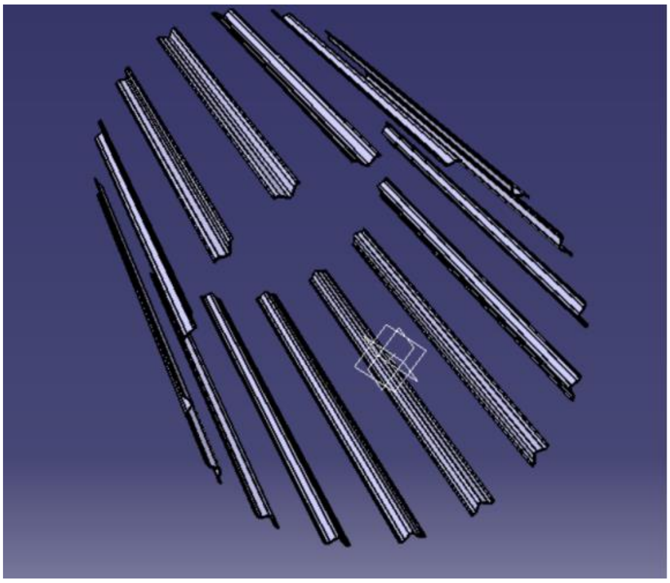


Figure 2.1 – Stringers

2.2.2 Frame

Frames are transverse components that determine the fuselage's cross-section. They're usually around 20 inches apart and help to define the aerodynamic form. The frames and stringers are spaced in such a way that the resultant bays support the skins and prevent them from buckling. Frames also allow point loads to be introduced into the fuselage. To transmit the stresses generated by these lifting surfaces into the fuselage, large frames are necessary at the wing-fuselage and tail-fuselage interfaces.

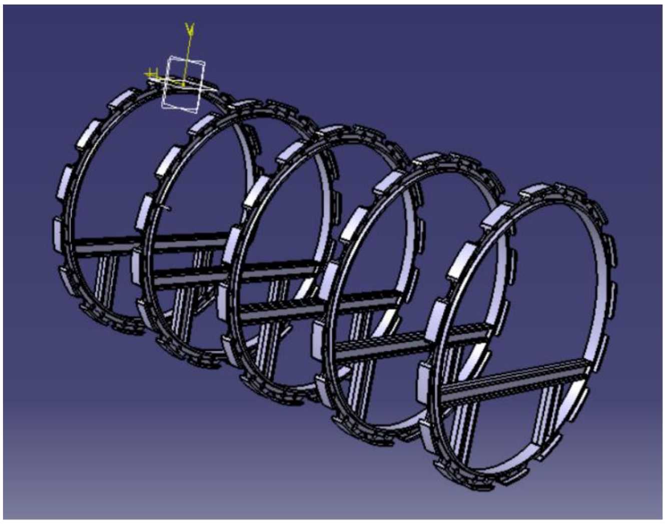


Figure 2.2 – Frame

2.2.3 Skin

Rivets secure the load-bearing skins to the stringers and frames of an aluminium aircraft. The skins bear the load and pass it to the stiffeners by shear. In a pressurised aeroplane, the skin and the frames work together to counteract the interior pressure stress. Allowing the skin to buckle reduces the skin's capacity to conduct and transmit shear; this creates a restriction that affects the spacing of the stringers and frames.

