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

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д.т.н., професор.
___________ С.Р. Ігнатович
«___» __________ 2021 р.

ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВРА

ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Аванпроект середньо магістрального двопалубного пасажирського літака»

Виконавець: ___________ **І.О.Ярмолюк**

Керівник: к.т.н., доцент ___________ **В.С. Краснопольський**

Нормоконтролер: к.т.н., доцент ___________ **С.В. Хижняк**

Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

DEPARTMENT OF AIRCRAFT DESIGN

APPROVED BY
Head of department
D.Sc., professor
__________ S.R. Ignatovych
«___» _________ 2021.

BACHELOR THESIS

ON SPECIALITY
"AVIATION AND SPACE ROCKET TECHNOLOGY"

Topic: «Preliminary design of the two-deck mid-range passenger aircraft »

Prepared by: __________ **Iryna Yarmoliuk**

Supervisor: PhD, associate professor __________ **V.S. Krasnopolskii**

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

Kyiv 2021

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет ____аерокосмічний____

Кафедра конструкції літальних апаратів

Освітньо-кваліфікаційний ступінь __«Бакалавр»__

Спеціальність 134 «Авіаційна та ракетно-космічна техніка»

Освітня програма: «Обладнання повітряних суден»

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

д.т.н., професор.

_________ С.Р. Ігнатович

«___» __________ 2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

Ірина Ярмолюк

1. Тема роботи: «Аванпроект середньомагістрального двопалубного пасажирського літака», затверджена наказом ректора від 21 травня 2021 року №815/ст.

2. Термін виконання проекту: з 24 травня 2021 р. по 20 червня 2021 р.

3. Вихідні дані до проекту: крейсерська швидкість V_{cr} = 920км/год, дальність польоту L = 6000 км, крейсерська висота польоту H_{op} = 10 km.

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 проект підйомника для людей з обмеженими можливостями.

5. Перелік обов’язкового графічного матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), проект авіаційного підйомника. (А1×1).

6. Календарний план-графік

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1	Отримання завдання, обробка статистичних даних.	24.05.2021-30.05.2021	

2	Розрахунок мас літака та його основних льотно-технічних характеристик.	31.05.2021-02.06.2021	
3	Розрахунок центрування літака.	03.06.2021-04.06.2021	
4	Розробка креслень по основній частині.	05.06.2021-06.06.2021	
5	Проектування авіаційного підйомника та розробка креслень по спеціальній частині.	07.06.2021-11.06.2021	
6	Оформлення пояснювальної записки.	12.06.2021-13.06.2021	
7	Захист дипломної роботи	14.06.2021-20.06.2021	

7. Дата видачі завдання: «24» травня 2021 року.

Керівник дипломної роботи ____________ В.С. Краснопольський

(підпис керівника) П.І.Б.

Завдання прийняв до виконання ___________ Ярмолюк Ірина

(підпис студента) П.І.Б.

NATIONAL AVIATION UNIVERSITY

Faculty ____Aerospace______
Department __of Aircraft Design__
Educational degree __«Bachelor»__
Specialty 134 "Aviation and space rocket technology"
Educational program __"Aircraft equipment"__

APPROVED BY
Head of department
D.Sc., professor
__________ S.R. Ignatovych
«___» _________ 2021.

TASK
for the bachelor thesis
Iryna Yarmoliuk

1. Topic: « Preliminary design of the two-deck mid-range passenger aircraft » approved by the Rector's order №815/ст. «21» May 2021 year.
2. Thesis terms: since 24.05.2021 year till 20.06.2021 year.
3. Initial data: cruise speed V_{cr}= 900 km/h, flight range L = 6000 km, operating altitude H_{op} = 10 km.
4. Content: 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: introduction and calculation of the lift for people with disabilities .
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), aviation lift design (A1×1).
6. Thesis schedule

№	Task	Time limits	Done
1	Task receiving, processing of statistical data.	24.05.2021-30.05.2021	
2	Aircraft take-off mass determination and flight performances calculation.	31.05.2021-02.06.2021	
3	Aircraft centering determination.	03.06.2021-04.06.2021	
4	Graphical design of the aircraft and its layout.	05.06.2021-06.06.2021	
5	Design of aviation lift and calculations. Drawings of the special part.	07.06.2021-11.06.2021	
6	Completion of the explanation note.	12.06.2021-13.06.2021	

7	Preliminary examination and defense of the diploma work.	14.06.2021-20.06.2021	

7. Date: «24» May 2021 year.

Supervisor ______________ V.S. Krasnopolskii

Student ______________ Iryna Yarmoliuk

РЕФЕРАТ

Дипломна робота «Аванпроект середньомагістрального двопалубного пасажирського літака» містить:

56 сторінок, 5 рисунків, 9 таблиць, 8 літературних посилань

Об'єкт дослідження: процес проектування літака транспортної категорії.

Предмет дослідження: Аванпроект середньомагістрального двопалубного пасажирського літака.

Мета роботи: створити аванпроект середньо магістрального двопалубного пасажирського літака та визначити його основні льотно-технічні характеристики.

Методи дослідження: в роботі застосовано метод порівняльного аналізу літаків-прототипів для вибору найбільш обґрунтованих технічних рішень, а також методи інженерних розрахунків для отримання основних параметрів проектованого літака. В спеціальній частині застосовано аналіз напружено-деформованого стану для розрахунку на міцність та статичне стискання елементів авіаційного підйомника.

Наукова новизна результатів: в спеціальній частині обґрунтовано застосування авіаційного підйомника для людей з обмеженими можливостями ,що дозволяє їм комфортно та без перешкод користуватись авіаційним транспортом..

Практична цінність роботи: результати роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

ПАСАЖИРСЬКИЙ ЛІТАК, АВАНПРОЕКТ ЛІТАКА, ЦЕНТРУВАННЯ ЛІТАКА, КОМПОНУВАННЯ ПАСАЖИРСЬКОЇ КАБІНИ, РОЗРАХУНОК ПІДЙОМНИКА

ABSTRACT

Bachelor thesis « Preliminary design of the two-deck mid-range passenger aircraft»

56 pages, 5 figures, 9 tables, 8 references

Object of study – design process of a civil airplane.

Subject of study – is Preliminary design of the two-deck mid-range passenger aircraft

Aim of bachelor thesis – is to create a preliminary design of an airplane and estimate its flight performances.

Research and development methods – the design methodology is based on prototype analysis to select the most advanced technical decisions and engineering calculations to get the technical data of designed aircraft. In special part analysis of the stress-strain state to calculate the strength and static compression of the elements of the aircraft lift

Novelty of the results – in a special part the use of an aircraft lift for people with disabilities is substantiated, which allows them to use air transport comfortably and without obstacles

Practical value – the results of the work can be used in the aviation industry and in the educational process of aviation specialties.

PASSENGER AIRCRAFT, PRELIMINARY DESIGN, CENTER OF GRAVITY CALCULATION, PASSENGER CABIN LAYOUT, CALCULATION OF AVIATION LIFT

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 21 22Y 00 00 00 52 TW	Task for work	1	
	2	NAU 21 22Y 00 00 00 52	Mid-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 21 22Y 00 00 00 52 EN	Mid-range passenger aircraft	59	
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 21 22Y 00 00 00 52 AD	Design of aviation lift	1	

		NAU 21.22Y.00.00.00.52.EN				
Done by	Yarmoliuk I.O	Preliminary design of the two-deck mid-range passenger aircraft. (List of diploma work)	list	sheet	sheets	
Checked by	Krasnopolskii V.S.			9	59	
St.control.	Khyzhniak S.V.		ASF 402			
Head of dep.	Ignatovich S.R.					

Content

INTRODUCTION

During the last time we can observe the significant increase of volume of passenger traffic and notably at the local airlines that increased the need for passenger traffic. There was a need for planes to transport for medium distances, which at low load factor allow to avoid financial losses. To provide profitable operation of aviation flying vehicles with high reliability and regularity of flights in the highly competitive global market there is a need for a new aircraft in civil aviation that meet the requirements of the ICAO. In addition there is a need for an aircraft that is adapted for people with disabilities. In particular:

-Flight safety;

- Increasing comfort operation;
- Reducing emissions of harmful gases and others.

The designed plane must also satisfy the following requirements:

- Comfortable passenger compartment that meets the highest requirements;
- To perform take-off and landing on unequipped unpaved runways;
- Operation in a wide temperature range;
- Reliability of operation;
- Adapted for people with disabilities.

The purpose of this diploma project is to create an aircraft intended for the carriage of 440 passengers on middle distance routes and suitable to comfortably transport people with disabilities.

1. PROJECT PART. ANALYSIS OF PROTOTYPES AND SHORT DESCRIPTION OF DESIGNING AIRCRAFT

1.1 Choice of the performances of the designed plane

The selecting of the optimum design parameters of the aircraft is the multifactor optimization task aimed to form a design of future aircraft including the whole complex of flight-technical, weight, geometrical, aerodynamic and economic characteristics.

At the initial stage of aircraft scheme determination usually are used methods of statistics analysis and approximate determination of aerodynamic and flight characteristics. To determine a general view of airplane is necessary to calculate masses of the aircraft itself and its parts, as well as geometrical parameters and engine performances.

Prototypes of the designed aircraft were in class 150-170 passengers. Such aircraft as Boeing 767-100, Boeing 747-SP and Boeing 747 will compete with designed aircraft in this market segment. Statistic data of prototypes are presented in table 1.1.

