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 ближньньомагістрального літака пасажиромісткістю 80 осіб»

Виконав: ___________ **Олександр ПАЛІЄНКО**

Керівник: канд.техн.наук, доцент ___________ **Тетяна МАСЛАК**

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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 short-range aircraft with 80 passenger capacity»

Prepared by: _________ Olexandr PALIYENKO

Supervisor: PhD, associate professor __________ Tetiana MASLAK

Standard controller: PhD, associate professor __________ Sergiy KHIZNYAK

Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Academic Degree «Bachelor»

Specialty: 134 "Aviation and Aerospace Technologies"

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

TASK
for the bachelor degree thesis

PALIYENKO OLEXANDR

1. Topic: «Preliminary design of a short-range aircraft with 80 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}=830 kmph, flight range L=1780 km, operating altitude H_{op}=11.9 km, 80 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, conceptual design of the seat thigh pad position.

5. Required material: general view of the airplane (A1×1); layout of the airplane (A1×1); assembly drawing of the passenger seat (A1×1).

Graphical materials are performed in AutoCAD.

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	14.06.2022–19.06.2022	

7. Date: 23.05.2022

Supervisor ____________ Tetiana MASLAK

Student ____________ Olexandr PALIYENKO

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет

Кафедра конструкції літальних апаратів

Освітній ступінь «Бакалавр»

Спеціальність 134 «Авіаційна та ракетно-космічна техніка»

Освітньо-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н, проф.
__________ Сергій ІГНАТОВИЧ
«_____» _____________ 2022 р.

ЗАВДАННЯ
на виконання дипломної роботи студента

ПАЛІЄНКО ОЛЕКСАНДР

1. Тема роботи: «Аванпроект ближньомагістрального літака пасажиромісткістю 80 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 80, дальність польоту з максимальним комерційним навантаженням 1780 км, крейсерська швидкість польоту 830 км/год, висота польоту 11,9 км.

4. Зміст пояснювальної записки: вибір параметрів та обгрунтування схеми проектованого літака, вибір двигунів, розрахунок геометрії та центрування літака, проектування крісла з регулюванням подушки сидіння.

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

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	14.06.2022–19.06.2022	

7. Дата видачі завдання: 23.05.2022 рік

Керівник дипломної роботи ___________ Тетяна МАСЛАК

Завдання прийняв до виконання ___________ Олександр ПАЛІЄНКО

РЕФЕРАТ

Дипломна робота «Аванпроект ближньомагістрального літака пасажиромісткістю 80 осіб» містить:

45 сторінок, 18 рисунків, 7 таблиць, 12 посилань

Об’єкт проектування - ближньомагістральний пасажирський літак для 80 осіб.

Предмет проектування – механізм регулювання кута подушки крісла.

Мета роботи: аванпроект ближньомагістрального пасажирського літака та визначення його основних льотно-технічних характеристик.

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 необхідно розробити концепцію механізму регулювання кута подушки крісла, а також розрахувати міцність конструкції.

Актуальність роботи – механізм регулювання кута подушки крісла дозволяє набагато підвищити комфортність пасажира під час перельоту, адже він може налаштувати його так як йому буде зручно, й він зможе прийняти практично будь-яке положення під час польоту.

Практичне значення дипломної роботи полягає в підвищенні комфорту пасажира, результати роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

АВАНПРОЕКТ ЛІТАКА, КОМПОНУВАННЯ ПАСАЖИРСЬКОЇ КАБІНИ, ЦЕНТРУВАННЯ ЛІТАКА, ПАСАЖИРСЬКЕ СИДІННЯ, ПОДУШКА

ABSTRACT

Bachelor thesis «Preliminary design of a short-range aircraft with 80 passenger capacity» consists of:

45 sheets, 18 figures, 7 tables, 12 references

Object of study – short-range aircraft with a capacity of 80 passengers.

Subject of study – the mechanism of adjustment of a angle of a cushion of a seat.

Aim of bachelor thesis – is a preliminary design of an short-range aircraft, choice the best flight performances of the designing aircraft.

Research and development methods – the design methodology is based on the analysis of prototypes, the most advanced technical decisions and engineering calculations to get the technical data of designed aircraft. In special part, it is about the concept the mechanism of adjustment of a angle of a cushion of a seat.

Novelty of the results –the mechanism of adjustment of a angle of a coshion of a seat allows to increase much comfort of the passenger during flight as it can adjust it as it will be convenient to it, and it will be able to accept practically any position during flight.