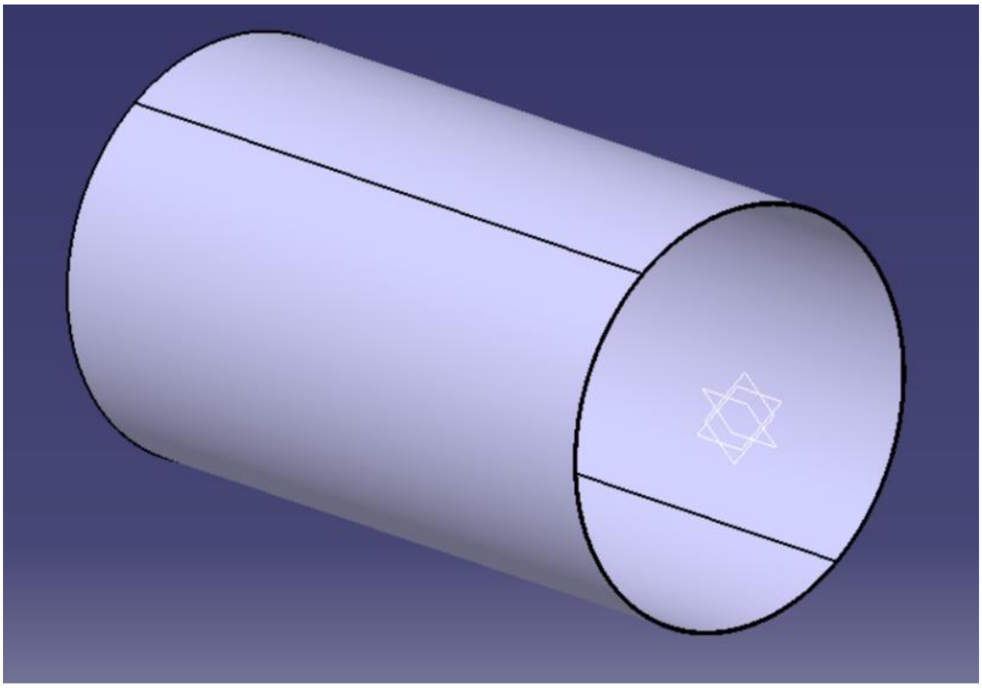


Figure 2.3 – Skin

2.2.4 Rivets

In aircraft construction and repair, it is the most frequent method for fastening or joining aluminium alloys. A rivet is a metal pin that connects two or more metal sheets, plates, or other pieces of material. When a rivet is made, a head is created on one end.

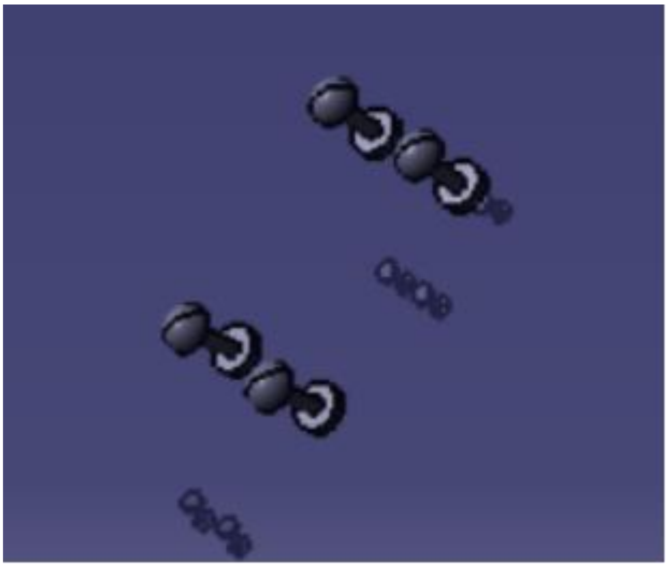


Figure 2.4 – Rivets

2.2.5 Assembly

The fuselage is made of the four part of structural. Then ,we could assembly them together, the result is like the fig below.

