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

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д.т.н., проф.
_____________Сергій ІГНАТОВИЧ
«_____» ___________ 2022 рік

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

Тема: «Аванпроект пасажирського літака середньої дальності місткістю 185 пасажирів»

Виконав: ___________ТАН Мяо

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Київ 2022

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

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

BACHALOR DEGREE THESIS
ON SPECIALTY
"AVIATION AND AEROSPACE TECHNOLOGIES "

Topic: «Preliminary design of a mid-range aircraft with 185 passenger capacity»

Prepared by: __________**TANG Miao**

Supervisor: PhD, associate professor __________**M. V. Karuskevich**

Standard controller: PhD, associate professor __________**S.V. Khizhnyak**

Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Academic Degree «Bachelor»

Specialty: 185 "Aviation and Aerospace Technologies"

APPROVED BY
Head of the Department
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«___» _______ 2022

TASK
for the bachelor degree thesis

TANG MIAO

1. Topic: «Preliminary design of a mid-range aircraft with 185 passenger capacity» confirmed by Rector's order № 489/ст from 10.05.2022.
2. Thesis term: from 23.05.2022 to 19.06.2022.
3. Initial data: cruise speed V_{cr}=870 km/h, flight range *L*=5700 km, operating altitude H_{op}=10 km, 185 passengers.
4. Content (list of topics to be developed): choice and substantiations of the airplane scheme, choice of initial data; engine selection, aircraft layout, center of gravity position calculation, designing of automatic lifting aircraft luggage rack.
5. Required material: general view of the airplane (A1×1); layout of the airplane (A1×1) 3D of Ball transfer unit.

Graphical materials are performed in Auto CAD and CATIA.

6. Thesis schedule:

Task	Time limits	Done
Task receiving, processing of statistical data	23.05.2022–28.05.2022	
Aircraft geometry calculation	28.05.2022–31.05.2022	
Aircraft layout	31.05.2022–03.06.2022	
Aircraft centering	03.06.2022–05.06.2022	
Graphical design of the parts	05.06.2022–12.06.2022	
Completion of the explanation note	12.06.2022–14.06.2022	
Defense of diploma work	14.06.2022–20.06.2022	

7. Date: 23.05.2022

Supervisor __________ M.V. KARUSKEVICH

Student __________ TANG Miao

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет

Кафедра конструкції літальних апаратів

Освітній ступінь «Бакалавр»

Спеціальність 185 «Авіаційна та ракетно-космічна техніка»

Освітньо-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н, проф.
__________ Сергій ІГНАТОВИЧ
«_____» _____________ 2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

ТАН МЯО

1. Тема роботи: «Аванпроект середньомагістрального літака пасажиромісткістю 185 осіб», затверджена наказом ректора № 489/ст від 10 травня 2022 року.

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

3. Вихідні дані до роботи: максимальна кількість пасажирів 185, дальність польоту з максимальним комерційним навантаженням 5700 км, крейсерська швидкість польоту 870 км/год, висота польоту 10 км.

4. Зміст пояснювальної записки: вибір параметрів та обгрунтування схеми проектованого літака, вибір двигунів, розрахунок геометрії та центрування літака, проектування механізму автоматичного відкривання полки для ручної поклажі.

5. Перелік обов’язкового графічного матеріалу: загальний вигляд літака (A1×1), компонувальне креслення фюзеляжу (A1×1);3D блок передачі м'яча.

Графічні матеріали виконуються в Auto CAD і CATIA.

6. Календарний план-графік:

Завдання	Термін виконання	Відмітка про виконання
Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів	23.05.2022–28.05.2022	
Вибір та розрахунок параметрів проєктованого літака	28.05.2022–31.05.2022	
Виконання компонування літака	31.05.2022–03.06.2022	
Розрахунок центрування літака	03.06.2022–05.06.2022	
Виконання креслень літака	05.06.2022–12.06.2022	
Оформлення пояснювальної записки та графічної частини роботи	12.06.2022–14.06.2022	
Захист дипломної роботи	14.06.2022–20.06.2022	

7. Дата видачі завдання: 23.05.2022 рік

Керівник дипломної роботи __________ М.В. Карускевич

Завдання прийняв до виконання __________ ТАН Мяо

ABSTRACT

Explanatory note to the diploma work “Preliminary design of the mid-range passenger plane with 185 passengers capacity”

63 pages, 19 figures, 9 tables, 11 references and 3 drawings

Object of the design is development of the mid-range aircraft with 185 passengers capacity.

Aim of the diploma work is the preliminary design of the aircraft with its design primary characteristic.

The methods of design are analyzise of the prototypes and selection of the most advanced technical decisions to find the geometry for main parts of the plane, such as wing, tail unit, fuselage, and landing gear. The range of the aircraft center of gravity has been found for tipical loading cases.

The diploma work contains explanatory notes with calculations, drawings of the aircraft general view and layout, preliminary design of the Ball Mat Module for cargo hold and container compartment.

AIRCRAFT, PRELIMININARY DESIGN, DRAWING, LAYOUT, CENTER OF GRAVITY, BALL MAT MODULE.

NAU 22.16T.00.00.00.42 EN

Performed by	Tang Miao			*Preliminary design of mid-range passenger aircraft with 185 passenger capacity*	Letter	Sheet	Sheets
Supervisor	Karuskevich M.V.						63
Adviser					402 AF 134		
Stand.contr.	Khizhnyak S.						
Head of dep.	Ignatovych S.						

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 22 16T 00 00 00 42 TW	Task for work	1	
	2	NAU 22 16T 00 00 00 42	Mid-range passenger aircraft	2	
A1		Sheet 1	General view	1	
A1		Sheet 2	Fuselage layout	1	
A4	3	NAU 22 02M 00 00 00 42 EN	Mid-range passenger aircraft	63	
			Explanatory note		
			<u>Documentation for assembly units</u>		
3D	4	NAU 21 16T 00 00 00 42	Design of Ball transfer unit	1	

		NAU 22.16T.00.00.00.42 EN	
Performed by	Tang Miao	Preliminary design of mid-range passenger aircraft with 185 passenger capacity	Letter / Sheet / Sheets: 63
Supervisor	Karuskevich M.V.		
Adviser			402 AF 134
Stand.contr.	Khizhnyak S.		
Head of dep.	Ignatovych S.		

CONTENT

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
BM	Ball Mat module
CM	The center of the mass

Introduction

According to the development of the aviation industry in recent years and the improvement of human living standards,for civil aviation,the number of passengers carried by the aircraft,as well as the requirements for the flight speed and distance of the aircraft have also been continuously improved.At the same time, more and more people are pursuing the comfort of taking airplanes,especially those passengers who take long-distance airplanes.Therefore,I designed a 185-seat medium-distance passenger plane based on these phenomena.The purpose of designing this aircraft is to increase the passenger capacity while increasing the passenger’s satisfaction with flying on the aircraft.At the same time,it reduces the economic losses of the supplier and demonstrates the advantages of the aircraft under the trend of fierce global competition.Increase the income of civil aviation.

The designed passenger aircraft has the following advantages:

-Increase the distance between seats.

-Increase the width between the seats.

-Increase the area of public use area.

-Low fuel consumption.

-Improve the airworthiness and safety of the aircraft.

-Improve the operability of the captain.

The purpose of this course project is to create an aircraft that can be used to transport 185 passengers and luggage on a medium-distance route.The special part deals with conceptual and preliminary design of the Ball Mat module.

National and international standards, airworthiness laws, rules, recommendations have been taken into account, including FAR-25, CS-25, ICAO civil aviation law and CCAR-25. [1]

PART 1. AIRCRAFT PRELIMINARY DESIGN

1.1.Short description of prototypes

The design of an airplane is a process of implementing multiple steps and procedures in order to design the airplane that the designer wants.The first stage of aircraft design is to estimate the initial data of the aircraft based on the data of the same type of aircraft in previous years and the designer's design plan, and then select the types of various external devices and the aerodynamic layout.According to the general shape of the first stage, the second stage calculates whether it is reasonable and whether it achieves the designer's goal.Finally, a wind tunnel test is carried out to determine whether the safety and quality meet the standards. If the standards are not met, the data will be modified according to the results of the wind tunnel experiment. If it reaches the standard,it can be mass-produced after going through a series of follow-up processes.So the choice of initial data is very important.[2]

The prototype of the aircraft I chose to design is a 118-185 seat midway passenger aircraft.Such aircraft include:B737-900ER, A320 and A321.According to the search, the important initial data of these three types of aircraft are shown in table 1.1.

Table 1.1 – Prototypes technical data

PARAMETER	PLANES		
	B737-900ER	A320	A321
The purpose of airplane	Passenger	Passenger	Passenger
Max payload	19692	19900	25300
Flight crew,(persons)	2	2	2
Passengers	177	150	185
Flight rang with $G_{payload,max}$,[km]	5925	6112	5926
Range of cruising altitudes,[km]	12500	12500	14850
Productivity		3444	1310

Table 1.1 – Prototypes technical data

Number of engines and their type	CFM56-7×2	CFM56-5B×2	CFM56-5B2 ×2
Take off thrust,[KN]	121.4×2	148×2	147.3×2
Cruising thrust,[KN]	24.38×2		
Take off run distance,[m]	2450	2090	1590
Maximum Take off Mass,[kg]	85130	78000	83000
Landing Mass,[kg]	66360	66000	73500
Empty weight fraction,%	52.48	54.62	51.64
Fuel fraction,%	25.26	31.35	29.30
Payload Fraction,%	22.26	14.3	19.06
Wing span,[m]	42.1	34.10	35.80
Sweep back angle at 1/4 of the chord,[°]	25.02	25	25
Fuselage length,[m]	42.1	37.57	44.51
Fuselage diameter,[m]	3.76	4.14	4.14
Passenger cabin width,[m]	3.54	3.70	3.70
Passenger cabin length,[m]		27.51	34.44

1.2.Short description of the new aircraft

The plane is a cantilever low-wing monoplane with bypass turbojet engines placed in rear part of fuselage and tricycle landing gear with a front single-strut landing gear and two main gears.