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

AIRCRAFT PRELIMINARY DESIGN, PASSENGER CABIN LAYOUT, CENTER OF GRAVITY POSITION, PASSENGER SEAT, CUSHION

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 22 04P 00 00 00 25 TW	Task for work	1	
	2	NAU 22 04P 00 00 00 25	Short-range passenger aircraft	2	
A1		Sheet 1	General view		
A2		Sheet 2	Fuselage layout		
A4	3	NAU 22 04P 00 00 00 25 EN	Short-range passenger aircraft	29	
			Explanatory note		
A1	4	NAU 22 04P 00 00 00 25 AD	Assembly drawing of passenger seat	1	

NAU 22 04P 00 00 00 25 EN

Done by	Paliyenko O.R	
Checked by	Maslak T.P	
St.control.	Khyzhniak S.V.	
Head of dep.	Ignatovych S.R.	

Preliminary design of a short-range passenger aircraft with 80 passenger capacity (List of diploma work)

list	sheet	sheets
	4	45

134 AKF 402

CONTENT

Department of Aircraft Design				NAU 22 04P 00 00 00 25 EN			
Performed by	Paliyenko O.			Content	Letter	Sheet	Sheets
Supervisor	Maslak T.P.						
					402 AF 134		
Stand.contr.	Khizhnyak S.V.						
Head of dep.	Ignatovych S.R.						

INTRODUCTION

The aviation industry is growing fast despite the periodic problems with pandemic of last years. To set up the aviation industry the new requirements must be met: fuel efficiency, engines with the lowest pollution of carbon dioxide and carbon oxide, investigation of a new composite materials implementation on the aircraft airframe. Competitiveness of aircraft manufacturers in the market is also defined by the conveniences for passengers. That is why the presented work is focused on comfort of passenger seats. At a time when most countries are prioritizing many long-haul passenger aircraft, the most attention will be to the regional aircraft that can be accessed by everyone for fast, short journeys. So, the main goal for diploma work is to create an aircraft with the following priorities: flight range 1780 km, economy, comfort, reliability, ensuring less pollution for the environment, easy in maintenance and operation.

For the main prototypes with the capacity of 90-150 passengers and able to land on all possible airfields in case of emergencies are the next ones: Brazilian ERJ-175, E190 and MRJ-90.

Most short-range aircraft with the economy class have completely ordinary seats that have parameters for standard person. It is not quite right to build everything under one standard. Every passenger is differ and may have some health problems. Therefore, a flight duration in 3-4 hours on a regular seat can lead not only to discomfort, but also to pain, which will have an extremely negative impact on the conveniences and even on the reputation of airlines.

The special part of diploma work is devoted to the conceptual design of the universal seat, in which the passenger can adjust it to himself. Settings include the ability to change the angle of the backrest, angle of seat cushion.

1. PRELIMINARY DESIGN OF A SHORT-RANGE AIRCRAFT

1.1. Analysis of prototypes and short description of aircraft

According to the task of diploma work the aircraft with capacity up to 100 passengers and with possibility to land in any European airfield in case of emergencies the next prototypes were considered (table 1.1): American, British, Dutch aircraft, namely: Boeing 717, McDonnell Douglas MD-90, British Aerospace ATP, Fokker 100, Brazilian ERJ-175, E190 and the newer MRJ-90.

Table 1.1 – Operational-technical data of prototypes

Parameter	Planes		
	MRJ-90	ERJ-175	E-190-2
The purpose of airplane	Passenger	Passenger	Passenger
Crew / flight attendance	2/2	2/2	2/2
Maximum take-off weight, kg	42800	40370	56400
Maxinum payload, kg	11650	10094	13500
Passengers	88	88	114
The altitude of flight, m	11900	11500	10668
Flight range, km	3770	4074	5278
Take off distance, m	1740	2244	1615
Number and type of engines	2xPW1217G	2×GE CF34-8E	2×GE CF34-10E
Fuselage cross-section	circular	double-bubble	double-bubble
Sweepback on 1/4 chord, ^{0}	28	28	30

The airframe of the aircraft could be manufactured from aluminum alloys with combination of carbon fiber composite materials for the empennage, for the high lift devices, foe ailerons, for the nose part of the fuselage.