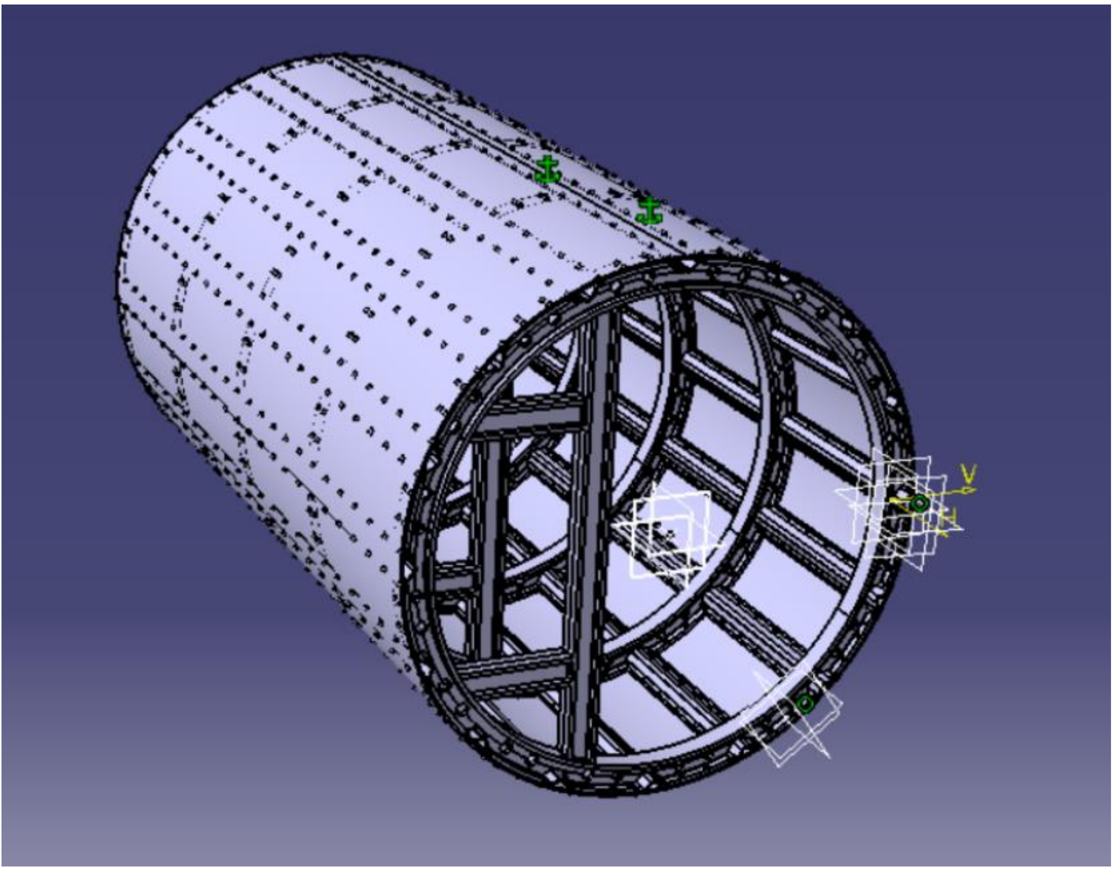
.

Figure 2.5 – Assembly

2.3 Static Analysis

CATIA is the industry's unquestioned leader, having started in the aerospace sector. Precision, safety, and dependability for a wide range of commercial, defence, and aerospace applications. CATIAV5 is a CAD/CAE/CAM integration package that includes Analysis & Simulation, a comprehensive and easy-to-use engineering analysis tool. This module allows you to easily construct basic finite element analysis for engineering-like real-world issues by simply describing loads and restrictions.

Finite element analysis GPS for individual components and GENERATive Assembly Structural Analysis for assemblies gas are two often employed functionalities. Its engineering analysis module is capable of doing computer analysis on a wide range of issues, including electricity, structure, fluids, thermodynamics, electromagnetic fields, human-machine integration, and collision problems. As a result, it's commonly employed in industries including automotive, aircraft, construction, biomedicine, bridges, electronics, heavy machinery, sports equipment, and micro-electromechanical systems.

I utilise structural analysis to simulate stress in a single frame in this part. Assume that the frame bears the weight of the skin.

Aluminum and carbon fiber are two of the most common materials used in the construction of airplane fuselages. In the past, most commercial airplanes featured an aluminum fuselage. Since the advent of the Boeing 787 and the Airbus A350, however, many airplanes now feature a carbon fiber fuselage. You can still find airplanes with an aluminum fuselage. Most airplanes, in fact, use this material for their fuselage. With that said, carbon fiber fuselages are on the rise[13].

Carbon fibre and aluminium are two very distinct materials. Aluminum has the atomic number 13 and is a metal. It is the most plentiful metal on the planet. Carbon fibre, on the other hand, is a man-made substance made up of numerous individual carbon strands knitted together. Carbon fibre has a diameter of around 5 to 10 micrometres for each strand of carbon. Only aluminium is classified as a metal among the two materials. Carbon fibre is a polymer, hence it's categorised as such.

Aluminum is affordable because it is the most plentiful metal on the planet. Because of its inexpensive cost, this metal is a common choice for fuselages among aircraft manufacturers. When the fuselage is made of aluminium, aerospace manufacturers may develop and produce planes at a reduced cost.

Aluminum is also quite light. Aerospace manufacturers must take weight into account while developing planes. The higher the weight of an aeroplane, the more power it requires to create and maintain lift during flight. As a result, fuselages are frequently made of aluminium. Aluminum enables the manufacture of light aeroplanes.

One of the most significant advantages of carbon fibre fuselages is their strength. Carbon fibre is extremely strong, even stronger than steel or aluminium. Individual strands of carbon are woven together to make carbon fibre, an ultra-strong mesh-like material. As a result, fuselages built of carbon fibre can withstand more physical stress than fuselages made of other materials.