A swept wing with a high aspect ratio, which is based on new supercritical profile. Fuselage has circular cross section.Tail has a T-type construction, with adjustable vertical stabilizer mounted on the fin. Rudder and elevators are equipped with aerodynamic balance.

1.2.1.Fuselage

Based on the analysis of the prototype and the case of aircraft design in previous years, I was designing the fuselage of this aircraft. I chose the fuselage with the prototype section. And the tail is a contraction section, forming a streamline, reducing the air resistance to the aircraft. In order to facilitate manufacturing, the fuselage adopts a monocoque fuselage without truss beams and stringers. In order to improve the support of the skin, a denser normal frame is arranged along the length of the fuselage, sometimes called a dense frame structure. It is used where the bending moment is small and there is no large opening. When designing the fuselage, I also designed a pressurized cabin because I considered the fatigue damage of the aircraft structure under repeated loads. Generally, fatigue cracks are prone to occur in places where the tensile stress is large and the stress is concentrated. The skin of the pressurized cabin of the fuselage is often in tension under the action of the internal and external pressure difference. At the same time, the stress concentration near the cockpit doors and windows and the structural connection joints is relatively serious, which is the most prone to fatigue cracks. In order to prevent the aircraft from affecting flight safety due to structural fatigue, I avoided the problem of excessively high tensile stress of the pressurized cabin skin during the structural design.[4]

1.2.2.Wing

When I designed the aircraft, I considered that I might optimize the design of the aircraft in the later period, replace or repair the engine, so I used the lower single wing to expand the passenger's field of vision. At the same time, a proliferation device is designed on the wing to better meet the requirements of the design scheme. Dampers are also installed on the wing to prevent shock waves from affecting the flight of the aircraft. And optimized the way the fuselage and the wings are connected, reducing the impact of drag generated here.

1.2.3.Tail unit

When designing the tail fin of the aircraft, I chose a conventional vertical tail. Vertical tail, referred to as vertical tail. It plays a role in maintaining the balance, stability and control of the aircraft's heading. The principle is similar to that of a flat tail. The vertical tail is only arranged on the upper part of the aircraft axis. This is because when taking off and landing, the head of the aircraft is tilted up and the tail is very close to the ground, so the vertical tail surface cannot be arranged. Like the flat tail, the front half of the vertical tail surface is usually fixed, called the vertical stabilizer; the rear half is hinged on the rear of the stabilizer, and can be steered and deflected, called the rudder. The function of the vertical tail is to keep the turning in a state of no side slip; to keep the nose aligned with the runway when landing with crosswind; to balance the asymmetric yaw moment during flight (for example, the yaw caused by the parking of one engine in multiple engines). A damper can be installed in the rudder control system to prevent the yaw phenomenon of the aircraft in high-altitude and high-speed flight. The frame has only one vertical tail (single vertical tail). It is located in the plane of symmetry of the aircraft.

1.2.4.Crew cabin

The cabin refers to the space for crew members, passengers, and luggage in the aircraft. It can also store some equipment and emergency equipment needed during the flight. Since my original intention of designing this aircraft is to satisfy passengers, bring convenience to passengers, and increase the experience of passengers, when I design this aircraft, the proportion of passenger cabin area has increased. When designing passenger positions When it is time to meet my plan requirements, whether it is economy class or business class, the seats of passengers are widened, and the width of the aisle is also widened, making it more convenient for passengers to get on and off the plane and pass the aisle.If passengers' satisfaction with the aircraft increases, the aircraft can stand out in the competition of modern civil aviation aircraft and become a rookie.[3]

1.2.5.Passenger furnishing

Based on my analysis of the prototype aircraft and previous aircraft design cases, when I designed and designed this aircraft, I took into account the passenger ’ s experience and comfort in the aircraft.In order to bring convenience to the passengers, I designed the kitchens both in the front and rear of the cabin. , The area is large, it is designed according to the number of passengers carried by the aircraft, which can ensure that each passenger is taken care of when distributing food and improve the happiness of passengers. At the same time, I also designed four toilets based on the number of passengers, which are convenient for passengers to use, and each toilet has an area of one square meter.There is a filter water tank in the toilet, which is convenient for passengers to wash their faces and hands. There is also a toilet tank for easy flushing of the toilet.The passenger seat is adjustable. When designing the aircraft, I specifically inquired the prototype seat data, increased the distance between the seats, and the distance between the front and rear seats has also increased,so that the passengers can use them according to themselves’ need to adjust the seat.

At the same time, the plane is also equipped with three first aid kits, one in the front compartment, one in the middle compartment, and one in the rear compartment, so as to facilitate the use of passengers in emergency situations. Basic safety facilities such as oxygen masks, fire extinguishers, and smoke masks on the plane are also equipped, and special personnel are regularly inspected and replaced. The evacuation lights and "EXIT" lights on the aircraft are installed where passengers can see at a glance to prevent them from getting out of danger according to the command of the flight attendant in the event of a danger.

1.2.6.Control system

According to my analysis of the control system of the prototype "A321", there are two pilot seats in the cockpit of the aircraft I designed, one is the captain's operating

position and the other is the deputy captain's operating position.

The flight control system is composed of a control surface, cockpit controls, hinges and necessary mechanical mechanisms to control the flight of the aircraft.

The cockpit control device generally takes the following form:

The control rod-or a control crank, is fixedly connected to a cylinder to control the roll and pitch of the aircraft by manipulating the ailerons and elevators.

Rudder pedal-control the yaw of the aircraft.

Although some airplanes use different forms of control surfaces, such as rudder or flaperons, in order to prevent pilot confusion, the airplane is still designed to control roll and pitch with control sticks and control yaw with pedals.

In addition to the primary roll, pitch, and yaw control devices, pilots can also use some auxiliary control devices to better control the flight to reduce workload. The most common is a wheel-shaped device that controls the pitch and trim, which relieves the pilot's pressure on maintaining the plane's pitch balance. (Rudder trim and roll trim are generally only found in large airplanes, but some small airplanes also contain this equipment). Many airplanes also have lift-increasing devices-flaps, which are convenient for taking off and landing. The landing gear of some aircraft can be retracted to increase or decrease the air resistance of the aircraft. There are also some more advanced equipment, such as intake flaps (which can increase drag and cool the engine), leading edge slats, spoilers, etc. All of these require corresponding operating equipment.

1.2.7.Landing gear

According to my data analysis of the prototype and the inquiry of previous years, I chose to use the first three-point landing gear. The reasons for adopting this type of landing gear are as follows:

The first three-point landing gear has the following advantages: simple landing, safe and reliable. If the actual speed during landing is greater than the specified value, the impact force acting on the main wheel will reduce the angle of attack sharply when the main wheel touches the ground, so it is impossible to produce a "jump" phenomenon like the rear-front three-point landing gear. It has good directional stability and is safer when landing in a crosswind. When taxiing on the ground, maneuvering and turning are more flexible. There is no danger of standing upside down, so strong braking is allowed. Therefore, the taxiing distance after landing can be reduced. Because the fuselage of the aircraft is in a horizontal or nearly horizontal state during stop, take-off, and landing, the downward field of view is better. The impact is small.[4]

Although the first three-point type has many shortcomings: the arrangement of the nose landing gear is more difficult, especially for single-engine aircraft, the remaining space in the front of the fuselage is very small. The nose landing gear bears a large load, a large size, and a complex structure, so the mass is large. The landing roll is at a low angle of attack, so the air resistance cannot be fully utilized for braking. When taxiing on an uneven runway, the ability to overcome obstacles (ditches, mounds, etc.) is also relatively poor. The front wheel will produce shimmy phenomenon, so it is necessary to have equipment and measures to prevent shimmy, which increases the complexity and weight of the front wheel.

Nevertheless, due to the high landing speed of modern aircraft, and ensuring the safety of landing has become the primary decisive factor in considering the determination of the landing gear form, and the first three-point type has obvious advantages compared with the last three-point type in this regard, and it is the most widely used application.

1.3.Geometry calculations for the main parts of the new aircraft

The geometric calculation and shape selection of the aircraft include the selection of initial data, the determination of the relative positions of the main components, the calculation of various loads and the analysis of safety performance.

1.3.1.Wing design

The initial data of the wing is determined by the take-off weight m_0 and the specific wing load P_0.

Take off weight:

$$M_0 = 99035 \text{ (kg)}$$

Wing loading take off:

$$P_0 = 6.521$$

Aspect ratio:

$$AR = Span^2/Area = 9.40$$

Taper ratio:

$$TR=3.40$$

Full wing area with extensions is:

$$A_{\text{wing}} = \frac{M_0 \cdot g}{F_0} = \frac{99035 \times 9.8}{6.521} = 148.833 (m^2)$$

Wing span is:

$$L = \sqrt{A_{\text{wing}} \cdot AR} = \sqrt{148.833 \times 9.40} = 37.4 (\text{m})$$

Chord of root：

$$C_{\text{root}} = \frac{2S_W \cdot TR}{(1+TR) \cdot L_W} = 6.15 (\text{m})$$

Chord of tip：

$$C_{\text{tip}} = \frac{C_{\text{root}}}{TR} = 1.81 (\text{m})$$

1.3.2.Aerodynamic chord

Mean aerodynamic chord is equal:

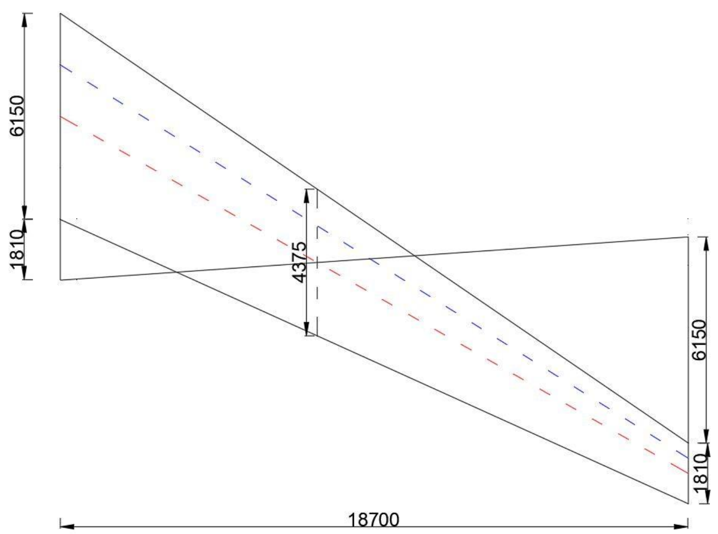


Figure 1.1– Determination of the wing mean aerodynamic chord

According to the requirements of the prototype and my design plan, the main parameters and aerodynamic chord length of the wing can be determined. After that, the data calculation of the accretion device and the selection of the geometry of the wing profile airfoil can be started.[5]

Ailerons. Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$L_{\text{ail}} = 0.35\frac{L_W}{2} = 0.35\times 37.4\times\frac{1}{2} = 6.545(m)$$

Aileron area:

$$S_{\text{ail}} = 0.065\times\frac{S_W}{2} = 0.065\times\frac{148.833}{2} = 4.837(m^2)$$

Chord of ailerons root and tip:

$$\text{b}_{\text{ail tip}} = 0.24\times C_W = 0.24\times 2 = 0.48(\text{m})$$

$$\text{b}_{\text{ail root}} = 0.24\times C_W = 0.24\times 3.5 = 0.84(\text{m})$$

where C_{W} is the length of the chord.

Width of slats:

$$\text{b}_{\text{slatsroot}} = 0.1\times C_{\text{root}} = 0.1\times 6.15 = 0.615(\text{m})$$

$$\text{b}_{\text{slatstip}} = 0.1\times C_{\text{tip}} = 0.1\times 1.81 = 0.181(\text{m})$$

Because this aircraft has 2 engines, so:

$$S_{\text{tips}} = 0.05\times S_{\text{ail}} = 0.05\times 4.837 = 0.242(\text{m}^2)$$

The geometric parameters of the airfoil and plane shape of the wing are usually designed according to the requirements of the cruise state, and the relative camber and other parameters of the airfoil are determined according to the requirements of the design lift coefficient. Therefore, in order to determine the lift coefficient, the data of the accretion device must be determined.

Flaps. Since the Flaps type designed for this aircraft is three slotted Fawlers flaps. So:

$$b_f = 0.3$$

Width of flaps:

$$b_{\text{flaps tip}} = 0.3 \times C_W = 0.3 \times 3.6 = 1.08(\text{m})$$

$$b_{\text{flaps root}} = 0.3 \times C_W = 0.3 \times 5.2 = 1.56(\text{m})$$

Based on my understanding of domestic and foreign aircraft design and the analysis of prototypes, the selection of the aircraft's proliferation device, fuselage wings, tail, etc.; connections, have been applied and optimized.

Based on the above calculation of the wing data and the relative position of the accretion device, the general shape of the wing is shown in Figure 1.2:

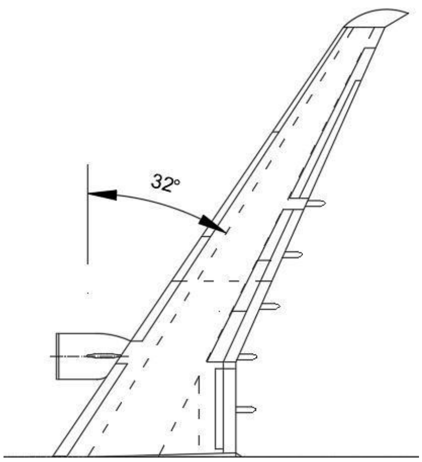


Figure 1.2 - The general shape of the wing

1.3.3. Fuselage design and layout of the cabin

Number of passengers:

$$N_{\text{passenger}} = 185\,.$$

Fuselage diameter: D_{f} =4.20m.

Fineness ratio of the fuselage:

$$FR = \frac{L_{\text{f}}}{D_{\text{f}}} = 9.00\,.$$

Length of the fuselage:

$$L = FR \cdot D_{\text{f}} = 37.8\text{m}\,.$$

Length of forward fuselage:

$$L_{\text{forward}} = 1.2 \times 4.20 = 5.04(\text{m})\,.$$

Length of after fuselage:

$$L_{\text{after}} = 5.45(\text{m})\,.$$

Length of passenger's cabin:

$$L_{\text{passengers}} = L - L_{\text{forward}} - L_{\text{after}} = 37.8 - 5.04 - 5.45 = 27.31(\text{m})\,.$$

When choosing the cross-sectional shape, I referred to the cross-sectional shape of the prototype and consulted the information of related passenger aircraft in recent years. In addition to meeting the requirements of aerodynamics, the layout of the aircraft was optimized and the fuselage was also improved. strength. Therefore, I chose a circular cross-section. This choice can enable the supplier to reduce economic losses while ensuring safety. The width of the skin used by the airliner is reduced.

Seat layout and data. Because the number of passenger types on this aircraft is 185, the layout adopts 3+3.Two rows of business class and twelve rows of economy class.

Width of seat:

$$L_{\text{seat 3-class}} = 1600(\text{mm});$$
$$L_{\text{seat 2-class}} = 1650(\text{mm}).$$

Width of aisle:

$$L_{\text{asile 3-class}} = 510(\text{mm});$$
$$L_{\text{asile 2-class}} = 550(\text{mm}).$$

Width of cabin:

$$B_{\text{cabin}} = \text{n}_{\text{bi}} \cdot L_{\text{seat}} + \text{n}_{\text{aisle}} \cdot L_{\text{ailse}} + 2\delta_1 + 2\delta_{\text{wall}}$$

$\delta_1 = 50\text{mm}$;

$\delta_{\text{wall}} = 120\text{mm}$.

$$B_{\text{cabin 2-class}} = 2 \times 1650 + 550 + 2 \times 50 + 2 \times 120 = 4190(\text{mm});$$
$$B_{\text{cabin 3-class}} = 2 \times 1600 + 510 + 2 \times 50 + 2 \times 120 = 4050(\text{mm}).$$

The distance between the seat and the seat:

$$L_{\text{seat bus}} = 960(\text{mm});$$
$$L_{\text{seat bus}} = 870(\text{mm}).$$

The distance between the first row of seats and the wall:

$$L_{wall} = 1200 (mm).$$

The distance between the last row and the wall:

$$\sigma = 250 (mm).$$

Length of business class and economy class:

$$L_{bus} = 1200 + 250 + 960 \times 1 = 2410 (mm);$$

$$L_{eco} = 1200 + 250 + (29 - 1) \times 870 = 25810 (mm).$$

.

As follow figure 2.3 for business class and economy class seat maps:

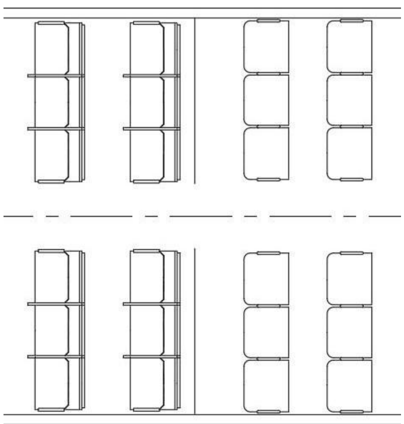


Figure 1.3 - Business class and economy class seat maps

Galleys. Because the design is a 185-seat midway plane, we need to distribute food and beverages to passengers during the flight.Therefore,we provide a large area of pantry and kitchens at the front and rear, which can take care of more passengers and improve customer satisfaction degree.At the same time,toilets are provided at the front and rear,which can enhance the customer experience.[6]

Volume of buffets (galleys) is equal:

$$V_a = 0.11 \cdot N_{passenger} = 0.11 \times 185 = 20.35 (m^3).$$

Height of cabin:

$$H_{cabin} = 1.48 + 0.17 \cdot B_{cabin} = 705.48 (mm).$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V}{H_{cabin}} = \frac{20.35m^3}{705.48mm} = 28.84 (m^2).$$

As follow figures, front cabin galley and rear cabin galley:

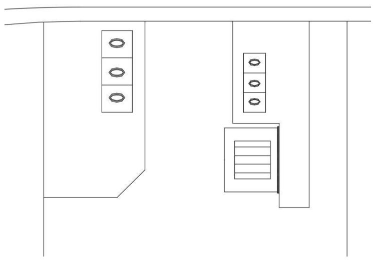


Figure 1.4 - Front cabin galley

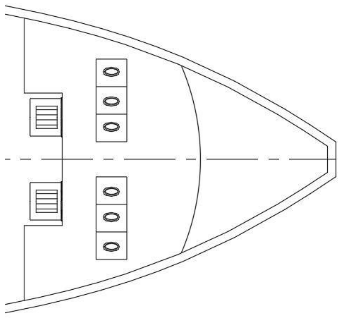


Figure 1.5 - Rear cabin galley

Wardrobe coat racks. Area of the floor for wardrobe coat racks:

$$S = 0.035 \cdot N_{passenger} = 0.035 \times 185 = 6.475 (m^2)$$

As follow figure,about the wardrobe coat racks for passengers:

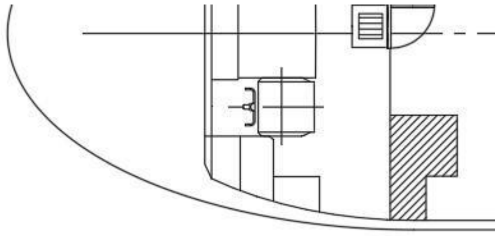


Figure 1.6 - Wardrobe coat racks for passengers

Lavatories. The number of toilet facilities is determined by the number of passengers and the flight time.Since the aircraft is a midway aircraft with a travel time of more than six hours, one toilet can be used by 50 passengers. Since the aircraft carries 185 passengers, a total of four toilets are required for passengers.