The key features of the designing aircraft will be: low wing monoplane, high aspect ratio wing, conventional tail unit, retractable tricycle-type with twin-wheeled landing-gear, high fineness ratio fuselage with circular shape and sharp nose, two high bypass ratio turbofan engines installed under the wing.

1.2. Aircraft geometry calculation and fuselage layout

Layout of the aircraft consists from composing the relative disposition of its parts and constructions, and all types of the loads (passengers, luggage, cargo, fuel, and so on).

Choosing the scheme of the composition and aircraft parameters is directed by the best conformity to the operational requirements.

1.2.1. Wing design

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

Wing area is:

$$S_{w=} \frac{m_o * g}{P_o} = \frac{34.443 \ * 9.8}{3.900} = 86.549m^2$$

Relative wing extensions area is 0.1.

Wing span is:

$$l = \sqrt{S_w * \lambda_w} = \sqrt{86.549 * 9.3} = 28.36m$$

Root chord is:

$$b_0 = \frac{2 * A_{w*}\eta_w}{(1+\eta_w) * l} = \frac{2 * 86.549 * 4.16}{(1+4.16) * 28.37} = 4.82m$$

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} = \frac{4.82m}{4.16} = 1.16m$$

Maximum wing width is determined in the current i-section and by its span it is equal:

$$C_i = C_w * b_t = 0.11 * 1.16 = 0.1276m$$

Board chord for trapezoidal shaped wing is:

$$b_{ob} = b_o * \left(1 - \frac{(\eta_w - 1) * D_f}{\eta_w * l_w}\right) = 4.82 * \left(1 - \frac{(4.16 - 1) * \ 3}{4.16 * 28.37}\right) = 4.4m$$

The mean aerodynamic chord can be determined by the geometrical method, which is shown at the figure 1.1.

Mean aerodynamic chord is equal: $b_{mac} = 3.36m$

Let's compare the geometrical method with analytical:

$$b_{mac} = \frac{2(4.82^2 + 4.82 * 1.16 + 1.16^2)}{3(4.82 + 1.16)} = 3.3633 \text{ m}$$

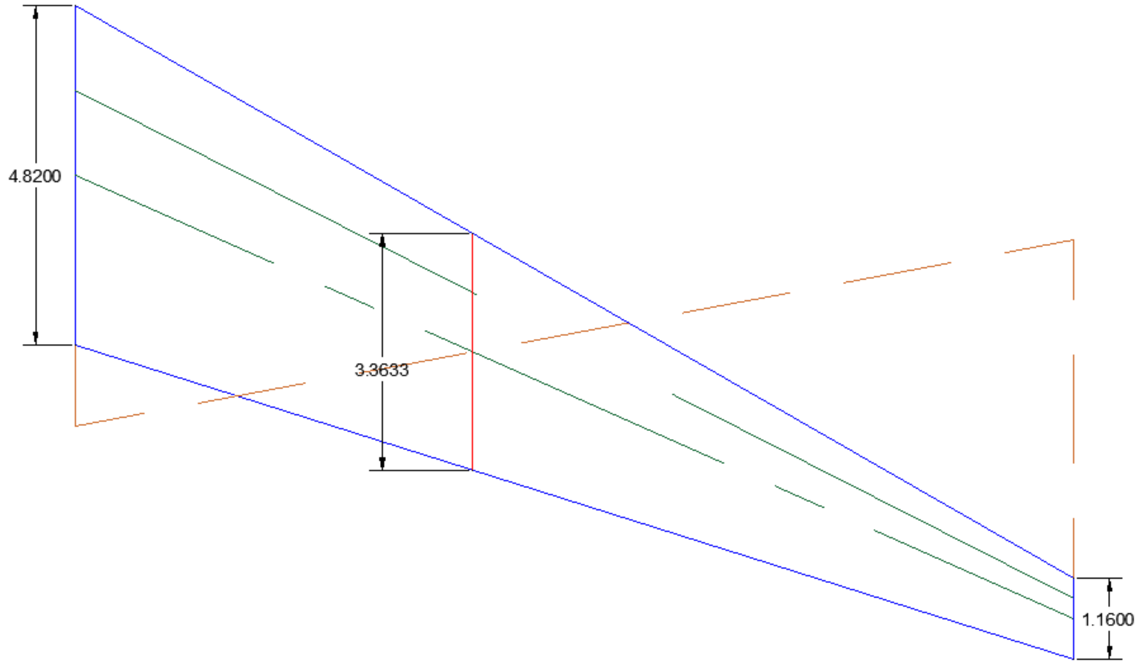

Figure 1.1 – Mean aerodynamic chord definition

After determination of the geometrical characteristics of the wing we come to the estimation of the aileron’s geometry and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ai} = 0.35 * \frac{l_w}{2} = 0.35 * \frac{28.36}{2} = 4.96m$$

Aileron area:

$$S_{ai} = 0.065 * \frac{S_w}{2} = 0.065 * \frac{86.54}{2} = 2.81m^2$$

In this aircraft will be the simple high lift device, so ailerons don't have tabs.