Carbon fibre is also a very light material. In fact, it is almost 40% lighter than aluminium. Carbon fiber's lightweight qualities, when paired with its remarkable strength, make it a preferred choice for big commercial aeroplanes.

The expense of carbon fibre is a disadvantage. Carbon fibre is more expensive than aluminium. This is owing to the fact that carbon fibre production is more time consuming. It takes more resources to manufacture than aluminium, which results in a greater price.

So in this section of the paper, we would like to choose aluminum as the material of the fuselage to make the analysis.

The Von Mises stress is depicted in the diagram below.

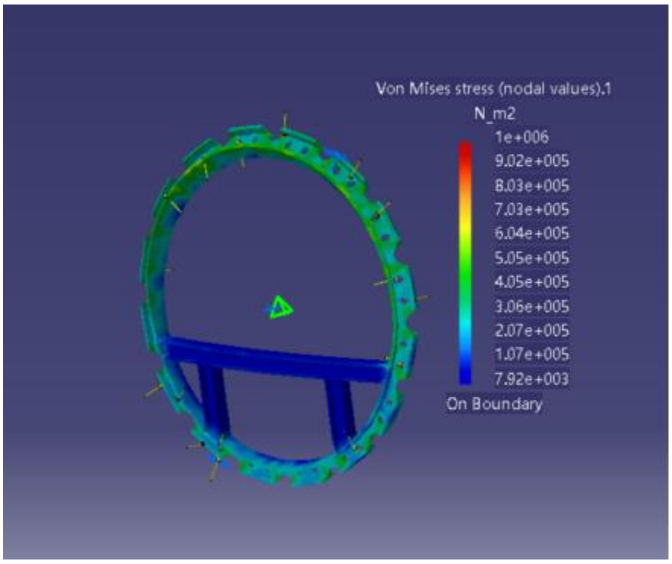


Figure 2.6 – Static analysis

The displacement magnitude is shown below.

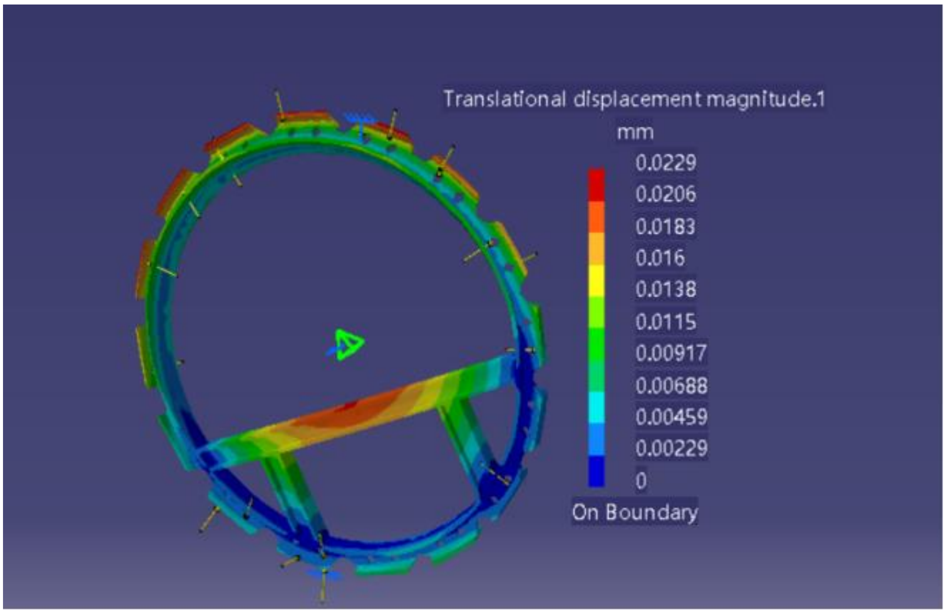


Figure 2.7 –displacement magnitude

Conclusion to part 2

Based on the first part, this section introduces the components of each part of the fuselage separately, and introduces their functions respectively. And use the relatively perfect CATIA software to model each part in 3D, and then use the CATIA assembly project to combine them to complete the drawing of the aircraft fuselage structure. Then through the built-in analysis module, the static strength analysis of the frame of the fuselage was carried out. Simulate the situation when it is connected to the fuselage, make corresponding constraints and loads, and finally show a force cloud map and stress cloud map to observe the main load part when it is stressed.