Table 1.1

Operational-technical data of prototypes

PARAMETER	PLANES		
	B 747	B-747 SP	Airbus A380
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attend. persons	3/3	3/13	2/15
Maximum take-off weight, m_{to}, kg	333400	267907	365508
Maximum payload, $m_{k.max}$, kg	18000	18000	67925
Amount of passenger seat	224	440	550
Cruise altitude $V_{w.ek.}$, m	12500	12500	13100

Flight range, $m_{k.max}$, km	5765	6000	8000
Take-off distance, $L_{t.d.}$, m	9800	9800	2374
Number and type of engines	4×GE CF6	4× JT9D-3A	4× GP7270
The shape of the cross-section fuselage	circular	circular	circular
Length of the fuselage, L_f, m	70.6	56	73
Fineness ratio	10.8	8.6	10.22
Sweepback on 1/4 chord line, ^{0}	35	35	32

The mutual location of aircraft parts, their number and shape is determined by the scheme. Airplane`s aerodynamic and operational characteristics directly depend on the components of the aircraft and its aerodynamic scheme. The scheme that has been chosen allows to increase the safety and regularity of flights and economic efficiency of the aircraft.

1.1.1 Brief description of the main parts of the aircraft

The aircraft is designed for commercial transportation of passengers and luggage on mid-range distances. The flight range with a maximum commercial load (49513 kg) is 6000 km.

A swept wing with a high aspect ratio is based on new supercritical airfoil. Fuselage has circular cross section. Empennage has conventional configuration, with adjustable horizontal stabilizer attached to the fuselage. Rudder and elevators are equipped with aerodynamic balance. The aircraft has 4 turbojet engines attached under the wing

Wing of the designed aircraft has torsion box type, trapezoidal in planform. Its aspect ratio is 6.96, taper ratio is 3.5, the sweepback angle is 34°. It has a slight aerodynamic washout and is made of aerodynamic supercritical airfoil with variable thickness. The high-lift devices of the leading edge represented by 5 sectional slats. Double-slotted flaps are used as high-lift devices of the trailing edge. To improve flight controllability in flight an ground spoilers are used.

Fuselage. The aircraft is made according to the classic aerodynamic scheme with low-wing location. It has a full-metal structure of the semimonocoque type. Its longitudinal structural elements are represented by of 96 stringers, and the transverse 120 formers. Such fuselage structure provides the lowest possible aerodynamic drag and high critical Mach number

In the cockpit are located pilot seats and flight engineer. The captain`s seat is on the left hand side, the first officer`s seat is on the right, the flight engineer working place is behind of the first officer pilot. In front of the pilots control panels are installed. There is one more control panel between them. Over the canopy there is an upper electric switchboard. The port side of the fuselage has a side console for the captain and at the starboard side a side console for the first officer.

There are control columns and pedals to control the aircraft attitude during flight ahead of the pilot's seats. On the dashboard flight-navigational instruments are mounted for monitoring the operation of the power plant and other systems.

There are windows and emergency exits on the left and right sides of the cabin . The passenger cabin has emergency exits and luggage racks along its both sides. At the bottom on the shelves are installed service panels with individual ventilation nozzles, lights, switchers of individual lighting, the call button of the flight attendant and the lighted numbers of the seats. General interior lighting is located in the central part of the ceiling: in addition, there are lights for the sides and the lower part of the luggage compartments.

Under the floor of the pressurized part of the fuselage are located the following rooms and compartments the front landing gear, the front cargo compartment, the rear cargo compartment, the technical compartment. The front and rear cargo compartments are pressurized; each has a hatch on the starboard side and is equipped with a container locking system.

The main structural elements of the fuselage are formers, stringers, longitudinal beams of the landing gear front support awning.

Tail unit of the designed aircraft has a conventional configuration, which consists of a fin with a rudder and a stabilizer with an elevator. The sweepback angle of vertical tail unit is 44° and the horizontal is 39°.

Crew cabin. Configuration of workspaces of pilots provides to any of them safety control of airplane. Characteristics of stability and controllability of the plane, the structure, flight navigation equipment and onboard systems, configuration of displays provide safe operation of airplane according to the aviation rules.

Application of conic windshields of a cockpit radome provides good visibility for pilots and satisfy the requirements of flight operation in the expected conditions. There is a possibility of manual and automatic control by any of pilots.

Location of devices and light signals on a control panel is carried out according to requirements of aviation rules. On the top of a control panel in a zone of the best access and review quickly used control panels of command radio stations and systems of automatic control are placed.

On the overhead control panel are placed fuel, hydraulic, power supply, anti-icing, air conditionings, start of engines and APU, fire extinguishing switches and a panel of the warning alarm system.

There are panels of navigation equipment, landing equipment, engine control levers on the central panel.

Passenger furnishing of the plane provides necessary comfort on board. It includes adjustable chairs of pilots, flight attendant seats and passenger seats, light filters ,light-protective blinds and toilet.

Between a crew cabin and a passenger cabin the toilet room and galley are placed (toilet on the left board, galley on the right board). In a toilet are located a tanks with water and technical liquid. In a toilet the toilet bowl of water vacuum type is mounted. There are three first-aid kits onboard(one in a crew cabin, one is included in crash equipment and one in tail part).

Emergency equipment includes ropes, oxygen masks, smoke-proof masks, oxygen devices, the manual fire extinguishers, first-aid kits, axes, emergency radio stations and a radio beacon, light marking of evacuation ways, emergency lighting, a board "EXIT" near each emergency exit, life jackets on crew work places, safety belts on crew members and passenger seats.

Control system of the designed aircraft includes: elevator control system, stabilizers, rudder, ailerons, air brakes, flaps and slats.

The aircraft control system includes the automatic on-board control system designed to improve the stability and controllability of the aircraft during flight in all regimes since take-off to landing, to provide aircraft control during climb, cruising flight and descent by signals of navigation systems airborne complex, as well as to provide automatic and direction control of the aircraft during approach.

The aircraft control system operates in the following modes:

- steering control mode – the mode in which aircraft control is made by the captain or the first officer pilot by the usual movement of command levers (columns, steering wheels, pedals) when the automatic system is operating;

- semi-automatic control mode – the mode in which the pilot drives the plane (using the same command levers) by the position of captain the control column or other navigation-flying devices with simultaneous operation of the automatic system;

- automatic control mode – the mode in which the aircraft is controlled by the automatic system in conjunction with the flight-navigation complex.

The main controls is doubled: each pilot has command levers of these systems installed on the consoles in front of their seats. Control can be performed simultaneously by two pilots and separately by captain or first officer.

Landing gear is a support system that provides the required position of the aircraft during parking and its movement during take-off, landing and taxiing on the airfield.

The landing gear of the aircraft is made on a multi-support scheme, which includes 1 nose gear and 4 main. They are attached to the main airframe.

Nose landing gear is placed in front of the center of gravity, that eliminates nose over and apply effective braking of the wheels to reduce the run.

The main supports are located behind the center of gravity of the aircraft. The front support has two wheels and each main one has a bogie with six wheels.

Pneumatics of wheels carry the load during landing and moving on airfield and transmit it to the struts.

Retracting of the landing gear back has its advantages and disadvantages. Such retracting does not cause a significant displacement of the center of gravity of the aircraft and does not require increased capacity of the lift cylinders, since in this case it is not necessary to overcome parasitic drag.

The aircraft has a control system for steering the wheels of the nose gear, which greatly improves the maneuverability of the aircraft during taxiing. The steering of the wheels is controlled by deflecting the rudder pedals.

The main bypass of the landing gear has a hydraulic braking system for the wheels and devices that automatically apply the braking force to the wheels.

1.1.2 Choice and description of power plant

During the aerodynamic calculation performed according program developed at department of aircraft design the maximum required take-off thrust was obtained. It is

193 kN. With respect to this value for designed aircraft was chosen the engine JT9D-3A.

GE CF6/PW4000/JT9D is a family of high-bypass turbofan engines produced by GE Aviation. Based on the TF39, the first high-power high-bypass jet engine, the CF6 powers a wide variety of civilian airliners(Table 1.2). Installed on passenger aircrafts such as: Airbus A300, Boeing 747 SP, the Boeing 767 and Airbus A310 and many other.

Table 1.2

Prototype aircraft engines

Name	GE CF6	JT9D-3A	GP7270
Type	high-bypass turbofan engine	high bypass ratio jet engine to power a wide-body airliner	two-spool high-bypass turbofan engine
Compressor	1-stage low-pressure axial compressor 5-stage turbine; 16-stage high-pressure compressor	Eight-stage IP axial compressor, six-stage HP axial compressor	24 swept wide-chord, 5-stage low-pressure axial compressor; 9-stage high-pressure axial compressor

Weight	8,176 lb 3,709 kg	8,713 lb (3952 kg)	6,712 kg (14,797 lb)
Thrust	41 500 lbf (185 kN)	43,500 lbf (193 kN)	311 кN
Length	188 in (478 cm)	154.89 in (3.934 m)	286.9 in (729 cm)
Bypass ratio	5.76–5.92:1	5,0: 1	8.8:1
Diameter	105 in (267 cm)	234 cm	316 cm
Overall pressure ratio	24,3:1	23,4:1	43,9:1

1.2 Geometry calculations for the main parts of the aircraft

Layout of the aircraft is determined by relative disposition of its parts and structures and requires the calculation of all types of loads caused by passengers, cargo, fuel and so on. The choice of the scheme, composition and aircraft parameters is directed to the best meets the operational requirements.