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

$$N_{\text{lov}} = 3$$

Area of lavatory:

950mm×1150mm;

Width of lavatory:

L=1m.

As followed from figure 1.7, lavatory for passengers:

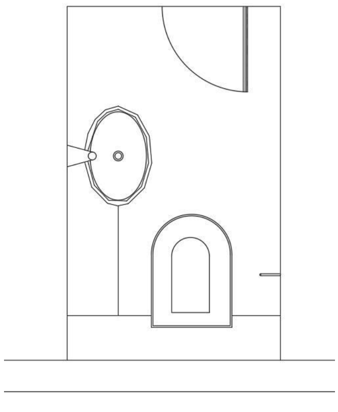


Figure 1.7 - Lavatory for passengers

When designing this aircraft, I referred to the prototype data and used the prototype data.

The internal layout of the engine room is shown in figures 1.8:

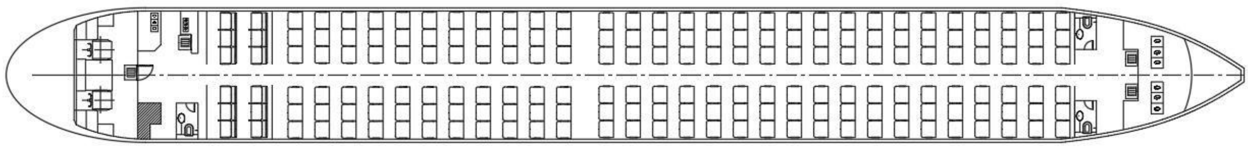


Figure 1.8 - The internal layout

1.3.4.Tail unit design

The layout of the tail unit is also very important and is a part of aerodynamics. The tail unit mainly controls the longitudinal stability of the aircraft. According to the data and conclusions of the relevant aerodynamic reference book, it can be concluded that the stopping point of the aircraft must be behind the center of gravity of the aircraft. The calculation of the distance between these points and the aerodynamic chord of the wing The value of the length is related, so it can be concluded that the aerodynamic chord length of the wing is directly related to the longitudinal stability.

Determination of the tail unit geometrical parameters as follows:

Normal scheme:

$$L_{HTU} = 3.5 \cdot \mathrm{b}_{MAC} = 15.31(\mathrm{m});$$

$$L_{VTU} \approx L_{HTU} = 15.31(\mathrm{m}).$$

Area of horizontal tail unit is equal:

$$A_{HTU} = 0.8$$

$$S_{HTU} = \frac{\mathrm{b}_{MAC} \cdot S_W}{L_{HTU}} \cdot A_{HTU} = 34.05(\mathrm{m}^2)$$

Area of vertical tail unit is equal:

$$A_{VTU} = 0.1$$

$$S_{VTU} = \frac{L_W \cdot S_W}{L_{VTU}} \cdot A_{VTU} = 36.393(\mathrm{m}^2)$$

Determination of the elevator area and direction:

Elevator area:

$$S_{\mathrm{el}} = 0.35 \cdot S_{HTU} = 0.35 \times 34.05 = 11.9175(\mathrm{m}^2)$$

Rudder area:

$$S_{\mathrm{rudder}} = 0.21 \cdot S_{VTU} = 0.21 \times 36.393 = 7.643(\mathrm{m}^2)$$

Choose the area of aerodynamic balance.

M=0.78＞0.75

So:

$$S_{\mathrm{abel}} \approx S_{\mathrm{abrudder}} = 0.2 \cdot S_{\mathrm{control\,serface}} = 0.2 \times 11.9175 = 2.3835(\mathrm{m}^2)$$

The area of trim tab:

$$S_{\mathrm{tabs}} = 0.1 \times S_{\mathrm{rudder}} = 0.1 \times 7.643 = 0.7643(\mathrm{m}^2)$$

Determination of the TU span.

TU span is related to the following department:

$$L_{ro} = 0.32 \times L_W = 11.97 (m)$$

The height of the vertical TU:

Because engine in the root part of the wing,so:

$$h_{bo} = 0.15 \times L_W = 0.15 \times 37.4 = 5.61 (m)$$

Because the airplane is low wing and M＜1：

So the ratio of horizontal and vertical TU:

$$\eta_{ro} = 2.5$$
$$\eta_{bo} = 3$$

The aircraft is a transonic aircraft, so:

$$\lambda_{bo} = 1$$
$$\wedge_{ro} = 4$$

Determination of horizontal tail unit chords:

$$b = \frac{2S_{HTU}}{(\eta_{ro} + 1) L_{ro}} = 1.27 (m)$$
$$b_{root} = b_{end} \cdot \eta_{ro} = 3.18 (m)$$
$$b_{HTU-MAC} = 2.36 (m)$$

As follow pictures ,about the determination of mean aerodynamic chord for the horizontal tail unit and vertical tail unit.

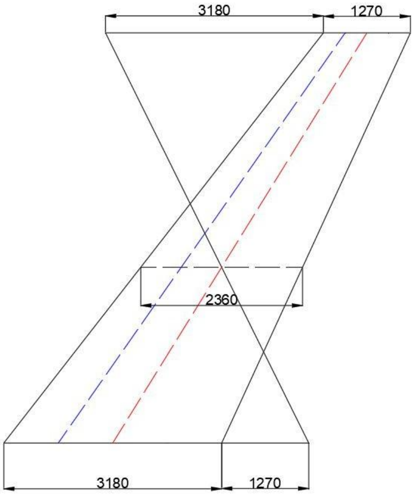


Figure 1.9 - The determination of mean aerodynamic chord for horizontal tail

Determination of vertical tail unit chords:

$$b = \frac{2S_{VTU}}{(\eta_{bo}+1)\ L_{bo}} = 1.19(m)$$
$$b_{root} = b_{end} \cdot \eta_{bo} = 3.57(m)$$
$$b_{VTU-MAC} = 2.580(m)$$

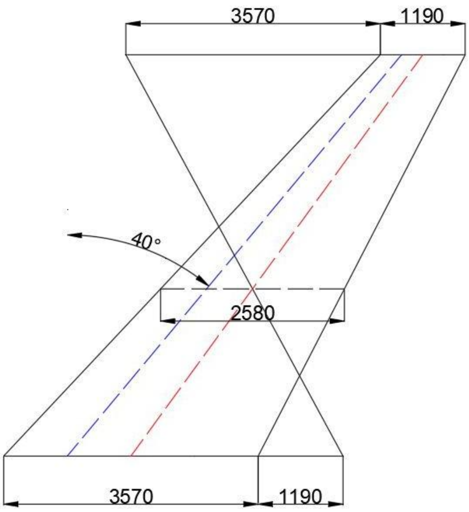


Figure 1.10 - The determination of mean aerodynamic chord for vertical tail unit

1.3.5.Landing gear design

In the initial stage of aircraft design, after determining the position of the aircraft's center of gravity, and without the final assembly drawing, the initial data of the landing gear can only be determined by the data of the prototype.

Main wheel axel offset is:

$$B_{\mathrm{m}} = 0.2 \cdot \mathrm{b}_{MAC} = 0.2 \times 4.375 = 0.875(\mathrm{m})$$

Because the passenger plane is a medium-sized aircraft with 185 seats, the aircraft has extremely high load requirements, and it is necessary to strictly design the landing gear so that the landing gear can withstand greater loads. The landing gear is very important for the take-off and landing of the aircraft, so the following process will talk about designing the initial data of the landing gear.[7]

The wheelbase of the landing gear comes from the expression:

$$B = 0.3 \cdot L_{\mathrm{f}} = 11.34(\mathrm{m})$$

Front wheel axial offset will be equal:

$$B_{\mathrm{n}} = B - B_{\mathrm{m}} = 10.465(\mathrm{m})$$

Wheel track is:

$$T = 0.7 \cdot B = 7.938(\mathrm{m}) < 12(\mathrm{m})$$

In order to prevent excessive lateral deflection of the nose during take-off or landing, so if T>2H, where H – Is the direct vertical distance between the center of gravity and the vicinity.

The wheels used in the landing gear need to select data and materials according to the operating load and take-off weight of the aircraft. The front landing gear may be affected by dynamic loads. Taking into account the influence of various factors, we have installed brake pads on the front wheel and the main wheel.

The load on the wheel is determined:

Nose wheel load is equal:

$$F_{\text{nose}} = \frac{B_{\text{m}} \cdot \text{m}_0 \cdot 9.18 \cdot K_{\text{g}}}{B \cdot Z} = \frac{0.875 \cdot 99035 \cdot 2 \cdot 9.08}{11.34 \cdot 2} = 70149.792(\text{kg} / \text{m}^2)$$

where K_g is dynamics coefficient. $K_g = 2.0$

Main wheel load is equal:

$$F_{\text{main}} = \frac{9.81 \cdot (B - B_{\text{m}}) \cdot \text{m}_0}{B \cdot \text{n} \cdot Z} = 209747.877(\text{kg} / \text{m}^2)$$

The size of the leading gear as follow table 2.1:

Table 1.2 - Aviation tires for designed aircraft

	Nose leading gear	Main leading gear
Tire	26×6.75-14	34.5×9.75-18
Ply rating	16	26

As is a cross-sectional view of the leading gear:

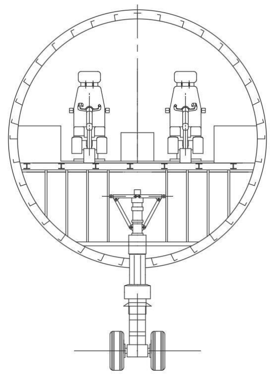


Figure 2.11 - A cross-sectional view of nose leading gear

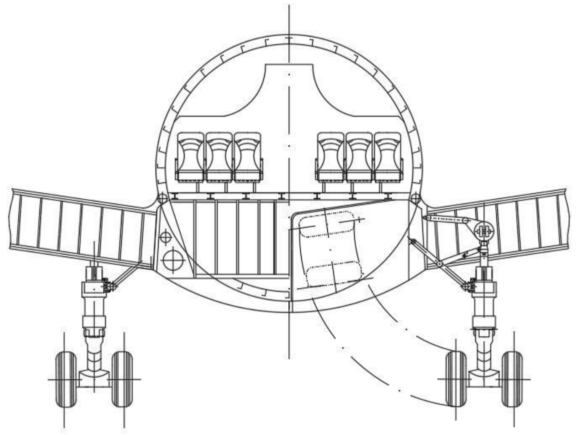


Figure 2.12 - Across-sectional view of main leading gear

1.3.6.Engine selection

When I designed the aircraft, I considered not only to bring convenience to passengers, but also to bring economic effects to the supplier, so I chose the engine model CFM56-5B2, which I think is the best in the world. A successful commercial engine, the design of CFM56-5A improves the performance of the engine as a whole, and reduces the user's various costs, meets the higher thrust requirements of the engine, has a lower fuel consumption rate, and can increase the range of the aircraft. I also considered maintenance issues. CFM56-5A reduced maintenance costs by 15%, reduced engine replacement time, and improved the accessibility of various systems. [8]

The related engine data are shown in table 1.3.