Ailerons have only axial balance.

$$S_{ail} = 0.25 * 2.81 = 0.7025m^2$$

The range of aileron deflection will be 25 degree upward, 15 degree downward.

Designing aircraft can be equipped with simple slotted flaps without slats. So, according to the prototypes the relative chords of wing high-lift devices is:

b_f = 0.28..0.3 – for one slotted flaps;

In the small distance from the root cross section of the wing (b_{wing}=4,8 m) the flaps start, so the chord of the flap in this cross-section is:

$$b_f = 0.28 * 4.8 = 1.3 \text{ m}$$

The position of the spars in the wing are shown in the fig.1.2.

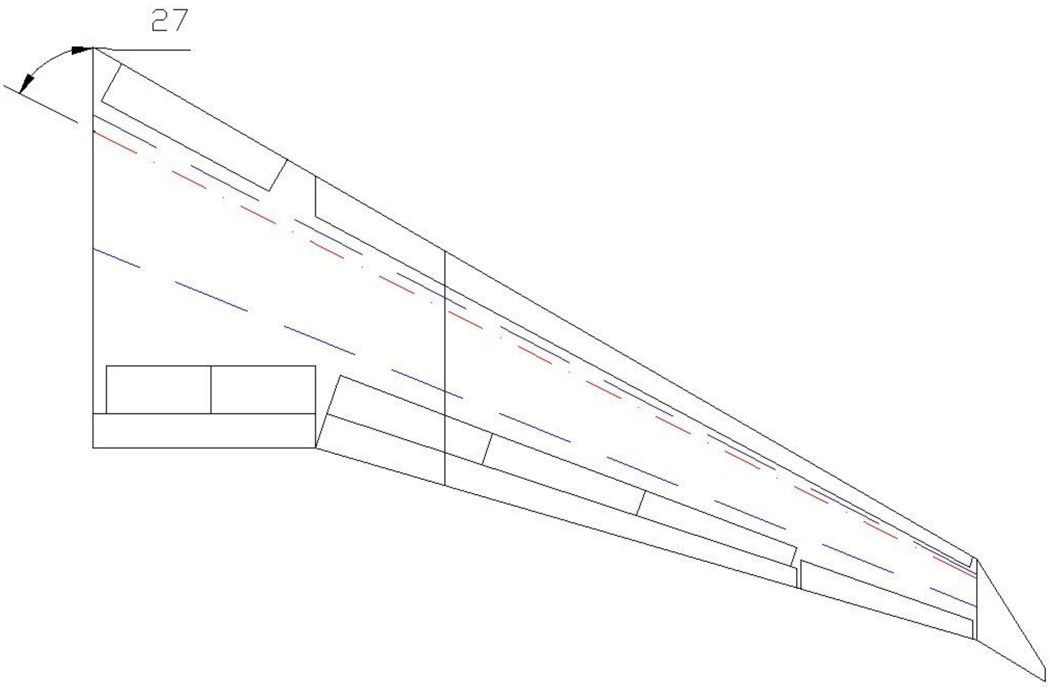

Figure 1.2 – Wing design with spars and high lift devices

1.2.2 Fuselage layout

Fuselage length is equal:

$$l_f = \lambda_f * D_f = 11 * 3 = 33 \text{ m}$$

For transonic airplanes fuselage nose part has to be:

$$l_{fnp} = D_f * 2.1 = 3 * 2.1 = 6.3 \text{ m}$$

According to the design of prototypes, the fineness ratio for the nose part and for the tail unit could be taken as the next.