1.2.1 Wing geometry calculation

Geometrical characteristics of the wing are determined from the take-off weight m_0 and specific wing load P_0.

Full wing area with extensions is:

$$S_{wfull} = \frac{m_0 \cdot g}{P_0} = \frac{267907 \cdot 9.8}{6400} = 410.23 \text{ m}^2 ,$$

where S_w – wing area, m^2; g – acceleration due to gravity m/s^2.

Relative wing extensions area is 0.1 Wing area is:

$$S_w = 410.23 \cdot 0.7 = 287.161 \text{ m}^2$$

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{287.161 \cdot 7} = 44.83 \text{ m} ,$$

where l – wing span, m; λ_w – wing aspect ratio.

Root chord is:

$$b_0=\frac{2\cdot S_w\cdot\eta}{(1+\eta)\cdot l}=\frac{2\cdot 287.161\cdot 3,2}{(1+3.2)\cdot 44.83}=9.76\text{ m},$$

where b_0 – root chord, m; η_w – wing taper ratio.

Tip chord is:

$$b_t=\frac{b_0}{\eta}=\frac{9.76}{3.2}=3.05\text{ m},$$

where b_t – tip chord, m.

Maximum thickness of the wing is determined in the forehead i-section and it is equal to:

$$C_i=C_w\cdot b_t=0.12\cdot 3.05=0.366\text{ m},$$

where c_i – wing thickness in i-section, m; c_w – related wing thickness.

On board chord for trapezoidal shaped wing is:

$$b_{ob}=b_0\left(1-\frac{\eta-1}{\eta}\cdot\frac{D_f}{l}\right)=9.76\cdot\left(1-\frac{3.2-1}{3.2}\cdot\frac{6.5}{44.83}\right)=8.79\text{ m},$$

where b_b – wing board chord, m; D_f – fuselage diameter, m.

Type of wing structural scheme determines quantity of spars and its position as well as places of wing joints. On the modern aircraft usually used double or triple spar wing. The designed aircraft has two spars.

The geometrical method of mean aerodynamic chord determination is used (fig. 2.1). Mean aerodynamic chord is equal to:b_{max}= 6.752 m

After determination of the geometrical characteristics of the wing estimation of the ailerons geometry and high-lift devices may be done.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span is:

$$L_{ai}=(0.3\ldots0.4)\cdot\frac{l}{2}=0.3\cdot\frac{44.83}{2}=6.72\ \text{m},$$

where l_{ail} – ailerons span, m.

Aileron area is:

$$S_{ai}=0.03\cdot\frac{287.161}{2}=4.31\ \text{m}^2,$$

where S_{ail} – ailerons area, m.

Increasing of l_{ail} and b_{ail} more than recommended values is not necessary. With the increase of l_{ail} more than given value the increase of the ailerons coefficient and the high-lift devices span decreases too. With b_{ail} increase, the width of the wing chord decreases.

There is a tendency to decrease relative wing span and ailerons area for modern airplane. In this case for the transversal control of the airplane spoilers together with the ailerons are used. That's why the span and the area of high-lift devices may be increased, which improves take-off and landing characteristics of the aircraft.

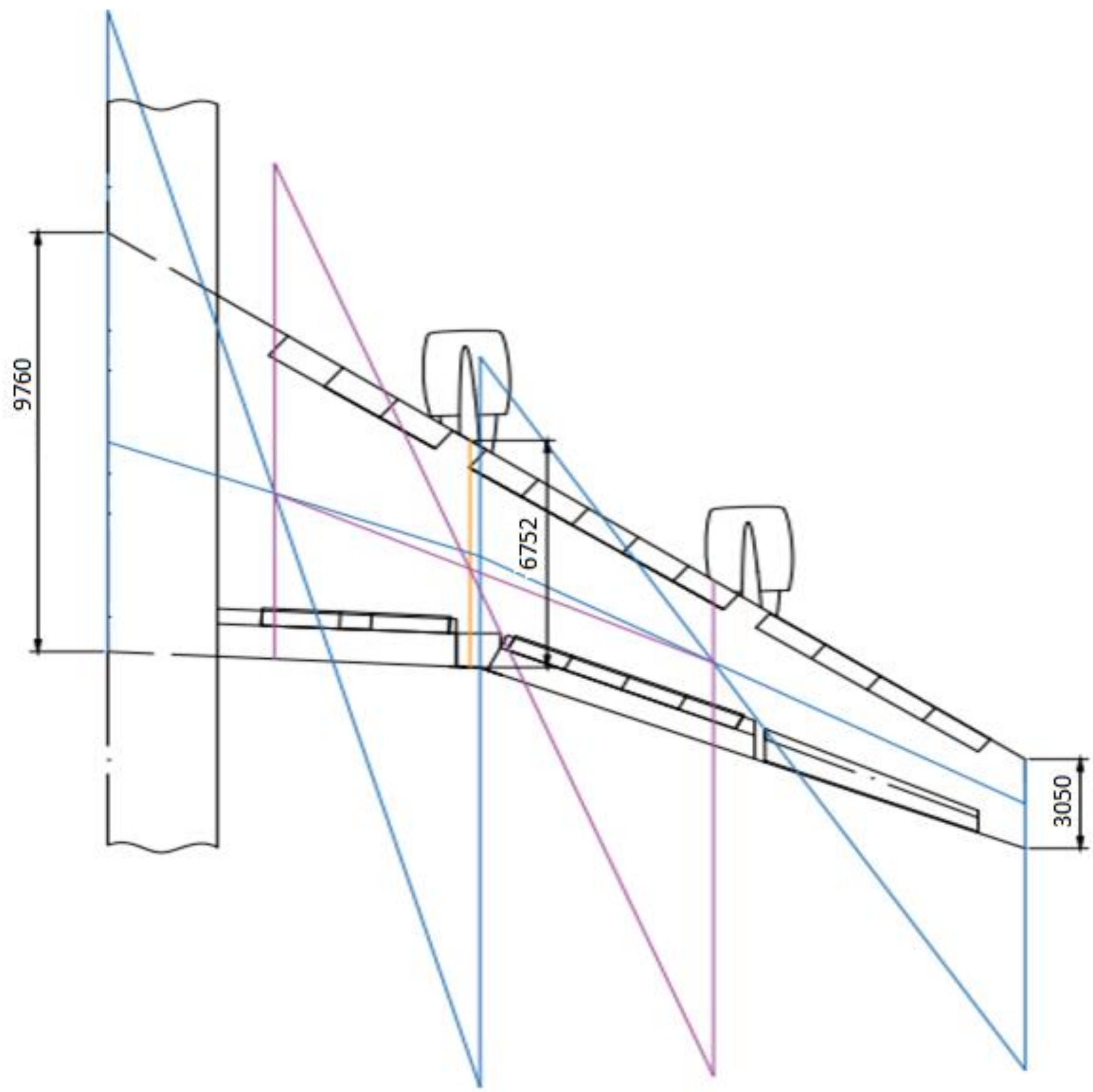

Fig. 1.1. Determination of mean aerodynamic chord.

Aerodynamic compensation of the aileron.

Axial is

$$S_{axinail} \leq (0.3 \ldots 0.31) \cdot S_{ail} = 0.305 \cdot 4.31 = 1.31 \text{ m}^2$$

Inner axial compensation is

$$S_{inaxial} = (0.3..0.31)\ S_{ail}$$

Area of ailerons trim tab. For four engine airplane

$$S_{ai} \leq (0.07\ldots0.08)\cdot S_{ai} = 0.075\cdot4.31 = 0.32\ \text{m}^2:$$

Range of aileron deflection is: Upward $\delta'_{ail} \geq 20^\circ$; Downward $\delta''_{ail} \geq 10^\circ$.

The aim of determination of wing high-lift devices geometrical parameters is the providing of take-off and landing coefficients of wing lifting force, assumed in the previous calculations with the chosen high-lift devices and the type of the airfoil.

In the modern design relative chords of wing high-lift devices are:

b_{sf} = 0.25..0.3 – for the split edge flaps;

b_f = 0.28..0.3 – one slotted and two slotted flaps;

b_f = 0.3..0.4 – for three slotted flaps and Fowler`s flaps;

b_s = 0.1..0.15 – slats.

Effectiveness of high-lift devices rises proportionally to the wing span increase, serviced by high-lift devices, so we need to obtain the biggest span of high lift devices ($l_{hld} = l_w - D_f - 2l_{ail} - l_n$) due to use of flight spoiler and minimizing the area of engine and landing gear nacelles.

To choose the structural scheme, hinge-fitting scheme and kinematics of the high-lift devices it is needed to take into account the statistics and experience of native and foreign aircraft designs. Have to be mentioned that in the majority of existing designs of high-lift devices they are made by spar structural scheme.

1.2.2 Fuselage layout

The shape and the size of fuselage cross section are chosen according to the aerodynamic demands.

For subsonic airplanes wave drag may be ignored as it is in significant so we need to choose value of skin friction drag C_{xf} and parasitic drag C_{xp} from the list of conditions. During the transonic and subsonic flights shape of fuselage nose part affects the value of wave drag C_{xw}. Application of circular shape of fuselage nose part significantly decrease it.