GENERAL CONCLUSION

During the design process, I summary them in the following result

– Preliminary design of the Mid-range passenger aircraft with 240 passenger capacity；

– Cabin layout of the Mid-range passenger aircraft with 240 passenger capacity ；

– General view of the Mid-range passenger aircraft with 240 passenger capacity;

– The center of gravity calculations of the airplane;

– The choice of engine accord to the aircraft thrust;

– The model of the fuselage section;

– The the strength analysis for Frame .

The plane is a low-wing passenger airplane with 4 bypass turbojet engines under its wings which looks like A340. Due to the massive size of the aircraft, a six-wheel landing gear with a front single-strut landing gear and four main landing gear was chosen to better sustain the aircraft's weight. A swept-back airfoil with a high aspect ratio based on a novel supercritical airfoil. The tail fin has a standard frame on which the movable vertical tail fin is mounted. Both the rudder and the elevator are aerodynamically balanced. When determining the center of gravity, the final center of gravity should be 50- 60% of the fuselage, taking into account wing geometry, fuselage center of gravity calculation.

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Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	240
Flight Crew Number	2
Flight Attendant or Load Master Number	6
Mass of Operational Items	2851.09 kg
Payload Mass	25080kg
Cruising Speed	871 km/h
Cruising Mach Number	0.81
Design Altitude	11 km
Flight Range with Maximum Payload	8000 km
Runway Length for the Base Aerodrome	2.55 km
Engine Number	4
Thrust-to-weight Ratio in N/kg	2.8
Pressure Ratio	37.4
Accepted Bypass Ratio	5.00
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.43
Aspect Ratio	9.26
Taper Ratio	3.98
Mean Thickness Ratio	0.12
Wing Sweepback at Quarter of Chord	34°
High-lift Device Coefficient	1.1
Relative Area of Wing Extensions	0.01
Wing Airfoil Type	supercritical
Winglets	no
Spoilers	yes
Fuselage Diameter	5.64m
Fineness Ratio of the fuselage	9.00
Horizontal Tail Sweep Angle	35°
Vertical Tail Sweep Angle	40°

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	Cy=0.49
Induce Drag Coefficient	Cx = 0.009

ESTIMATION OF THE COEFFICIENT $D_m = M_{critical} - M_{cruise}$

Cruising Mach Number	0.81
Wave Drag Mach Number	
Calculated Parameter D_m	0.006

Wing Loading in kPa (for Gross Wing Area)

At Takeoff	6.56
At Middle of Cruising Flight	5.25
At the Beginning of Cruising Flight	6.32

Drag Coefficient of the Fuselage and Nacelles	0.01
Drag Coefficient of the Wing and Tail Unit	0.009

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.03
At Middle of Cruising Flight	0.03
Mean Lift Coefficient for the Ceiling Flight	0.49
Mean Lift-to-drag Ratio	15.35
Landing Lift Coefficient	1.52
Landing Lift Coefficient (at Stall Speed)	2.29
Takeoff Lift Coefficient (at Stall Speed)	1.87
Lift-off Lift Coefficient	1.37
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.57
Start Thrust-to-weight Ratio for Cruising Flight	2.39
Start Thrust-to-weight Ratio for Safe Takeoff	2.86
Design Thrust-to-weight Ratio Ro	2.98
Ratio $D_r = R_{cruise} / R_{takeoff}$ Dr	0.83

SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):

Takeoff	35.45
Cruising Flight	58.34
Mean cruising for Given Range	63.46

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03
Block Fuel	0.34

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.10
Horizontal Tail	0.008
Vertical Tail	0.008
Landing Gear	0.03
Power Plant	0.09
Fuselage	0.08
Equipment and Flight Control	0.10
Additional Equipment	0.008
Operational Items	0.01
Fuel	0.38
Payload	0.14

Airplane Takeoff Weight	M =168708kg
Takeoff Thrust Required of the Engine	125kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.01
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.01
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.006
Furnishing Equipment Weight Fraction	0.01
Flight Control Weight Fraction	0.004
Hydraulic System Weight Fraction	0.01
Electrical Equipment Weight Fraction	0.02
Radar Weight Fraction	0.002
Navigation Equipment Weight Fraction	0.003
Radio Communication Equipment Weight Fraction	0.001
Instrument Equipment Weight Fraction	0.004
Fuel System Weight Fraction	0.01