Fuselage nose part fineness ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} = \frac{3.9}{3} = 1.3$$

Tail unit fineness ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} = \frac{9.1}{3} = 3.03$$

Cabin width could be calculated:

$$B_{cabin} = n_2 b_2 + n_n b_n + 2\delta = 2 * 1090 + 380 + 2 * 50 + 2 * 80 = 2.82m$$

Length of passenger cabin cabin:

$$L_{cabin} = L_1 + (n_{raws} - 1)L_{seat} + L_2 = 1200 + (20 - 1) * 870 + 250 = 17.98m$$

Cabin height in the aisle if the cabin is equal:

$$H_{cabin} = 1.48 + 0.17 * B_{cab} = 1.48 + 0.17 * 2.82 = 1.96\text{m}$$

Since the luggage compartment is located in the tail (figure 1.3), it is possible to make a more spacious cabin (figure 1.4).

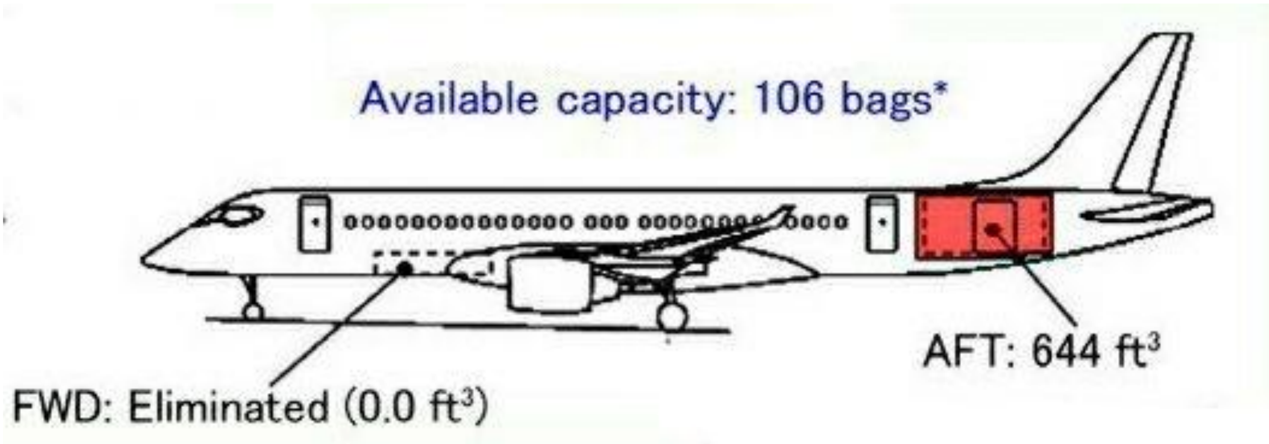

Figure 1.3 Possible layout of the baggage compartment

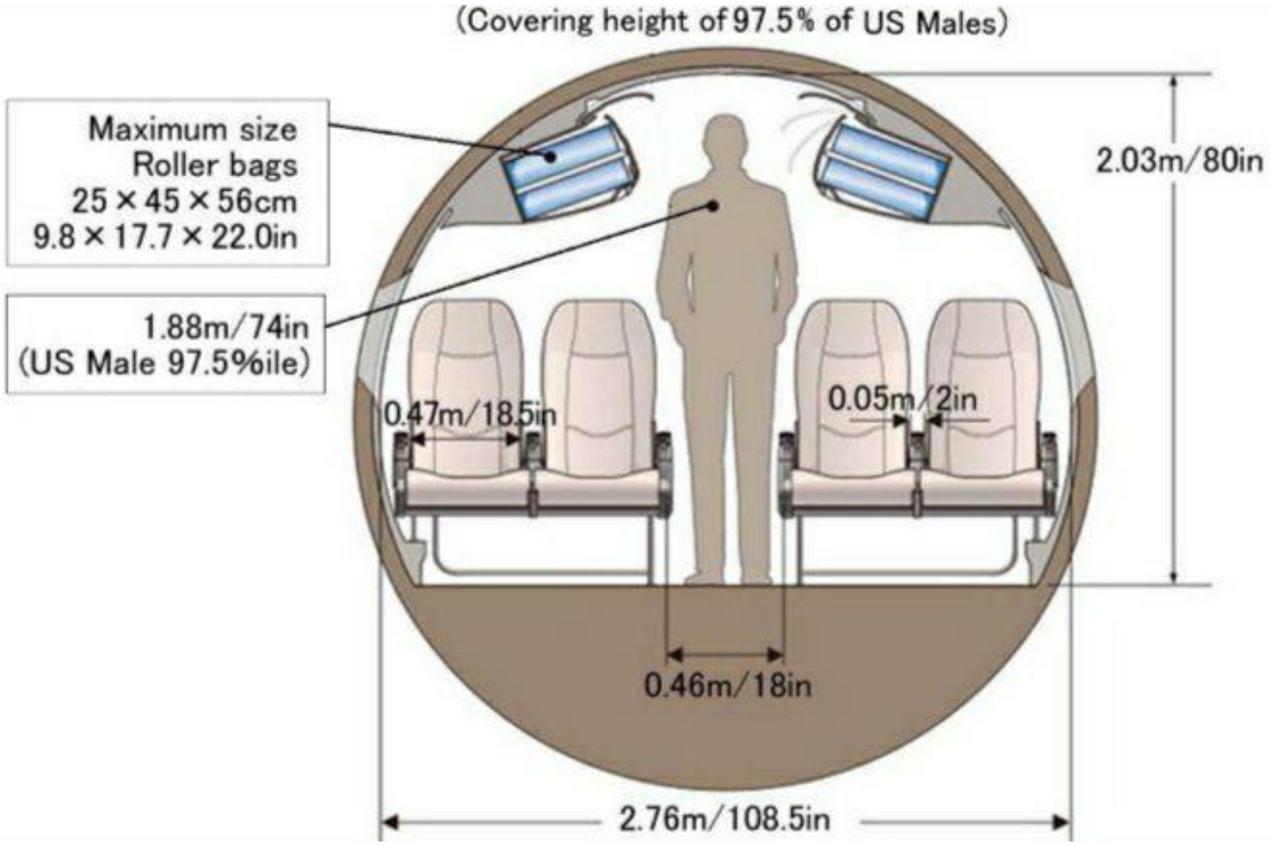

Figure 1.4 – Fuselage interior

1.2.3 Cargo compartment. Galleys and lavatories design

Cargo compartment volume is equal:

$$V_{cargo} = V * n = 0.2 * 80 = 16m^3$$

Volume of buffets(galleys) is equal:

$$V_{gally} = (0.1 \dots 0.12)N_{pass} = 0.11 * 80 = 8.8m^3$$

Area of the floor in buffets(galleys) is equal:

$$S_{gally} = \frac{V_{gally}}{H_{cab}} = \frac{8.8}{1.96} = 4.49m^2$$

Number of toilet facilities is determined by the number of passengers and flight duration.