Table 1.3 - The related engine data

Engine type	Trust	Bypass ratio	Compression ratio	Weight
CFM56-5B1	130kN	5.5	35.4	2380kg
CFM56-5B2	140kN	5.5	35.4	2380kg
CFM56-5B3	150kN	5.4	35.5	2380kg

1.4.The range of the centre of gravity calculation

1.4.1.Trim sheet of equipped wing

There are also many masses equipped on the wing, including the structural mass of the wing itself, the quality of the equipment installed inside the wing, and the quality of the fuel installed on the wing. The main landing gear is installed in the position of the wing, so the mass of the main landing gear is included in the mass of the wing equipment. Although the front landing gear is installed in the fuselage, the mass of the front landing gear is also included in the mass of the wing equipment. The quality register contains three categories: the coordinates of the center of gravity, the name of the object, and the quality itself. The projection of the nose point of the average aerodynamic chord (MAC) on the XOY plane is the coordinate origin of the center of mass. The end of the aircraft accepts the positive meaning of the center of mass coordinate.

An example list of aircraft mass objects, where the engine is located at the end of the fuselage, including the names given in Table 1.4.

The coordinate of the power center of the equipped wing is defined by the following formula:

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

$$Y'_W = \frac{\Sigma m'_i Y'_i}{\Sigma m'_i}$$

Table 1.4 - Trim sheet of equipped wing masses

N	object name	Mass		C.G coordinates Xi, m	Mass moment, Xi * mi
		Units 1×10^{-3}	total mass m(i), kg		
1	wing (structure)	113.59	11249.39	1.88	21162.91
2	fuel system	9.6	950.74	1.86	1767.77
3	Flight control system , 30%	1.68	166.38	2.625	436.74
4	electrical equipment, 10%	3.15	311.96	0.4375	136.48

Table 1.4 - Trim sheet of equipped wing masses

5	anti-ice system , 40%	8.68	859.62	0.4375	376.09
6	hydraulic systems , 70%	11.13	1102.26	2.625	2893.43
8	power plant	49.09	4861.63	-1.78	-8653.70
9	equipped wing without landing gear and fuel	196.92	19501.97	0.93	18119.73
10	nose landing gear	7.45	737.81	-15.5	-11436.07
11	main landing gear	29.8	2951.24	4.16	12277.17
12	Fuel	404.5	40059.66	1.8375	73609.62
13	Total	638.67	63250.68	1.46	92570.45

1.4.2.Trim sheet of 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. The example list of the objects for the aircraft, which engines are mounted to the fuselage, is given in table 1.5.

The C.G. coordinates of the fully equipped fuselage are determined by formulas:

$$X_f' = \frac{\Sigma m_i' x_i'}{\Sigma m_i'}$$

$$Y_f' = \frac{\Sigma m_i' Y_i'}{\Sigma m_i'}$$

The distance from MAC leading edge to the C.G. point, determined by the designer Because I choose the low wing.

$$C = 0.23 \times B_{MAC} = 1.00625$$

Aircraft take off mass:

$$m_0 = 99035kg$$

Mass of fully equipped fuselage wing:

$$m_W = 63250.68kg$$

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

$$X_{MAC} = \frac{m_f x_f + m_w x_w^{'} - m_0 C}{m_0 - m_w} = 17.88 (m)$$

Table 1.5 - Trim sheet of equipped fuselage masses

N	Objects names	Mass		C.G coordinates Xi, m	mass moment
		Units 1×10^{-3}	total mass		
1	Fuselage	68.29	6763.10	18.75	126808.13
2	horizontal tail	8.73	864.58	36.00	31124.72
3	vertical tail	8.66	857.64	35.45	30403.45
4	Radar	3	297.11	0.50	148.55
5	radio equipment	2.2	217.88	0.80	174.30
6	instrument panel	5.2	514.98	1.50	772.47
7	aero navigation equipment	4.50	445.66	2.00	891.32
8	Flight control system 70%	3.92	166.38	16.52	2748.58
9	hydraulic system 30%	4.77	1102.26	22.95	25299.06
10	electrical equipment 90%	28.35	2807.64	13.54	38007.05
11	not typical equipment	3.20	316.91	4.00	1267.65
12	lining and insulation	6.40	633.82	18.75	11884.20

Table 1.5 - Trim sheet of equipped fuselage masses

13	anti ice system, 20%	4.34	429.81	15.90	6832.29
14	airconditioning system, 40%	8.68	859.62	23.80	20459.05
15	passenger seats (bussiness)	0.73	72.00	8.60	619.20
16	passenger seats (economic class)	10.48	1038.00	20.70	21486.60
17	seats of flight attendance	0.24	24.00	1.82	43.68
18	seats of pilot	0.30	30.00	1.49	44.70
19	Emergency equipment	3.35	28.00	7.50	210.00
20	lavatory1, galley 1	6.5	12.00	2.89	34.68
21	lavatory2, galley 2	6.5	38.00	30.50	1159.00
22	Operational items	1.89	186.88	26.00	4858.86
23	additional eguipment	3.21	317.90	5.00	1589.51
24	equipped fuselage without payload	193.44	18024.17	18.13	326867.04
25	Passengers(economy)	113.55	11245.00	20.70	232771.50
26	Passengers(bussiness)	7.88	780.00	8.60	6708.00
27	on board meal	2.80	277.50	32.00	8880.00
28	Baggage	33.62	3330.00	18.00	59940.00
29	cargo, mail	6.06	600.00	18.00	10800.00
30	flight attend	3.03	300.00	1.82	546.00
31	Crew	1.56	154.00	2.39	368.06
32	TOTAL	361.93	34710.67	18.64	646880.60

Table 1.5 - Trim sheet of equipped fuselage masses

33	TOTAL fraction for Checking	1000.60			

1.4.3.Calculations of the aircraft centre of gravity calculations range

According to the above tables 1.4 and 1.5, the position of the CG can be summarized. The summary data is shown in the following table 1.6 and the table 1.7.

Table 1.6 - Calculation of the C.G. positioning variants

Name	mass in kg	coordinate	mass moment
object	m_i	X_i, м	Kgm
equipped wing (without fuel and landing gear)	19501.97	18.81	366800.55
Nose landing gear (extended)	737.81	6.00	4426.86
main landing gear (extended)	2951.24	17.34	51174.55
fuel reserve	4005.97	19.72	78984.66
fuel for flight	27897.17	19.72	550041.78
equipped fuselage (without payload)	18024.17	18.13	326867.04
passengers of business class	11245.00	20.70	232771.50
passengers of economy class	780.00	8.60	6708.00
on board meal	277.50	32.00	8880.00
baggage	3330.00	18.00	59940.00
cargo, mail	277.50	32.00	8880.00
flight attend	3330.00	18.00	59940.00
cargo, mail	600.00	18.00	10800.00
Nose landing gear (extended)	737.81	4.00	2951.24
main landing gear (extended)	2951.24	17.34	51174.55

Table 1.7 - Airplanes C.G. position variants

№п/п	Name of regine of loading	mass in kg	mass moment m_iX_i	center of mass $X_{цм}$	centre of gravity position
1	take off mass (L.G. extended)	92958.33	1766214.95	19.00	0.26
2	take off mass (L.G. retracted)	92958.33	1764739.33	18.98	0.25
3	landing weight (LG extended)	65798.98	1216173.17	18.48	0.14
4	ferry version	73118.33	1376819.83	18.83	0.22
5	parking version	45221.17	828253.67	18.32	0.11

Conclusion to part 1

During the design process, in this work got the following results:

-The preliminary design of a medium-range aircraft capable of carrying 185 people;

-The cockpit layout of a medium-range aircraft for 185 passengers.

-Preliminary design of the aerodynamic shape of the wing;

-The location of the low-wing aircraft's engine is selected;

-The two engines are arranged under the wing to facilitate the maintenance after a problem occurs, and to facilitate the replacement of the engine that is not planned in the later stage;

-The design of the lifting device. Provide passengers to a greater degree: more convenient facilities, larger seating space, and more kitchens and toilets for passengers to use;

-The turbofan engine CFM56-5B2 is installed to provide high cruising speed and good thrust-to-weight ratio;

-Calculation of the main parameters of the landing gear;

-The choice of wheels and safety meet the requirements;

-The main parameter design and layout of the horizontal tail and the hammer straight tail.[9]

PART 2. PRELIMINARY DESIGN OF THE BALL MAT MODULE FOR CARGO HOLD AND CONTAINER COMPARTMENT.

The aim of the presented below preliminary design is acceleration of the procedure for the aircraft loading and unloading by application of the Ball Mat modules in the cargo holds and containers compartment.

2.1. Ball Mat principle of work.

A ball mat for the cargo and containers compartment of an aircraft is a known device to support cargo and assist the movement thereof.