Additional Equipment:

Equipment for Container Loading	0.005
No typical Equipment Weight Fraction(Build-in Test Equipment for Fault Diagnosis Additional Equipment of Passenger Cabin)	0.002

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	314.98km/h
Acceleration during Takeoff Run	2.23m/s^2
Airplane Takeoff Run Distance	1711m
Airborne Takeoff Distance	472m
Takeoff Distance	2183m

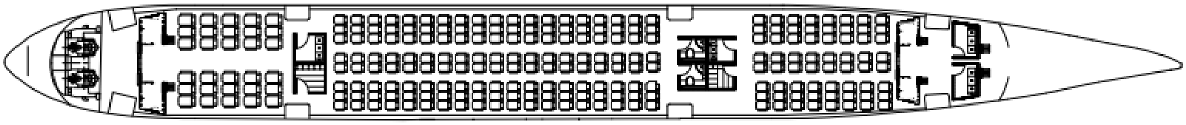
CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	283.48 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.94m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	2115.51m
Continued Takeoff Distance	2587.75m
Runway Length Required for Rejected Takeoff	2681.1m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	117930kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	21.8min
Descent Distance	52.81km
Approach Speed	268.37km
Mean Vertical Speed	2.13m/s
Airborne Landing Distance	524m
Landing Speed	253.37km/h
Landing run distance	854m
Landing Distance	1378m
Runway Length Required for Regular Aerodrome	2302m
Runway Length Required for Alternate Aerodrome	1957m