Since the number of passengers in this aircraft have less than the selected aircrafts for the prototype, namely 80, so the number of toilets is equal to:

$$n_{lav} = 2$$

Area of lavatory is standart:

$$S_{lav} = 1.5m^2$$

Customary width of lavatory: 950x1150

1.2.4 Tail unit design

Area of horizontal tail unit is equal:

$$S_{HTU} = 0.19 * S_w =* 86.5 = 16.43m^2$$

Area of vertical tail unit is equal:

$$S_{VTU} = 0.2 * S_w =* 86.5 = 17.3m^2$$

Determination of the elevator area:

$$S_{el} = 0.27 * S_{HTU} = 0.27 * 17.3 = 4.67m^2$$

Rudder area:

$$S_{rud} = 0.23 * S_{VTU} = 0.23 * 16.43 = 3.77m^2$$

Tip chord of horizontal stabilizer is:

$$b_{tHTU} = \frac{2 * S_{ro}}{(1 + \eta_{ro})l_{ro}} = \frac{2 * 16.4}{(1 + 2.8) * 9.08} = 0.95m$$

Root chord of horizontal stabilizer is:

$$b_{rHTU} = b_{tHTU} * 2.8 = 0.95 * 2.8 = 2.66m$$

Root chord of vertical stabilizer is:

$$b_{oVTU} = \frac{2 * S_{ro}}{(1 + \eta_{ro})l_{ro}} = \frac{2 * 17.3}{(1 + 3) * 15} = 4.6m$$

Tip chord of vertical stabilizer is:

$$b_{tVTU} = \frac{b_{oVTU}}{\eta_{VTU}} = \frac{4.6}{3} = 1.35m$$

1.2.5 Landing gear design

Wheel track of prototype: 5,3 m. Length of the fuselage of prototype: 35,8 m. Length of designing aircraft is 33 m. Since the layout of the aircraft is very similar, it was decided to make a wheel track of 5.3 m.