It works like this:A loader will move a container into the aircraft through one of the large cargo doors.Just inside the door is a ball mat, a device in the floor of the cargo hold that reduces the friction in the movement of the container inside the compartment to the place where it will be locked. The container can be moved forwards or backwards by motorized rollers in the floor,the so-called PDUs(Power Drive Units).

Ball mats:

1) are omni-directional load-bearing spherical balls mounted inside a restraining fixture. They are identical in principle to a ball computer mouse upside-down, or a trackball, except there is an array of them side-by-side.[10]

2) Typically the design involves a single large ball supported by smaller ball bearings (fig.2.1).They are commonly used in an inverted ball up position where objects are quickly moved across an array of units, known as a ball transfer table, a type of conveyor system.This permits manual transfer to and from machines and between different sections of another conveyor system;

3) Prior to the invention of the ball transfer unit, first patented by Autoset Production Ltd in 1958, these applications were solved by the use of inverted casters.However, casters recognize a trail, meaning that the wheels had to align before directional change could be achieved.

This design can also be used non-inverted ball down position as a type of caster, but design is restricted by load-bearing limitations and the hardness of floor surface.

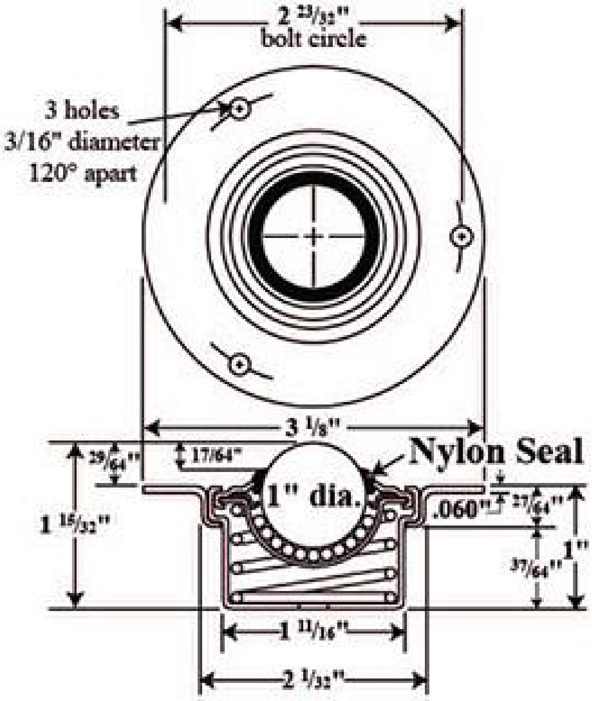


Fig.2.1 – Typical Ball Transfer unit

2.2. Location of the Ball Mat modules in the designed aircraft

Ball Mat module can be installed nearby the cargo hatch as it is shown in fig.2.2.

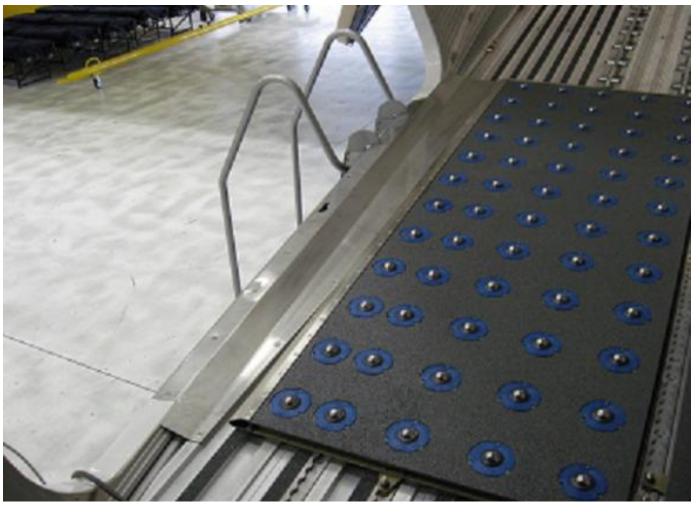


Fig.2.2 – Ball Mat module nearby the cargo hatch

The Ball Mat installed in the compartment of the plane selected as a plane-analogous is shown in fig2.3

Fig.2.3 - Ball Mats of the plane A321, selected as a prototype in the preliminary design procedure (part 1)

Location of the forward and aft cargo compartment in the typical mid-range plane is shown in fig 2.4.

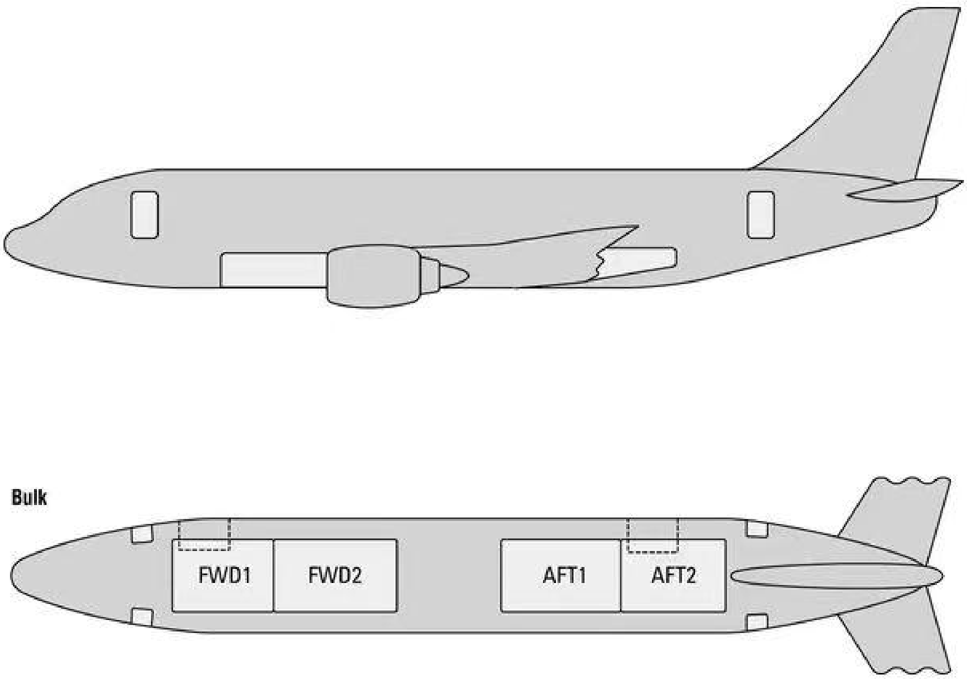


Fig.2.3 – Location of the cargo hatches in typical mid-range passenger aircraft

2.3. Dimensions of the Ball Mat module

Dimensions of the Ball Mat modules depends greatly on the dimensions of the hatches (if the modules is installed nearby the hatch, and cargo holds, if the modules cover entire hold). The experience of the contemporary aircraft have been analyses on the base of the information presented in the table 2.1.

Table 2.1 – Dimensions of cargo holds and cargo doors

Make/Model	Max Payload Tonnes	Max Loadable Volume CBM3	Cargo Hold Dims L×W×H cm	Cargo Door Size W×H cm
Boeing 727	23.5	144	2712 x 351 x 218	340 x 218
DC9	17	120	210 x 274 x 205	345 x 205
Boeing 737	16	115	2100 x 310 x 220	340 x 215
BAe ATP	8.2	78	1500 x 195 x 180	250 x 169
ATR 72	8	75	1795 x 225 x 175	294 x 180
Antonov 26	6.5	45	1110 x 220 x 160	230 x 171
Antonov 74	6.5	45	1000 x 215 x 220	226 x 220
Fokker 27	6.3	58	1336 x 210 x 190	228 x 175

2.4. Loads on the Ball Mat module

Loads on the Ball Mat module and load on one ball transfer unit are calculated on the base of accepted floor loading limitations.

These limitations are: a) running load limitations; b) area load limitations.

Running load limitation: The running load limitation is the maximum load acceptable on any given fuselage length of an aircraft floor.

Unit: kg/m or lb/ft.

Running load = Weight of the piece /Length of the piece in the flight direction = W/L.

We can get that the maximum running load of forward compartment is:

$$\frac{W}{L} = \frac{4086}{8.13} = 502.6 kg/m.$$

The maximum running load of after compartment is:

$$\frac{W}{L} = \frac{4540}{8.03} = 565.4 kg/m.$$

Area load limitation is the maximum load acceptable on any surface unit of an aircraft floor. It prevents the load from exceeding the capability of the aircraft structure (floor beams,floor posts,floor panels and frames).

Unit: kg/m^2 or lb/ft^2.

Area load = Weight of the piece /Contour Area=W/S.

We can get that:

The maximum area load of forward compartment is:

$$\frac{W}{S} = \frac{4086}{8.13 * 3.18} = 158 kg/m^2.$$

The maximum running load of after compartment is:

$$\frac{W}{S} = \frac{4540}{8.03 * 3.18} = 177.8 kg/m^2.$$

2.5. Selection of the Ball Transfer Unit

At the moment, the more suitable for our task standard Ball Transfer units are manufactured by the ALWAYSE.

Some examples of the ALWAYSE products are shown below (table 2.2).

These are ball transfer unites selected on the base of their loading analysis, presented here.

To find load on one Ball Transfer Unit we need knowledge about required density of BTU in the floor panel.

It was found that there are 406 ball transfer units in forward compartment and aft compartment, so that the number of BTU in one m^2 will be:

In forward compartment:

406/(8.13*3.18)=16

In aft compartment:

406/(8.03*3.18)=20

Then the load on one BTU will be:

In forward compartment:

$$\frac{158 kg/m^2}{16} = 9.875 kg/m^2 .$$

In aft compartment:

$$\frac{177.8 kg/m^2}{20} = 8.89 kg/m^2 .$$

Table 2.2 – Characteristics of two types of ball transfer units manufactured by ALWAYSE

Type	Advantages

Table 2.2 – Characteristics of two types of ball transfer units manufactured by ALWAYSE

805 Series	The original heavy duty air cargo unit. The industry standard and suitable for most conditions.
888 Series	Reduced friction for easier movement of ULDs. Improved corrosion resistance. The new series also features a modified dirt exit hole with a 30% increase in the opening area.