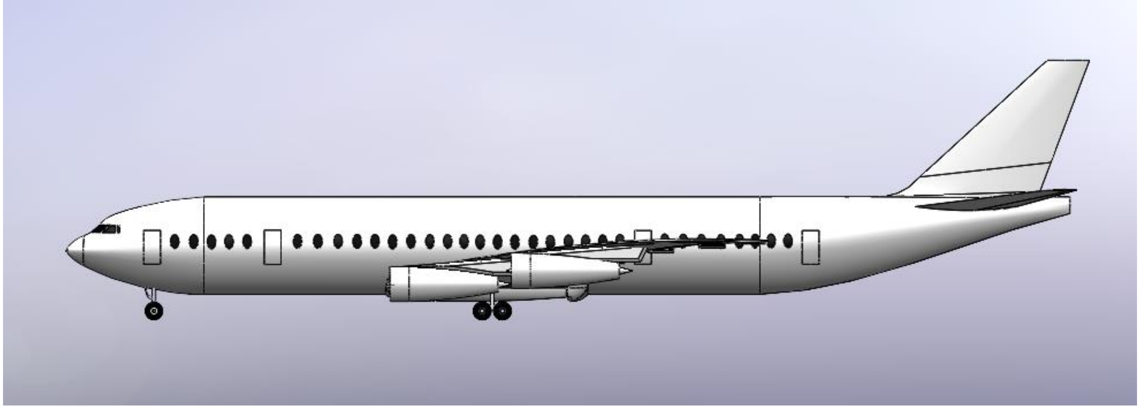
Appendix B



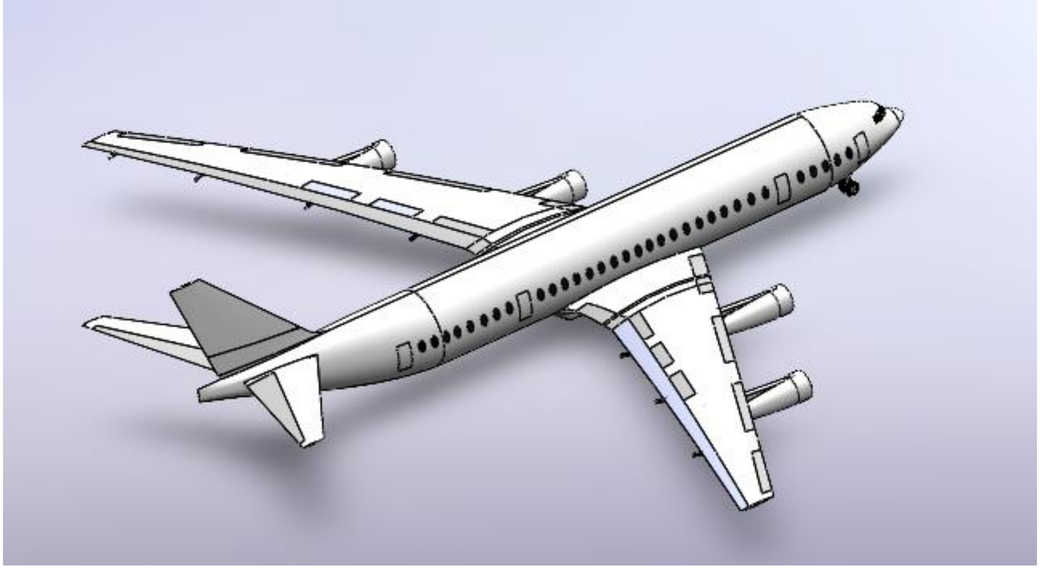
Aircraft cabin layout top view

Appendix C

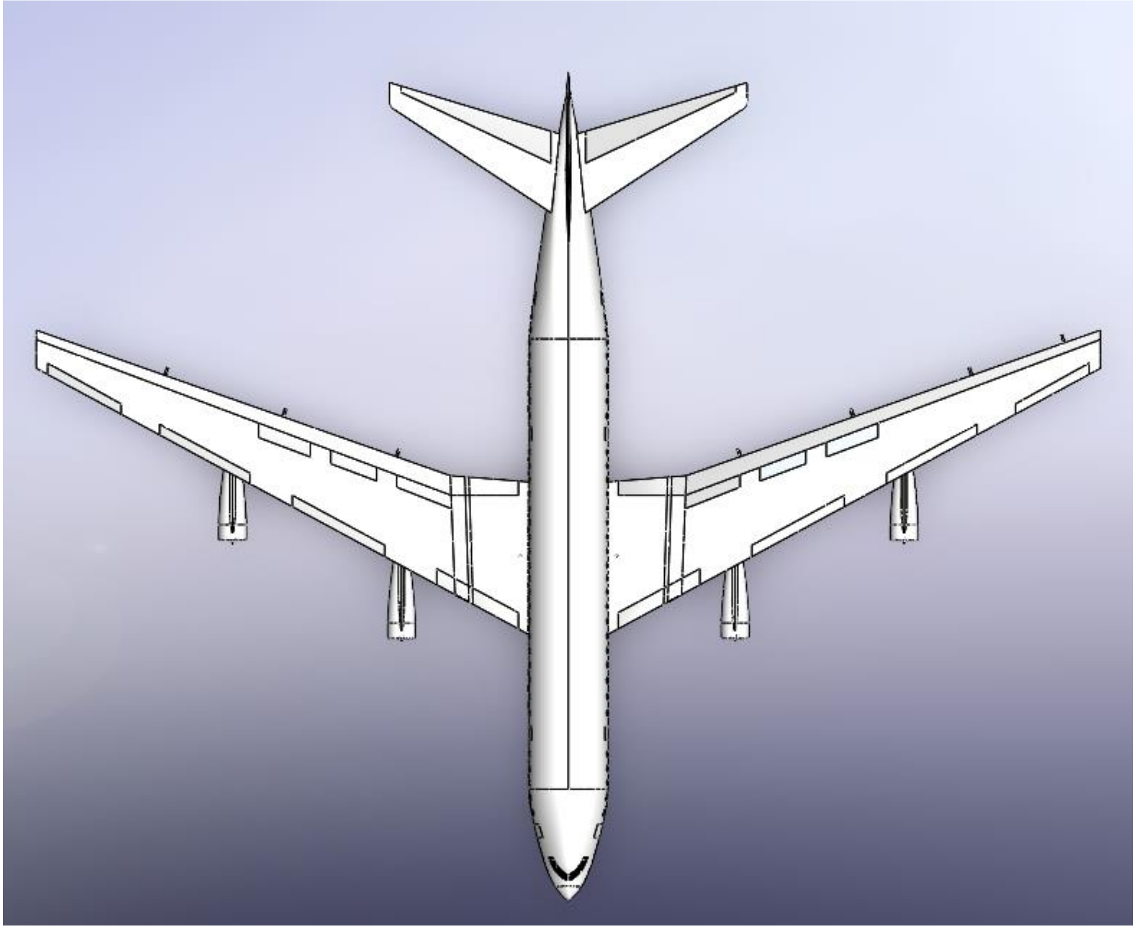
Front view of aircraft



Left view of aircraft



Aircraft axonometric drawing



Top view of aircraft

Aircraft axonometric drawing