As a result of machine calculation, the following parameters of the fuselage were obtained:

$$D_f = 6{,}5 \text{ m}$$

$$\lambda_f = 9$$

For transonic airplanes fuselage nose part has to be:

$$l_{fnp}=2.5 \cdot D_f=2.5 \cdot 6.5=16.25 \text{ m},$$

where D_f – fuselage diameter, m; l_{fnp} – length of fuselage nose part.

Except aerodynamic requirements it's necessary to consider strength and layout requirements.

To provide of the minimal weight, the best fuselage cross section shape is circular. In this case the fuselage skin area is minimal. As the partial case the combination of two or more vertical or horizontal series of circles may be used.

Considered geometrical parameters are: fuselage diameter D_f, fuselage length l_f, fineness ratio λ_f, nose part fineness ratio λ_{np}.

Fuselage length is determined considering the aircraft scheme, layout and airplane center-of-gravity position peculiarities and landing angle of attack α_{land}.

Fuselage length is equal to:

$$L_f=\lambda_f \cdot D_f=9 \cdot 6.5=58.5 \text{ m}$$

Nose part fineness ratio is equal to:

$$\lambda_{fnp}=\frac{l_{fnp}}{D_f}=\frac{16.25}{6.5}=2.5$$

Length of the fuselage rear part is equal to:

$$l_{frp}=\lambda_{\text{frp}} \cdot D_f=2{,}5 \cdot 6{,}5=16{,}25 \text{ m}$$

During the determination of fuselage length it`s necessary to minimize area of mid-section S_{ms} on the one hand and taking to account layout demands on the other hand.

For passenger airplanes fuselage mid-section first of all is influenced by the size of passenger. One of the main parameter, determining the mid-section of passenger airplane is the height of the passenger cabin.

For mid-range airplanes we may take the height as: h_1=1.75 m; passage width b_p=0.45...0.5 m; the distance from the window to the flour h_2=1 m; luggage space h_3=0.6...0.9 m.

The next parameters were chosen:

Cabin height is equal to:

$$H_{cabin}=1.48+0.17\cdot B_{cabin}=1.48+0.17\cdot 6=2.5 \text{ m},$$

where H_{cab} – cabin height, m; B_{cab} – width of the cabin, m.

The round cross section of the fuselage design is the best because it is the strongest and the lightest. But for passenger and cargo location this shape is not always the most convenient one. In the most cases, one of the most suitable ways is to use the double-bubble or oval shape of the fuselage. The oval shape is not suitable in the manufacturing, because the upper and lower panels will bend due to extra pressure and will demand extra bilge beams.

Step of formers in the fuselage structure is in the range of 360...500 mm. It depends on the fuselage type and class of passenger cabin.

The windows are placed in one row. The shape of the window is rectangular with the rounded corners. The window step corresponds to former step and is 500...510 mm.

Width of the cabin for economic class with seats configuration (3+3+3) is:

$$B_{cabin}=n_3 b_3+n_{aisle}\cdot b_{aisle}+2\delta=2\cdot 300+3\cdot 1430+2\cdot 550=6 \text{ m},$$

where n_3 – number of three-seat blocks; b_3 – width of three-seat blocks, m; n_{aisle} – number of aisles; b_{aisle} – width of aisle, m; δ – distance between external armrests to the decorative panels, m.

The length of passenger cabin is equal to:

$$L_{cab}=L_1+(n_{rows}-1)\cdot L_{seatpitch}+L_2=42 \text{ m},$$

where L_{cab} – length of passenger cabin, m; L_1 – distance from the wall to the back of the seat in first row, m; L_2 – distance from the back of the seat in last row to the wall, m; n_{rows} – number of rows; L_{sp} – seat pitch, m.

The passenger cabins of the first and second decks are divided into separate classes.

First deck:

- the first cabin of economy class –accommodates 110 people and has a length of 9 m;
- second cabin of economy class –accommodates 110 people, length 9 m;
- business class cabin – has 40 seats and a length of 11 m.

Second deck:

- the first cabin of economy class – seats 70 people, length 9 m;
- second cabin of economy class – seats 70 people, has a length of 9 m;
- business class cabin– has 40 seats and a length of 11 m.

The table 1.3 summarizes the typical parameters of passenger equipment

Table 1.3

Parameters of passenger equipment

Parameter name	Economy class chair	Economy class chair
Distance between armrests, mm	410	490
Armrest width, mm	50	80
Seat height above the floor, mm	320	300
Height of a chair above a floor, mm	1100	1100
Chair step, mm	810	1000
The angle of deviation of the chair from the vertical, deg	25	60
Width of the block from 2 armchairs, mm	970	1220
Width of the block from 3 armchairs, mm	1430	-
Width of the block from 4 armchairs, mm	1890	-
Passage width, mm	510 (first deck) 660 (other)	580

1.2.3 Luggage compartment

Given the fact that the unit of load on floor K = 400… 600 kg/m^2

The area of cargo compartment is S_{cargo}=55 m^2. Cargo compartment volume is equal to V_{cargo}=110 m^2. Luggage compartment design is similar to the prototype.

1.2.4 Galleys and buffets

International standarts provide two dishes if the plane made with a mixed layout. It is recommended that kitchen cupboards have to be located near the door between the cockpit and the passenger cabin. Refreshment and food can`t be placed near the toilet facilities or connect with wardrobe.

Volume of buffets(galleys) is equal to:

$$V_{galley}=0.11\cdot 440=48.4 \text{ m}^3 ,$$

where ν_{galley} – galley volume, m^3; ν_g – galley volume coefficient, m^3; n_{pass} – number of passengers.

Area of buffets(galleys) is equal to:

$$S_{galley}=\frac{V_{galley}}{H_{cab}}=\frac{48.4}{2.2}=22 \text{ m}^3 ,$$

where S_{galley} – galley area, m^2.

Number of meals per passenger breakfast, lunch and dinner – 0.8 kg; tea and water – 0.4 kg. Passengers are fed every 3.5…4 hour flight. Buffet design is similar to prototype.

1.2.5 Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t > 4:00 one toilet for 40 passengers.

The number of lavatories are chosen according to the prototype and it is equal to:

$$n_{lav}=\frac{n_{pass}}{40}=9 ,$$

where n_{lav} – number of lavatories.

Area of lavatory is:

S_{lav} =*2.25* m*2*

$S_{total\ toilet}$ =*20.25* m^2

Width of lavatory: 1 m. Toilets design is similar to the prototype.

1.2.6 Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is the choice of tail unit configuration. To provide longitudinal stability during overloading its center of gravity should be placed in front of the aircraft focus and the distance between these points, related to the mean value of wing aerodynamic chord, determines the rate of longitudinal stability.

Determination of the tail unit geometrical parameters.

Area of vertical tail unit is equal to:

$$S_{vtu} = (0.12 \ldots 0.2) S_{wing} = 51.69 \text{ m}^2 ,$$

where S_{VTU} – area of vertical tail unit, m^2; L_{VTU} – length of vertical tail unit, m; A_{VTU} – coefficient of static moment of vertical tail unit.

Area o horizontal tail unit is equal to:

$$S_{htu} = (0.18 \ldots 0.25) S_{wing} = 63.17 \text{ m}^2 ,$$

where S_{HTU} – area of horizontal tail unit, m^2; L_{HTU} – length of horizontal tail unit, m; A_{HTU} – coefficient of static momentum of horizontal tail unit.

Values L_{htu} and L_{vtu} depend on some factors. First of all their value are influenced by the length of the nose part and tail part of the fuselage, sweptback and wing location, conditions of stability and control of the airplane.

Determination of the elevator area and direction:

Elevator area is:

$$S_{ei} = 0.3 \cdot 51.69 = 15.507 \text{ m}^2 ,$$

where S_{el} – elevator area, m^2; k_{el} – relative elevator area coefficient.

Rudder area is:

$$S_{rud} = 0.3 \cdot 63.17 = 18.951 \text{ m}^2 ,$$

where S_{rud} – rudder area, m^2; k_r – relative rudder area coefficient.

The area of aerodynamic balance usually is $M \geq 0.75$, $S_{abea} \approx S_{abed} = (0.18…0.2)\ S_e$

Elevator balance area is equal to:

$$S_{eb} = 0.2765 \cdot S_{el} = 4.29 \text{ m}^2$$

Rudder balance area is equal to:

$$S_{rb} = 0.1 \cdot S_{rd} = 1.\ 9 \text{ m}^2 ,$$

where S_{eb} – area of elevator aerodynamic balance, m^2; S_{rb} – area of rudder aerodynamic balance, m^2.

The area of elevator trim tab is:

$$S_{tb} = 0.08 \cdot S_{el} = 0.08 \cdot 15.507 = 1.24 \text{ m}^2 ,$$

where S_{te} –elevator trim tab area.

Area of rudder trim tab is equal to:

$$S_{tr} = 0.1 \cdot S_{rud} = 0.1 \cdot 18.951 = 1.895 \text{ m}^2 ,$$

where S_{tr} –rudder trim tab area

For low-flying aircraft with wing-mounted engines at $M<1$ $h_{VTU}=(0.14…0.2)\ l_{wing}$ the span of the vertical tail is:

$H_{VTU} = 0.2 \cdot 44.83 = 8.96$ m

Root chord of horizontal stabilizer is:

$$l_{HTU} = (0.32…0.5) l_{wing} = 0.4 \cdot 44.83 = 17.932 \text{ m}$$

$$b_{0HTU} = \frac{2S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}} = 1.17 \text{ m} ,$$

where η_{HTU} – horizontal tail unit taper ratio; b_{0HTU} – root chord of horizontal stabilizer, m.