The distance from the centre of gravity to the main landing gear:

$$Bm = 0.17 * 3.36 = 0.57\text{m}$$

Wheel base comes from the expression:

$$B = 0.4 * 33 = 13.2\text{m}$$

The load on the wheel is determined:

For this aircraft chosen dynamics coefficient K_g = 2.0

Nose wheel load is equal:

$$P_{NLG} = \frac{(9.81 * Bm * k_g * \ m_o}{(B * Z)} = \frac{(9.81 * 0.57 * 2 * 34.443\ )}{(13.2 * 2)} = 13.95N = 3.135\ \text{lbs}$$

Main wheel load is equal:

$$P_{MLG} = \frac{(9.81*(B-Bm)* \ m_o)}{(B*n*Z)} = \frac{(9.81*(13.8-0.57)*34.443)}{(13.2*4*2)} = \ 40.49\text{N} = 9.1\ \text{lbs}$$

The height of the main landing gear allows to land the aircraft in an emergency without a nose wheel strike (fig.1.5), the runway.

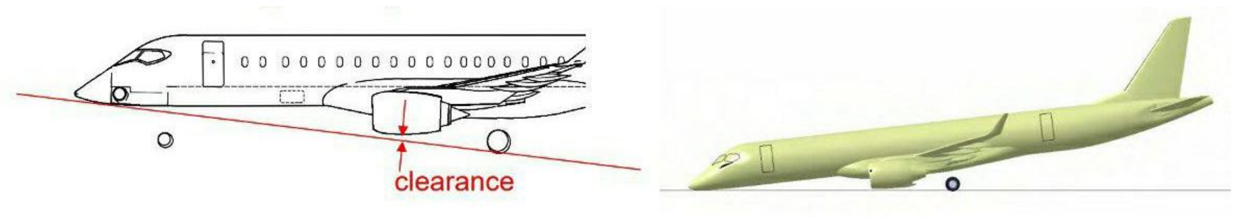

Figure 1.5 – Nose wheel strike and ground clearance

To choose the tires for the aircraft (table 1.2), we should now the loads on main wheel and nose wheel, speed for take off and landing.

Table 1.2 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
32x10.75-14	12	22x6.75-10	8

1.2.6 Engine description

Two high bypass ratio turbofan PW1217 (figure 1.6) with 78.2 kN maximum takeoff thrust (sea level, static condition and ISA) installed under the wings are taken for the aircraft.

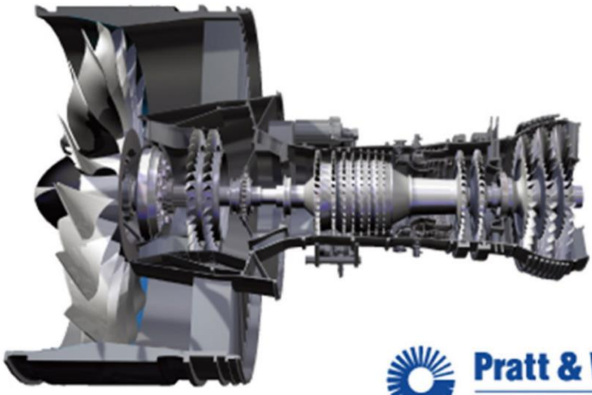

Figure 1.6 – Engine PW1217G

This new innovative engine has a lower noise level compared to the engine installed on the E-190 (fig.1.7), the main properties of the engine are presented in the table 1.3.