The drawing of the selected ball transfer unit as shown in fig.2.5.

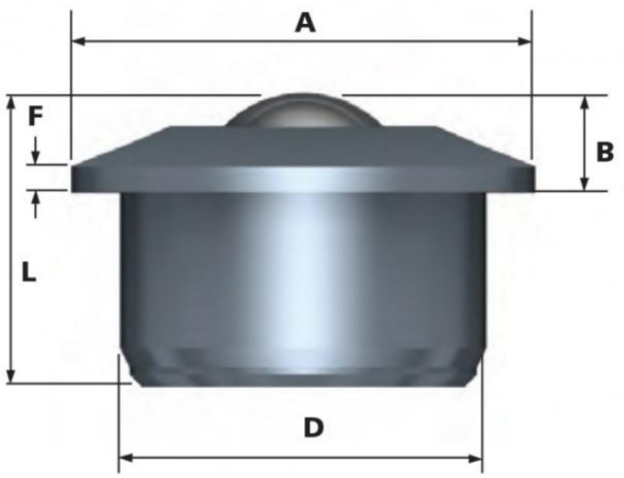


Fig. 2.5 – Ball transfer unit

Table 2.6 shows the detailed ball transfer unit of Type 805-30-16 and Type 880-30-16.

Table 2.3 - Ball transfer unit specific specification

	Type 805-30-16	Type 880-30-16
Max dynamic loading(kg) Load ball up	350	350
Weight(kg)	0.36	0.29
Load ball diameter(mm)	30	30

Table 2.3 - Ball transfer unit specific specification

Dimension A - Max Diameter (mm)	55	50
Dimension B - Working Height of Ball (mm)	13.8 +/- 0.2	13.8 +/- 0.2
Dimension D - Body Diameter (mm)	45 +/- 0.08	45 +/- 0.08
Dimension F - Flange Thickness (mm)	3.4	2
Dimension L - Overall Height (mm)	36.8	34.8
Fixing Methods	Hole	Hole
Material of Load Ball	Stainless Steel	Stainless Steel
Material of Support Ball	Stainless Steel	Stainless Steel
Tensile yield strength	207 MPa	207 Mpa
Unit Housing Material	Stainless Steel - Bright Zinc Plated	Stainless Steel - Bright Zinc Plated
Load Capacity Ranges	250 kg	250 kg

The unit weight of Type 880-30-16 is lower and it features a completely new design with improved Corrosion resistance and 10% Greater load ball exposure. Its tapered body is also more easier for installation.

2.6. Installation of the Ball Transfer Unit into the honeycomb panel.

Installation of the ball transfer units into the floor panel requires special attention. It is caused by the structural features of the floor. Let’s consider the structure of the typical floor beam designed as a sandwich honeycomb structure (fig. 2.6).

Floor panels have an important role in more than simply providing a flat surface to walk on. They are a **component of the aircraft structure**, which means they play a role in the overall safety of an aircraft during normal operations, emergency landings and rapid decompression events. Modern panels may also include additional functionality that can provide benefits in conductivity and cabin configuration versatility.

Floor panels, sometimes referred to as floor boards, are mounted to the aircraft's floor beams to provide a surface for passengers and crew to walk on and provide attachment points for certain furnishings and other components. They must be adequately strong and stiff to act as a supporting structure; durable to withstand use over time; light enough to help keep aircraft weight low; and in some cases, versatile to allow a variety of cabin configurations.[11]

Panels are commonly fabricated from honeycomb panels with glass/carbon/epoxy faces and an aramid core. Panels may have foam installed on surface areas to combat vibration, noise and in some cases provide a smoke seal to prevent smoke from entering the cabin. Some panels include edge fill, which helps prevent liquids from getting into the panel structure.

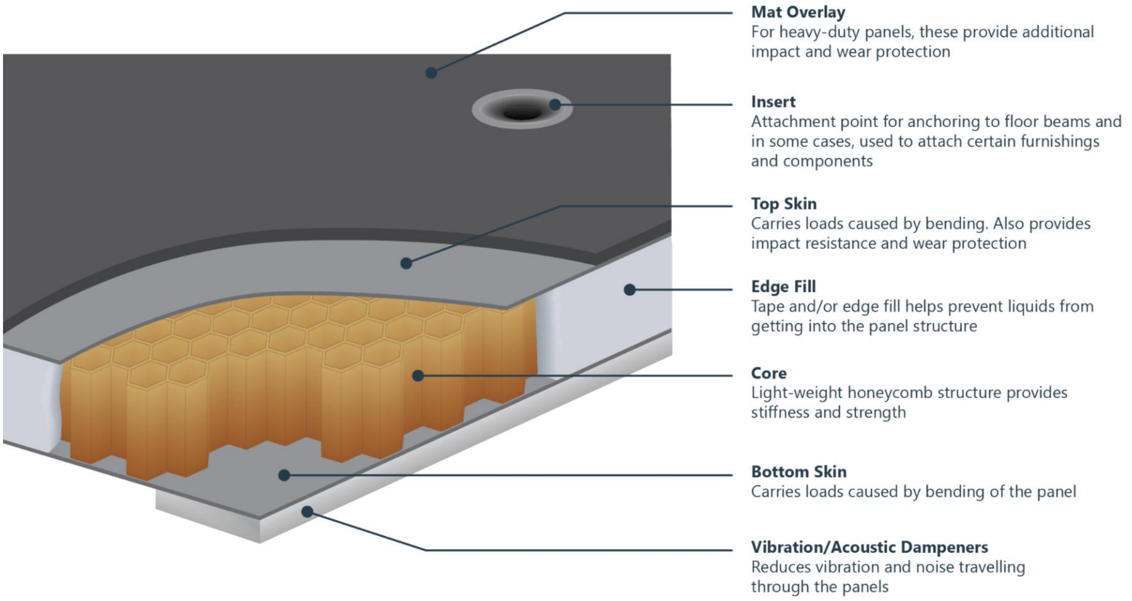
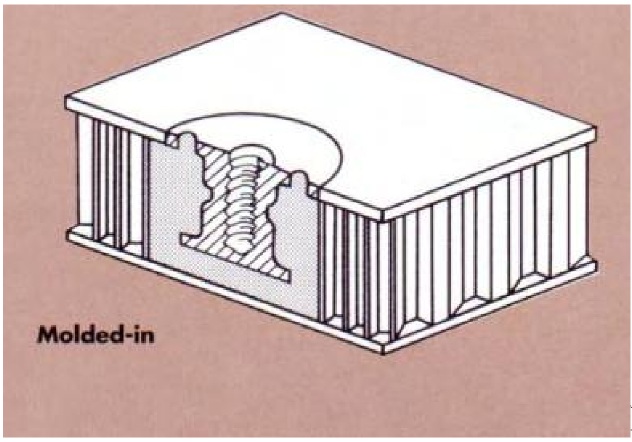


Fig.2.6 - Composite honeycomb sandwich panel

The use of composite honeycomb sandwich panels in aircraft structures provides the advantage of lightweight material in combination with an array of beneficial mechanical and chemical properties including: Durability, strength, stiffness, impact and crush-resistance, shear strength, flammability resistivity properties, sound and thermal insulation.

Structure of the honeycomb panels requires special approach to the fastener insert selection.

Basically there are two types of fastener inserts for honeycomb application: the molded-in type and the mechanical type (fig. 2.7).



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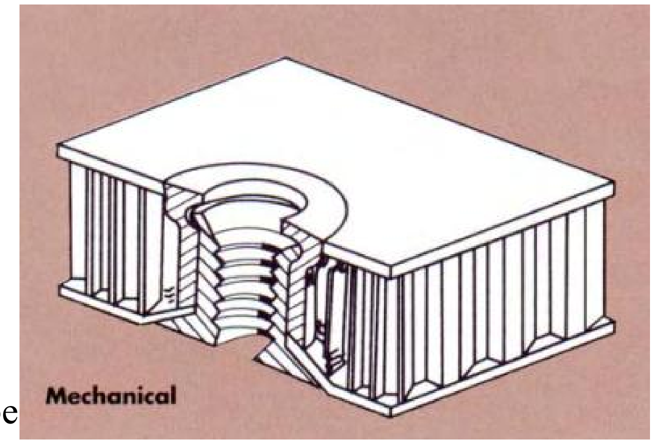


For sandwich structure the so-called I-beam method can be recommended as a simple preliminary step of the design process.

Conclusion to special part

As for the design of ball pad, we should not only select the type and number of ball units according to the aircraft we designed, but also design the structure and materials of floor plane.

The panel can be made of a honeycomb panel with carbon, glass, aramid core and epoxy surface. Foam may be installed on the panel surface to resist vibration, noise and, in some cases, smoke seals are provided to prevent smoke from entering the engine room. Some panels include edge filling, which helps prevent liquid from entering the panel structure.

According to the total weight of the number of aircraft passengers and the amount of luggage carried by each passenger, the number of ball units is selected according to the formula, and the type, size and material of the ball are selected according to the weight borne by each ball. My idea of designing the aircraft is to strive to create the best passenger plane with the least money and help operators save more costs and obtain the greatest benefits under the safest conditions.

General conclusion

The purpose of our thesis for this course design is to test our basic knowledge and prospects for the development of aviation in the future.We should learn the basics well in order to design a better airplane.What will the future aviation vehicle look like?What new features does it have?Compared with the current aviation aircraft,what kind of breakthroughs and progress have you made?etc.These questions need to be modern. We are looking for answers in continuous design experiments. If we want to be a good and outstanding aviation aircraft designer,then we should boldly imagine, be brave to innovate and practice, only in continuous practice. In the process,we can continuously improve our strength.Although,modern aircraft basically have big or small problems,they all need time and technological development, waiting for us to solve in the future.

In the course of course design, I not only consolidated my basic knowledge, but also applied my basic knowledge to practice. I enjoy the design process very much. In the future, I will continue to improve my abilities and do a good job. An excellent aviation aircraft designer.