Tip chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{b_{0HTU}}{\eta_{HTU}} = 5.85 \text{ m},$$

where b_{tHTU} – tip chord of horizontal stabilizer, m.

Root chord of vertical stabilizer is:

$$b_{0VTU} = \frac{2S_{VTU} \cdot \eta_{VTU}}{(1+\eta_{VTU}) \cdot l_{VTU}} = 1.09\text{m},$$

where b_{0VTU} – root chord of vertical stabilizer, m; η_{VTU} – vertical tail unit taper ratio; L_{VTU} – vertical tail unit span.

Tip chord of vertical stabilizer is:

$$b_{0VTU} = \frac{b_{0VTU}}{\eta_{VTU}} = 6.05 \text{ m},$$

where b_{tVTU} – tip chord of vertical stabilizer, m.

1.2.7 Landing gear design

Next step is determining geometrical parameters of the landing gear.

Main wheel axis offset is:

$$e = 0.18 \cdot b_{MAC} = 0.18 \cdot 6.752 = 1.22 \text{ m},$$

where k_e – coefficient of axes offset; e – main wheel axes offset, m.

With the large wheel axial offset the lift-off of the front gear during take-off is complicated and with small the ground strike of the airplane is possible, when the loading of the back of the airplane comes first. Landing gear wheel base may be calculated according the next expression:

$$B = 0.4 \cdot L_f = 17.93 \text{ m},$$

where B – wheel base.

Front wheel axial offset will be equal to:

$$d_{ng} = B\text{-}e = 17.93\text{-}1.22 = 16.71 \text{ m},$$

where d_n – nose wheel axes offset, m.

Wheel track is:

$$T = 0.396 \cdot B = 7.1 \text{ m},$$

where T – wheel track

Wheels for the landing gear is chosen by the size and operational loading. For the nose gear dynamic loading should be considered as well (table 1.4).

Type of the pneumatics (balloon, half balloon, arched) and the pressure in it is determined by the runway surface, which should be used. The breaks on the main wheel and for the front wheel are installed(table 1.5).

Nose wheel load is equal:

$$P_{NLG} = \frac{e \cdot m_0 \cdot g \cdot K_g}{B \cdot z} = \frac{1.22 \cdot 267\,907 \cdot 9.81 \cdot 1.5}{17.93 \cdot 2} = 134\,120 \text{N},$$

where P_n – nose wheel load, N; k_d – dynamics coefficient; z – number of wheels.

K_g = 1.5...2.0 – dynamics coefficient.

Main wheel load is equal:

$$P_m = \frac{(B\text{-}e) \cdot m_0 \cdot g}{B \cdot n \cdot z} = \frac{(17.93\text{-}1.22) \cdot 267\,907 \cdot 9.81}{17.93 \cdot 4 \cdot 4} = 153\,084 \text{ N},$$

where P_m – main wheel load, N; n – number of main landing gear struts.

Table 1.4

Nose gear wheel

Part No.	Size	Rated Load(Lbf)	Speed Rating (MPH)	Rated Pressure (Psi)
APS 00588	41x15.0-18	31400	225	190

Table 1.5

Main gear wheel

Part No.	Size	Rated Load(Lbf)	Speed Rating (MPH)	Rated Pressure (Psi)
APS 00571B	40x15.5-16	36300	235	180

1.3 Center of gravity calculation

1.3.1 Trim-sheet of the equipped wing

Mass of the equipped wing contains the mass of its structure, mass of the equipment located in the wing and mass of the fuel. Regardless of the place of mounting (to the wing or to the fuselage), the main landing gear and the nose gear are included in the mass list of the equipped wing. The mass list includes names of the objects, mass themselves and their center of gravity coordinates. The origin of the given coordinates of the mass centers is chosen by the projection of the leading edge of the mean aerodynamic chord (MAC) for the surface XOY. The positive values of the coordinates of the mass centers are accepted for the aft part of the aircraft.

The list of the mass objects for the aircraft, where the engines are located under the wing are given in the table 1.6. Coordinates of the center of mass for the equipped wing are defined by the formula (1.1).

$$X_w^{/} = \frac{\Sigma m_i^{/} x_i^{/}}{\Sigma m_i^{/}} \tag{1.1}$$

Table 1.6

Trim sheet of equipped wing

Name	Mass: Units	Mass: total mass m_i (kg)	CG coordinates x_i (m)		Moment $m_i\, x_i$ (kgm)
Wing (structure)	0.09469	25368.11383	(0.42 –0.45) **B$_{MAC}$**	3.0384	77078.47706
Fuel system, 40%	0.0114	3054.1398	In the wing C.G.	3.0384	9279.698368
Control system, 30%	0.0042	1125.2094	0.6 **B$_{MAC}$**	4.0512	4558.448321
Electrical equip. 10%	0.0236	632.26052	0.1 **B$_{MAC}$**	0.6752	426.9023031
Anti-icing system 70%	0.01237	3314.00959	0.1 **B$_{MAC}$**	0.6752	2237.619275

Hydraulic system, 70%	0.0133	3563,1631	0,6 $\mathbf{B_{MAC}}$	2,166	7717,811275
Power units	0.09696	25976,26272	geometrical	-5.44	141310,8692
Equipped wing without fuel and LG	0.23266	62331,24262	geometrical	0.6177338485	242135,8919
Nose landing gear	0.003589	961,518223	geometrical	-23.066	22806,05843
Main landing gear	0.04018	10764,50326	(0.5-0.6) $\mathbf{B_{MAC}}$	4,0512	43609,15561
Fuel	0.35139	94129,84073	(0,42–0,45) $\mathbf{B_{MAC}}$	3,0384	286034,4921
Equipped wing	0.627819	168197,1048	3,5350525		594585,598

1.3.2 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 structural part of the fuselage is given. The list of the objects, engines are mounted under the wing, is given in table 1.7.

The CG coordinates of the EF are determined by formula (1.2).

$$X_f = \frac{\Sigma m_i^/ X_i^/}{\Sigma m_i^/}; \tag{1.2}$$

The CG of equipped wing and fuselage is determined the moment equilibrium equation relatively to the fuselage nose may be made by formula (1.3).

$$m_f x_f + m_w (x_{MAC} + x_w^/) = m_0 (x_{MAC} + C) \tag{1.3}$$

where m_0 – aircraft take-off mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; $\boldsymbol{C}$ – distance from MAC leading edge to the CG point determined by the designer.

The wing MAC leading edge position relative to fuselage may be calculated by the formula:

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

$$= \frac{20805.65762 \cdot 832.68793 + 168197.1048 \cdot 3{,}5350525 - 267907 \cdot 6.752}{267907 - 168197.1048}$$

$$177.026 \text{ m}$$

$\boldsymbol{C}$ = (0.22...0.25) $\boldsymbol{B_{MAC}}$ – low wing ;

$\boldsymbol{C}$ = (0.25...0.27) $\boldsymbol{B_{MAC}}$ – center wing;

$\boldsymbol{C}$ = (0.23...0.32) $\boldsymbol{B_{MAC}}$ – high wing;

For swept wings; at χ = 30°...40° $\boldsymbol{C}$ = (0.28...0.32) $\boldsymbol{B_{MAC}}$

at χ = 45° C = (0.32...0.36) $\boldsymbol{B_{MAC}}$

Table 1.7

Trim sheet of equipped fuselage

№	Objects	Mass		Coordinates of C.G.		Moment (kgm)
		Units	Total (kg)	L/geometrical	Units	
1	Fuselage	0.07766	20805.65762	0.5 L_f	34.72	722372.4326
2	Horizontal tail unit	0.00856	2293.28392	(0.4-0.45)$\mathbf{B_{MAC}}$ **HT**	60.29	138262.0875
3	Vertical tail unit	0.00847	2269.17229	(0.4-0.45)$\mathbf{B_{MAC}}$ **VT**	60.29	136808.3974
Equipment						
4	Anti-icing system, 15%	0.01237	3314.00959	0.8 L_f	34.72	115062.413
5	Heat and sound isolation	0.0061	1683	0.5 L_f	28.56	48062

6	Control system 70%	0.0042	1125.2094	0.5 L_f	34.72	39067.27037
7	Hydraulic system 30%	0.0133	3563.1631	0.7 L_f	48.608	173198.232
8	Electrical equipment, 90%	0.0236	6322.6052	0.5 L_f	34.72	219520.8525
9	Radar	0.0019	509.0233	Nose fairing	0.5	254.51165
10	Air-navigation. system	0.0031	830.5117	In the 1st eq. comp	2	1661.0234
11	Radio equipment	0.0015	401.8605	the 1st frame	1	401.8605
12	Instrument panel	0.0036	964.4652	4-6 frame	2.5	2411.163
Passenger aircraft						
Passenger eq+ Non typical eq+ Additional equipment+ Service equipment						
13	Seats of pass. economical class	0.0122	3268.4654	134.4		439281.7498
14	Seats of pass. business class	0.008	2143.256	22.5		48223.26
15	Seats of crew	0.00047	125.91629	2.5		314.790725
16	Seats of flight attendance	0.00037	99.12559	9		892.13031
Furnishing (Lavatory, Galley/buffet)						
17	lavatory1, galley 1, lavatory2, galley 2 20%	0.00972	2604.05604	11.972		15587.8795
18	lavatory3, galley 3, lavatory4, galley 4, lavatory5, galley 5 30%	0.00324	868.01868	20.952		18186.72738
19	lavatory6, lavatory7, lavatory8, lavatory9 20%	0.00324	868.01868	31.926		27712.36438

20	lavatory10, galley 6, lavatory11, galley 7, galley 8, galley 9 30%	0.00486	1302.02802	57.867	75344.45543
	Cargo Aircraft				
21	Non typical eq.	0.004	578.62	7.3	7822.8844
22	Additional eq.	0.00805	2156.6513 5	18	38819.7243
23	**Equipped fuselage without payload**	0.21153	56670.367 71	39.71093	2250433.16
			Payload		
39	Mail/Cargo	0.0567	15190.3269	19	288616.2111
40	Crew	0.00337	865	3	2595
41	Flight Attendance	0.00279	770	29.75	22907.5
42	Baggage	0.03774	10110.8101 8	19	192105.3934
43	Meals	0.00399	1100	19.19	21107
44	Passengers	0.09886	28160	44	1239040
	Total	0.989419	97810.1222 5	832.68793	

1.3.3 Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variants calculation are given in table 3.3 and center of gravity calculation options given in table 3.4, completes on the base of both previous tables.

Table 1.8

Calculation of C.G. positioning variants

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G. M	kgm
Equipped wing without fuel and L.G.	63033.159	3.848923801	242609.8

Ending of the table 1.8

Nose landing gear (retracted)	961.518223	8.5	8172.905
Main landing gear (retracted)	10764.5033	4.0512	43609.16
Fuel	94139.8407	3.0384	286034.5
Equipped fuselage	58674.3121	34.00545	1995246
Passengers	30303.526	66.5	1287263.26
Food	1100	19,19	21107
Baggage of passenger	10110.8102	19	192105.4
Nose landing gear extended)	1038.33359	7.82546683	8125.445
Main landing gear (extended)	9345.00231	34	317730.1

Table 1.9

Airplanes C.G. position variants

№	Variants of the loading	Mass, kg	Moment of the mass, kg*m	Centre of the mass, m	Centering
1	Take-off mass (L.G extended)	267907	4057636.417	15.14569	-1.8437
2	Take-off mass (L.G. retracted)	267907	4331709.88	16.16871	-1.7132
3	Landing variant (L.G. extended)	185544.039	3804512.294	20.50463	-1.1601
4	Transportation variant (without payload)	227095.648	2852341.227	12.56009	-2.1735
5	Parking variant (without fuel and payload)	133433.493	2289638.272	17.1594	-1.5868

Conclusion to the project part

This part defines the basic geometric dimensions and centering of the designed aircraft. This made it possible to create a contour of the drawing.

During the calculation the main geometrical parameters caused by operational purpose, planned quantities of passengers and cargo, speed and altitude of flight, conditions of landing and take-off, were considered. All obtained values meet requirements for the short-range passenger aircrafts.

The centering of the designed aircraft was complete. The most forward center of gravity position of equipped aircraft is 39.7 from the origin of the leading edge of main aerodynamic chord. The most aft center of gravity position of equipped aircraft is 34 from the origin of the leading edge of main aerodynamic chord. Between these values centering of the aircraft should be performed.

Geometric parameters are almost calculated in the chosen prototypes. This fact allows us to conclude that the designed aircraft will successfully coincide with other models in the selected market segment.

In addition, the JTD9-3A engine meets the requirements that take into account the efficiency of aircraft design. The main features of the base section of the aircraft and their influence on the creation of the contour are clarified. Reliability analysis was performed.

As shown in the results of the reliability analysis, attention should be paid to the design of the control system elements, as this is an important part of the aircraft and directly affects its performance.

2. SPECIAL PART. ADAPTATION OF THE PASSENGER CABIN FOR PEOPLE WITH DISABILITIES

2.1 The problem of air transportation of people with disabilities

Ukraine is at the beginning of the path to creating a barrier-free environment for people with disabilities. For example, in the United States, this process took almost 30 years. Society needs to make every effort not to repeat the mistakes of other countries. One of the significant shortcomings in these processes is the almost universal lack of information on the accessibility of certain infrastructure facilities, not to mention the complete lack of information on the accessibility of entire infrastructure areas for people with disabilities.

Once in any city in Ukraine, a person with a disability first needs information about the availability of infrastructure and its facilities, including railway stations, airports, pharmacies, hospitals, shops, banks, places of culture and recreation. At the same time, in almost all cities, facilities and places of recreation accessible to people with disabilities appear or already exist, but it is almost impossible to find out about it while moving around the city.

The urgency of the problems of people with disabilities is determined by the fact that in Ukraine is a tendency to increase the number of people with disabilities due to declining health care, drug and alcohol abuse, increased environmental hazards, reduced opportunities for nutrition and recreation, deteriorating working conditions. The significance of the problems of disabled people or people with special needs is enhanced by increasing their share in the general structure of the population of Ukraine. Thus, over the past 6 years of the XX century, their share has increased from 2 million 102 thousand to 2 million 472 thousand people, ie from 4 to 4.7% of the total population. For example, in Ukraine the number of cases of cerebral palsy was 1.7-2 people per 1000 newborns in 1980-1982 years. In 1999-2000 years this situation has already risen.

According to state statistics, children's disability, even against the background of declining birth rates, has a steady upward trend. Thus, in 1994 the total rate of child disability in Ukraine was 130.194 children, in 1995 – 135.366. 1996 – 141.107. 1997 – 1.46930, in 1998 – 152.210. That is, in recent years the total number of children with disabilities has increased by 25.4 %. The main causes of disability are organic lesions of the nervous system, sensory diseases, mental disorders and congenital malformations.

The problem of the disabled or people with special needs is becoming more acute due to the growing morbidity of the population of Ukraine and certain isolation from the outside world. Insufficient public attention to this category of people, lack of places for them in the labor market and a certain indifference of society to them do not create, to put it mildly, conditions for the full formation of an active life position, stable positive self-esteem. Most people with disabilities do not have a lasting trust in the social environment, in ordinary people.

Socio-psychological adaptation of man is through the assimilation of social norms and values, adjusting to their capabilities. Its main indicators include the level of interaction, including communication with the environment and active life.

It is worth imagining how people with disabilities overcome the way to the airport, pass all the checks inside and how to get on board the plane. All these steps are difficult for them and require a lot of effort and mood. On board the aircraft there is a problem of movement in the cabin with narrow aisles, a trip to the lavatory or to the galley. Unfortunately, nowadays air travel is not available and adapted for such people. Therefore, an attempt was made to increase the accessibility and comfort of the aircraft for passengers with disabilities.

2.2 Analysis of lifts for people with disabilities

Modern lifts for disabled people are a wide range of equipment that differs in many parameters. Depending on where and under what conditions the equipment will be used, the type of lift may be selected with the optimal characteristics and principle of operation.

The most common lifting and transport equipment for moving wheelchair users are platforms of vertical and inclined movement. Both types of lifts can be either hydraulically or electrically driven. Their main advantage is that a person in a wheelchair can use the lift on their own without the assistance of an attendant.

Vertical lifts are stationary devices similar to a normal lift, they allow people in wheelchairs to climb and descend, overcoming level differences and flights of stairs. A vertical lift for disabled people is the most common type of specialized mechanisms in the form of a console platform (fig. 2.1). Designed for lifting / lowering people with disabilities in a vertical plane with maximum comfort and safety.

Fig. 2.1. Vertical lift.

The device consists of two systems: hydraulic and electrical. The hydraulic system is presented by a guide post, a movable platform with fences and a wicket, a ramp (moved to the platform for convenience) and a hydraulic lifting mechanism (fig. 2.2). The electrical system, in turn, consists of an electric motor, a control panel and also limits switches. The lifting capacity of the vertical lift in the basic version is 250 kg.

Fig. 2.2. Disabled vertical lift.

The safety of the hoist is ensured by limit switches that limit platform movements at the top and bottom points and the corrugated non-slip surface of the platform. It should be noted the possibility of installing a special module that stops the movement of the platform if foreign objects fall under the platform. You can also install a system of mechanical platform lowering on such a lift when the power supply is cut off. This model is often used in places where it is possible to install and fix the rack rail to the wall or to the ceiling. To form a pit 100 mm deep, it is possible to ensure the level of the platform is flush with the floor. The ramp is most often used (stationary or fixed on a platform).

Installation is possible both indoors and outdoors – mechanisms are resistant to climatic conditions. The required voltage for the operation of the lift is 220 / 380V.

Inclined platforms

An inclined lifting platform is installed against the wall at the entrance to the staircase and helps the disabled to climb to the desired floor (fig. 2.3). The inclined stair lift is a stationary device that is installed in homes and public buildings. In places where it is not possible to install a stationary lift, as a rule, tracked or walking step walkers are used.

Fig. 2.3. Inclined lifting platform.

Crawler Hoists

The electric mobile crawler hoist has a completely different design (fig. 2.4). The self-supporting structure of such a lift is equipped with a rubber track, thanks to which it moves smoothly over the steps. For safety, the mobile platform is equipped with runners and supports. The autonomy of the device is provided by the battery, thanks to it and the compact collapsible design, such a lift can be easily transported in a car and used both indoors and outdoors.