References

[1] Luo Shibin, Zhou Jiaming, Wang Dou, Liu Jun. Two-stage fusion wave-riding aerospace aircraft design and aerodynamic characteristics research[J]. Computer Simulation, 2021, 38(10): 38-42.

[2] Chen Cai, Qi Tong Baihui, Zhang Zemeng. Promote the standardization strategy to realize the "three good, one drop and one energy" in civil aircraft design [C] // Proceedings of the 18th China Standardization Forum., 2021:1626-1632. DOI: 10.26914/c.cnkihy.2021.024386.

[3] Zou Jian. The rapid design and automatic adjustment of civil aircraft cabin[J]. China High-tech, 2021(17): 67-68.

[4] Yang Juping, Chen Yi, Zhang Pengli, Xia Detian, Cheng Junqiang. Integrity design of civil aircraft flight control module[J]. Aeronautical Computing Technology, 2021, 51(04): 96-100.

[5] Higgins Ross J., Barakos George N., Shahpar Shahrokh et al. A computational fluid dynamic acoustic investigation of a tiltwing eVTOL concept aircraft[J] Aerospace Science and Technology, 2021, 111

[6] Wang Mingkai, Diepolder Johannes, Zhang Shuguang et al. Trajectory optimization-based maneuverability assessment of eVTOL aircraft[J] Aerospace Science and Technology, 2021(prepublish)

[7] Cipolla V., Abu Salem K., Palaia G. et al. A DoE-based approach for the implementation of structural surrogate models in the early stage design of box-wing aircraft[J] Aerospace Science and Technology, 2021, 117

[8] GAO Yuan, TIAN Yongliang, LIU Hu et al. Entropy based inverse design of aircraft mission success space in system-of-systems confrontation[J] Chinese Journal of Aeronautics, 2021, 34(12)

[9] Sanchez Florian, Huzaifa Abdul Malik, Liscouët-Hanke Susan Ventilation considerations for an enhanced thermal risk prediction in aircraft conceptual design[J] Aerospace Science and Technology, 2021, 108

[10] Liang ZHANG, Dongli MA, Muqing YANG et al. Optimization and analysis

of winglet configuration for solar aircraft[J] Chinese Journal of Aeronautics, 2020(prepublish)

[11] David Sziroczak, Istvan Jankovics, Istvan Gal et al. Conceptual design of small aircraft with hybrid-electric propulsion systems[J] Energy, 2020, 204(

Appendix

Appendix A :INITIALDATAAND SELECTED PARAMETERS

Passenger Number	185
Flight Crew Number	2
Flight Attendant or Load Master Number	5
Mass of Operational Items	1869.06 kg
Payload Mass	19332.50kg
Cruising Speed	870 km/h
Cruising Mach Number	0.8055
Design Altitude	10 km
Flight Range with Maximum Payload	5700 km
Runway Length for the Base Aerodrome	2.95 km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.3000
Pressure Ratio	32.50
Accepted Bypass Ratio	4.50
Optimal Bypass Ratio	4.50
Fuel-to-weight Ratio	0.2400
Aspect Ratio	9.40
Taper Ratio	3.40
Mean Thickness Ratio	0.120
Wing Sweepback at Quarter of Chord	32°
High-lift Device Coefficient	1.300
Relative Area of Wing Extensions	0.050
Wing Airfoil Type	supercritical
Winglets	no
Spoilers	yes

Fuselage Diameter	4.20m
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=0.45013
Induce Drag Coefficient	Cx = 0.00909

ESTIMATION OF THE COEFFICIENT

$D_m = M_{critical} - M_{cruise}$

Cruising Mach Number	0.80553
Wave Drag Mach Number	0.81817
Calculated Parameter D_m	0.0165
Wing Loading in kPa (for Gross Wing Area):	
At Takeoff	6.521
At Middle of Cruising Flight	5.432
At the Beginning of Cruising Flight	6.296
Drag Coefficient of the Fuselage and Nacelles	0.01147
Drag Coefficient of the Wing and Tail Unit	0.00911
Drag Coefficient of the Airplane:	
At the Beginning of Cruising Flight	0.03408
At Middle of Cruising Flight	0.03064
Mean Lift Coefficient for the Ceiling Flight	0.45013
Mean Lift-to-drag Ratio	14.69237
Landing Lift Coefficient	1.700
Landing Lift Coefficient (at Stall Speed)	2.550
Takeoff Lift Coefficient (at Stall Speed)	2.048
Lift-off Lift Coefficient	1.495
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.615

Start Thrust-to-weight Ratio for Cruising Flight	2.305
Start Thrust-to-weight Ratio for Safe Takeoff	3.142
Design Thrust-to-weight Ratio Ro	3.299
Ratio D r = R cruise / R takeoff Dr	0.734

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

Takeoff	35.5179
Cruising Flight	60.4361
Mean cruising for Given Range	66.0271

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.04045
Block Fuel	0.28169

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.11359
Horizontal Tail	0.00873
Vertical Tail	0.00866
Landing Gear	0.03725
Power Plant	0.09818
Fuselage	0.06829
Equipment and Flight Control	0.12584
Additional Equipment	0.00321
Operational Items	0.01887
Fuel	0.32214
Payload	0.19521
Airplane Takeoff Weight	M =168708kg
Takeoff Thrust Required of the Engine	125kN
Air Conditioning and Anti-icing Equipment Weight Fraction	0.0217
Passenger Equipment Weight Fraction(or Cargo Cabin Equipment)	0.0151
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0064

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Furnishing Equipment Weight Fraction	0.0130
Flight Control Weight Fraction	0.0056
Hydraulic System Weight Fraction	0.0159
Electrical Equipment Weight Fraction	0.0315
Radar Weight Fraction	0.0030
Navigation Equipment Weight Fraction	0.0045
Radio Communication Equipment Weight Fraction	0.0022
Instrument Equipment Weight Fraction	0.0052
Fuel System Weight Fraction	0.0096
Additional Equipment:	
Equipment for Container Loading	0.0000
No typical Equipment Weight Fraction	0.0032

(Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	300.62km/h
Acceleration during Takeoff Run	2.65m/ s^2
Airplane Takeoff Run Distance	1313m
Airborne Takeoff Distance	578m
Takeoff Distance	1892m

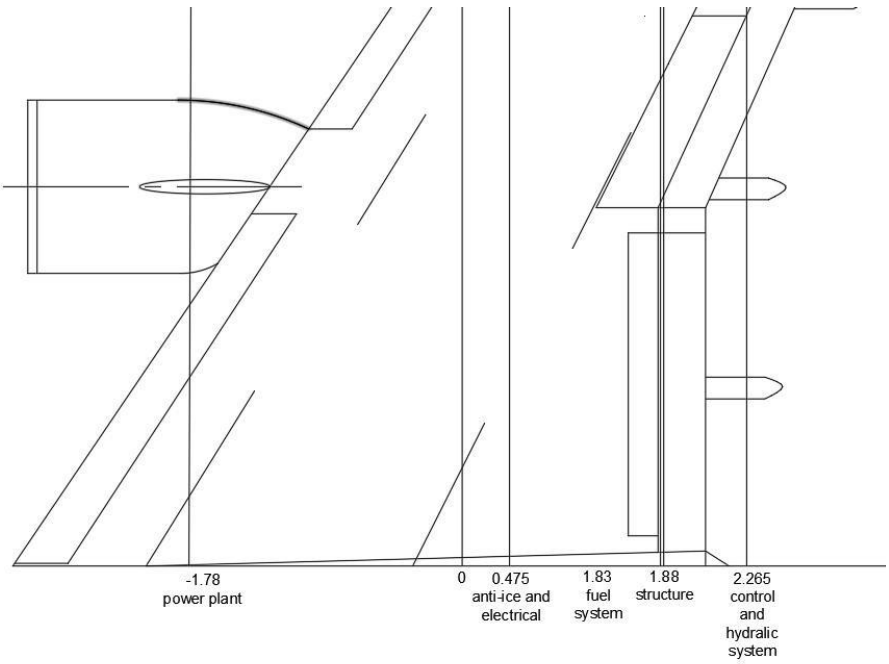
CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	285.59 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.42m/ s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	1975.57m
Continued Takeoff Distance	2553.97m
Runway Length Required for Rejected Takeoff	2643.97m

LANDING DISTANCE PARAMETERS

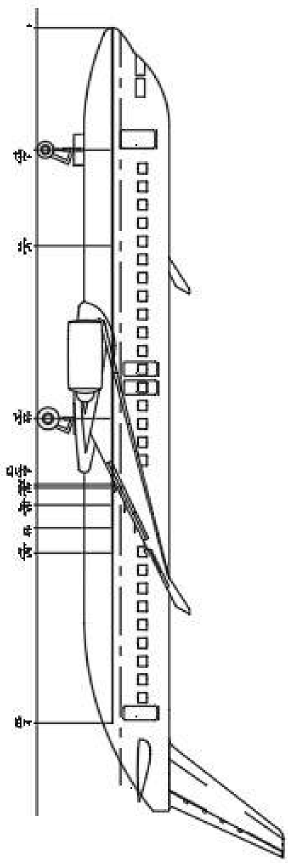
Airplane Maximum Landing Weight	75059kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	0.42min
Descent Distance	49.23km
Approach Speed	263.93km
Mean Vertical Speed	2.10m/s
Airborne Landing Distance	523m
Landing Speed	248.93km/h
Landing run distance	785m
Landing Distance	1308m
Runway Length Required for Regular Aerodrome	2184m
Runway Length Required for Alternate Aerodrome	1857m

Appendix B -Center of gravity of the wing



Appendix C-Center of gravity of the fuselage

Appendix C



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Performed		Tang Miao		
Cheked		Maslak T.P.		
Reviewd				
Approved				

Center of gravity of the fuselage

Letter	Weight	Scale

Sheet 1 Sheet 2

Appendix C

AKF 402