Fig. 2.4. The electric mobile crawler hoist.

To solve this problem, the plane needs to take a few steps:

1. Remove some seats from the cabin to accommodate people in wheelchairs. As an option, use the existing place for their landing and provide a place for mooring the stroller.

2. By redesigning the armrests, increase the width of the aisles to ensure the passage of a person in a wheelchair.

After the analysis and comparison of all lifts it may be concluded that all of the above mentioned lifts cannot be used in aircraft because they have an inconvenient mounting or too much weight.

3.To design a lift for a double-deck aircraft that meets aviation requirements

2.3 Aircraft lift project

One of the main elements that make the aircraft suitable for use by people of this category is a lift. According to the project, it consists of platform with rigid aluminum frame covered with sheets of metal and hydraulic system to drive it. Hydraulic system consist of tank, pump, manometer; bypass valve; check valve, relief valve, filter, throttle, distribution valve, booster.

The fluid from the tank is supplied by a pump through a distribution valve to the booster. As a result, the piston moves up and lifts the mass loaded on the platform. The pressure generated by the pump is controlled by a manometer. If it exceeds the standard value, the relief valve works, through which the excess liquid returns to the tank. This situation occurs when the maximum lift of the piston is achieved or when the lift is overloaded.

To provide necessary safety of the device the strength calculations have to be done. One of the critical structural elements of the lift is rod of the booster. Due to its big length main threat to it is buckling. That’s why stability calculation is required.

Determination of the operating load for the lifting mechanism (rod)

Operating load is**:**

$$F=\left((m_1+m_2)\cdot n+(m_1\cdot 2)+m_3\right)\cdot k\cdot g\cdot 2.5=\left((80+20)\cdot 2+160+23.5\right)\cdot 1.5\cdot 9.80665\cdot 2.5=14103\text{ N}$$

where m_1 – human weight, m_2 – wheelchair weight, m_3 – platform weight, k- safety factor.

Determination the diameter of the rod based on the static load.

Accept the wall thickness 2.5 mm. Area of the rod is:

$$A=\frac{\pi\cdot(D^2-d^2)}{4}$$

where *D* is larger diameter; *d* is smaller diameter.

Stress is:

$$\sigma=\frac{F}{A}$$

Allowable stress is:

$$[\sigma] = 250\text{MPa}$$

Using this condition area is equal to:

$$A=\frac{F}{[\sigma]}=\frac{14103}{250}\cong 56.4\ \text{mm}^2$$

From this two equations may be determined the diameter:

$$\frac{\pi\cdot(D^2-d^2)}{4}=56.4$$

$$\frac{5}{4}\pi(2D-5)=56.4$$

$$D=9.7\ \text{mm}$$

The accepted diameter is 10 mm. So, D =10 mm, d = 5 mm.

C**hecking the calculated rod for stability**.

Local stability calculation.

Critical strength is:

$$\sigma_{cr}=k\frac{\pi^2\cdot D}{b^2\cdot t};$$

where D – plate modulus, b-larger linear size, t-thickness.

Plate modulus is:

$$D=\frac{(E\cdot t^3)}{12\cdot(1-\nu^2)}=\frac{0.75\cdot 10^5\cdot 2.5^3}{12\cdot(1-0.34^2)}=110421$$

where E – elasticity modulus , ν – Poisson coefficient.

So, critical stress is

$$\sigma_{cr}=0.5\frac{3.14^2\cdot 110421}{10^2\cdot 2.5}=2180\ \text{MPa}$$

Proportionality coefficient is:

$$V=\frac{\sigma_{ult}}{\sigma_{cr}}=\frac{450}{2180}=0.206$$

where σ_{ult} =450 MPa is ultimate strength

Local stability is equal:

$$\sigma=\frac{\sigma_{ult}\cdot(1+V)}{(1+V+V^2)}=\frac{450\cdot(1+0.206)}{(1+0.206+0.206^2)}=435\text{ MPa}$$

General stability calculation

Area of the rod is

$$A=\frac{\pi\cdot(D^2\text{-}d^2)}{4}=\frac{3.14\cdot(100\text{-}25)}{4}=58.9\text{ mm}^2$$

Moment of inertia of the ring is

$$I=\frac{\pi\cdot(D^4\text{-}d^4)}{64}=\frac{3.14\cdot(10^4\text{-}5^4)}{64}=460.2\text{ mm}^4$$

Radius of inertia is

$$I=\sqrt{\frac{I_{min}}{A}}=\sqrt{\frac{460.2}{58.9}}=2.8\text{ mm}$$

Flexibility of the rod is

$$\lambda=\frac{\mu\cdot l}{i}=\frac{1\cdot 2500}{2.8}=894.4$$

where μ – effective length coefficient; l – cabin height.

Critical stress is

$$\sigma_{cr}=\frac{\pi^2\cdot E}{\lambda^2}=\frac{3.14^2\cdot 0.75\cdot 10^5}{894.4^2}0.925\text{ MPa}$$

So, strength test failed. To improve the stability of the rod accept the D=100 mm, t=2 mm and check again with a new parameters.

Local stability calculation

Determining of plate modulus:

$$D=\frac{(E\cdot t^3)}{12\cdot(1-\nu^2)}=\frac{0.75\cdot 10^5\cdot 2^3}{12\cdot(1-0.34^2)}=56535.5$$

Critical stress is

$$\sigma_{cr}=k\frac{\pi^2\cdot D}{b^2\cdot t}=4\cdot\frac{3.14^2\cdot 56535.5}{100^2\cdot 2}=111.6\text{ mm;}$$

General stability calculation

Area of the rod is

$$A=\frac{\pi\cdot(D^2-d^2)}{4}=\frac{3.14\cdot(10000-9216)}{4}=615.75\text{ mm}^2$$

Moment of inertia of the ring is

$$I=\frac{\pi\cdot(D^4-d^4)}{64}=\frac{3.14\cdot(100^4-96^4)}{64}=739518\text{ mm}^4$$

Radius of inertia is

$$I=\sqrt{\frac{I_{min}}{\text{A}}}=\sqrt{\frac{739518}{615.75}}=34.65\text{ mm}$$

Flexibility of the rod is

$$\lambda=\frac{\mu\cdot l}{i}=\frac{1\cdot 2500}{34.65}=72.15$$

Critical stress is

$$\sigma_{cr} = \frac{\pi^2 \cdot E}{\lambda^2} = \frac{3.14^2 \cdot 0.75 \cdot 10^5}{72.15^2} = 142.2 \text{ MPa}$$

Therefore, with a diameter of 100 mm, the stability is provided.

And for the second time the check on compression with the given diameter of 100 mm is carried out.

Stress is:

$$\sigma = \frac{F}{A} = \frac{14100}{615.75} = 22.89 \text{ MPa}$$

From this value may be concluded that the compression strength requirements are also satisfied.

Calculation of critical force

Critical force is

$$F_{cr} = \sigma_{cr} \cdot A = 111.6 \cdot 615.75 = 68718 \text{ N}$$

The coefficient of transverse bending is equal to $\varphi = 0.3328$

Available force is:

$$[F_{ava}] = \varphi \cdot [\sigma] \cdot A = 0.3328 \cdot 150 \cdot 615.75 = 68718 \text{ N}$$

Let’s determine stability factor:

$$[\eta] = \frac{F_{cr}}{F_{ava}} = 2.23$$

$$[\eta] = 1.3 \ldots 2.5$$

Stability is provided.

Conclusion of special part

In this part the static load calculation and stabilitity calculation were created.

During the calculation the rod and the platform have been tested for compression and stress and therefore all the rules were considered. All obtained values meet requirements for the mid-range passenger aircrafts. Calculations have shown that the development is successful. The lift will withstand the load and will perform its function.

There are also places for the disabled. Part of the seats in each of the classes of the aircraft was removed to create the possibility of the disabled person to sit in a chair with a wheelchair, as well as the possibility of attaching him to the wheelchair with mooring ropes. To comfortably move it in a wheelchair on the plane, one of the aisles was narrowed and the other in its background was widened and the armrests were removed in the middle. It is in this large passage that a person with disabilities is able to move independently through the cabin

The first aircraft adapted for people with disabilities has been created

General conclusions and recommendations

During this designing work I’ve got the next results

-adapted aircraft for disabled people;

- preliminary design of the mid range aircraft with 440 passengers;

- the schematic design of the layout of the mid-range aircraft with 440 passengers;

-the center of gravity of the airplane calculations;

- checking the main parameters of lift strength;

- the design of lift for disabled people;

Designed aircraft satisfies the planned aim of usage, its geometrical characteristics will provide the necessary aerodynamic performance, which will lead to efficient usage.

There were places for the disabled on the plane. Part of the seats in each of the classes of the aircraft was removed to create the possibility of the disabled person to sit in a chair with a wheelchair, as well as the possibility of attaching him to the wheelchair with mooring ropes. To comfortably move it in a wheelchair on the plane, one of the aisles was narrowed and the other in its background was widened and the armrests were removed in the middle. It is in this large passage that a person with disabilities is able to move independently through the cabin

A lift has been developed to improve the flight conditions for people with disabilities. The present invention satisfies all conditions of strength and static stability and verification.

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Appendix

APPENDIX A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number Flight	440
Crew Number	3
Flight Attendant or Load Master Number	13
Mass of Operational Items	4366.25 kg
Payload Mass	49513.2
Cruising Speed	920 km/h
Cruising Mach Number	0.8518
Design Altitude	10 km
Flight Range with Maximum Payload	6000 km
Runway Length for the Base Aerodrome	2.95 km
Engine Number	4
Thrust-to-weight Ratio in N/kg	2.8
Pressure Ratio	27
Assumed Bypass Ratio	5
Optimal Bypass Ratio	4.5
Fuel-to-weight Ratio	0.32
Aspect Ratio	7
Taper Ratio	3.2
Mean Thickness Ratio	0.120
Wing Sweepback at Quarter Chord	37.5 degree
High-lift Device Coefficient	1.050
Relative Area of Wing Extensions	0.060

Wing Airfoil Type - supercritical
Winglets - yes
Spoilers - yes

Fuselage Diameter	6.5 m
Finesse Ratio	9
Horizontal Tail Sweep Angle	35 degree
Vertical Tail Sweep Angle	40 degree

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.38817
Induce Drag Coefficient	0.00899

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

Cruising Mach Number	0.85182
Wave Drag Mach Number	0.86876
Calculated Parameter D_m	0.01694

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	6.4
At Middle of Cruising Flight	5.238
At the Beginning of Cruising Flight	6.184

Drag Coefficient of the Fuselage and Nacelles	0.01087
Drag Coefficient of the Wing and Tail Unit	0.00904

Drag Coefficient of the Airplane:	
At the Beginning of Cruising Flight	0.03133
At Middle of Cruising Flight	0.02970
Mean Lift Coefficient for the Ceiling Flight	0.38817
Mean Lift-to-drag Ratio	13.06816
Landing Lift Coefficient	1.366
Landing Lift Coefficient (at Stall Speed)	2.049
Takeoff Lift Coefficient (at Stall Speed)	1.690
Lift-off Lift Coefficient	1.234
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.684
Start Thrust-to-weight Ratio for Cruising Flight	2.583
Start Thrust-to-weight Ratio for Safe Takeoff	2.734
Design Thrust-to-weight Ratio	2.844
Ratio $D_r = R_{cruise} / R_{takeoff}$	0.945

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

Takeoff	37.5183
Cruising Flight	63.2332
Mean cruising for Given Range	66.6577

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.04591
Block Fuel	0.30549

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.09469
Horizontal Tail	0.00856
Vertical Tail	0.00847
Landing Gear	0.04018
Power Plant	0.09696
Fuselage	0.07766
Equipment and Flight Control	0.11029
Additional Equipment	0.01060
Operational Items	0.01630
Fuel	0.35139
Payload	0.18481

Airplane Takeoff Weight	267907 kg
Takeoff Thrust Required of the Engine	190.47 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0203
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0132
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0057
Furnishing Equipment Weight Fraction	0.0181
Flight Control Weight Fraction	0.0042
Hydraulic System Weight Fraction	0.0133

Electrical Equipment Weight Fraction	0.0236
Radar Weight Fraction	0.0020
Navigation Equipment Weight Fraction	0.0031
Radio Communication Equipment Weight Fraction	0.0015
Instrument Equipment Weight Fraction	0.0036
Fuel System Weight Fraction	0.0114

Additional Equipment:

Equipment for Container Loading	0.0066
No typical Equipment Weight Fraction (Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0040

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	327.82 km/h
Acceleration during Takeoff Run	2.13 m/s^2
Airplane Takeoff Run Distance	1938 m
Airborne Takeoff Distance	472 m
Takeoff Distance	2411 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

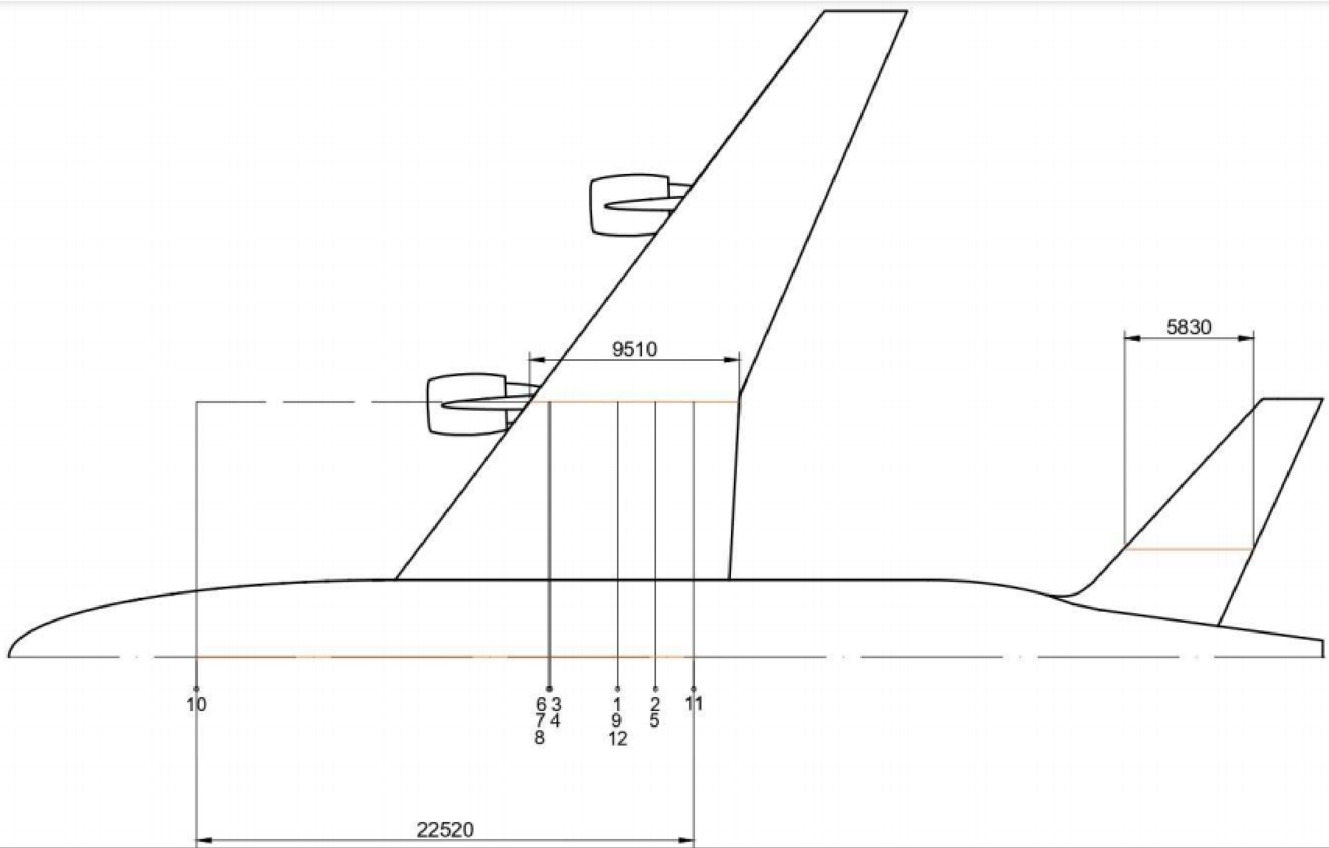
Decision Speed	295.04 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.91 m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	2390.92 m
Continued Takeoff Distance	2863.17 m
Runway Length Required for Rejected Takeoff	2967.51 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	195364 kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	19.9 min.
Descent Distance	50.87 km
Approach Speed	286.11 km/h
Mean Vertical Speed	2.25 m/s
Airborne Landing Distance	530 m
Landing Speed	271.11 km/h
Landing run distance	981 m
Landing Distance	1512 m
Runway Length Required for Regular Aerodrome	2525 m
Runway Length Required for Alternate Aerodrome	2147 m

APPENDIX B

№	Name	CG coordinates x_i (m)
1	Wing (structure)	3.0384
2	Fuel system, 40%	3.0384
3	Control system, 30%	4.0512
4	Electrical equip. 10%	0.6752
5	Anti-icing system 70%	0.6752
6	Hydraulic system, 70%	2.166
7	Power units	-5.44
8	Equipped wing without fuel and LG	0.6177338485
9	Nose landing gear	-23.066
10	Main landing gear	4.0512
11	Fuel	3.0384
12	Equipped fuselage	3.5350525



APPENDIX C

№	Objects	Coordinates of C.G.
1	Fuselage	34.72
2	Horizontal tail unit	60.29
3	Vertical tail unit	60.29
4	Anti-icing system, 15%	34.72
5	Heat and sound isolation	28.56
6	Control system 70%	34.72
7	Hydraulic system 30%	48.608
8	Electrical equipment, 90%	34.72
9	Radar	0.5
10	Air-navigation. system	2
11	Radio equipment	1
12	Instrument panel	2.5
13	Seats of pass. economical class	134.4
14	Seats of pass. business class	22.5
15	Seats of crew	2.5
16	Seats of flight attendance	9
17	lavatory1, galley 1, lavatory2, galley 2 20%	11.972
18	lavatory3, galley 3, lavatory4, galley 4, lavatory5, galley 5 30%	20.952
19	lavatory6, lavatory7, lavatory8, lavatory9 20%	31.926
20	lavatory10, galley 6, lavatory11, galley 7, galley 8, galley 9 30%	57.867