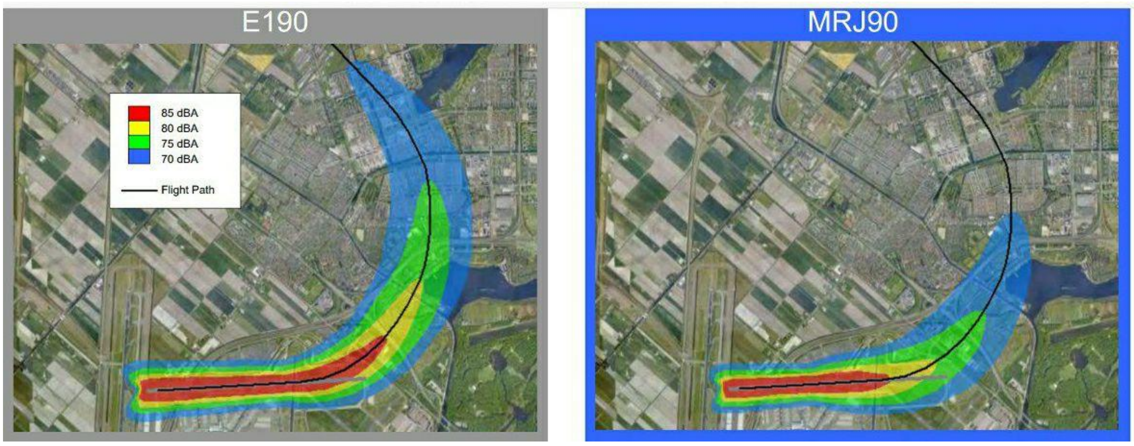

Figure 1.7 – Landing noise level of the engine

Table 1.3 – Main characteristics of the power plant

Model	Thrust	Bypass ratio	Dry weight
Pratt & Whitney 1217G	17,600 lbf (79 kN)	9.0	8,207 lb (3,723 kg) \ (4,630)

1.3 Aircraft center of gravity calculation

To provide longitudinal balance of the aircraft, the correct layout and calculation of the masses of the aircraft have to be done. The most forward and most aft center of gravity position is limited for the aircraft, and it depends on the possibility to compensate the moment of wing lift force by the moment of stabilizer. The aerodynamic moment of the stabilizer depends on the area of it and distance from the centre of gravity of the aircraft to the aerodynamic centre of the stabilizer. At the preliminary design of the aircraft, at this stage of calculations we know only aircraft geometry. So, to find the range of centre of gravity position we should estimate the mass moments of all equipment and mass of the structure, they must be in equilibrium from nose part and from tail part. Even more, the aircraft has to be in equilibrium from left and right, side mass and aerodynamic balance also.

1.3.1 Trim sheet of equipped wing

The weight of equipped wing includes the weight of wing structure, the weight of the equipment, located in the wing, and the weight of the fuel. The coordinates of the center of force of the equipped wing are determined by the formulas:

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

The results of the mass moment calculation for the masses of the wing is presented in the table 1.4.

Table 1.4 - Trim sheet of equipped wing

Object name	Mass		C.G coordinates Xi, m	Mass moment, Xi ·mi
	Units	Total mass m(i), kg		
Wing (structure)	0.1259	4335.34	1.45	6269.29
Fuel system	0.0045	154.99	1.43	221.53
Flight control system, 30%	0.0026	89.90	2.02	181.39
Electrical equipment, 10%	0.0034	117.11	0.34	39.38
Anti-ice system , 40%	0.0098	336.16	0.34	113.05
Hydraulic systems , 70%	0.0155	532.83	2.02	1075.15
Power plant 1,2	0.1082	3726.04	-2.00	-7452.09
Equipped wing without landing gear and fuel	0.2698	9292.38	0.05	447.71
Nose landing gear	0.0066	227.94	-11.95	-2724.01
Main landing gear	0.0375	1291.68	1.85	2389.16
Fuel	0.1572	5412.72	1.41	7645.25
Total	0.4711	16224.72	0.48	7758.11

1.3.2 Trim sheet of the equipped fuselage

The origin of the coordinates is chosen in the side view of the aircraft in the nose of the fuselage. All masses of the fuselage will receive the positive coordinations.

The centre of gravity coordinates of the fuselage masses are determined by formula and the results are presented in the table 1.5:

$$X_f = \frac{\Sigma m_i' X_i'}{\Sigma m_i'};$$

After the determination of the centre of gravity of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively to the fuselage nose:

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

From the formula we could determine the wing mean aerodynamic leading edge position relative to fuselage nose, it means X_{MAC} value by formula:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w} = 15.24 \text{ m}$$

Table 1.5 - Trim sheet of equipped fuselage masses

Objects names	Mass		C.G coordinates Xi, m	Mass moment
	Units	Total mass		
Fuselage	0.1240	4269.21	16	68307.36
Horizontal tail	0.0165	569.34	30.6	17421.89
Vertical tail	0.0163	561.08	30.2	16944.51
Radar	0.0036	123.99	0.5	62.00
Radio equipment	0.0027	93.00	0.8	74.40
Instrument panel	0.0062	213.55	1	213.55
Aero navigation equipment	0.0053	182.55	1.5	273.82
Flight control system 70%	0.0061	209.76	12	2517.09
Hydraulic system 30%	0.0066	228.36	16	3653.71
Electrical equipment 90%	0.0306	1053.96	10	10539.56
Additional eguipment	0.0028	96.44	3	289.32
Lining and insulation	0.0116	399.54	14	5593.54
Anti ice system, 20%	0.0049	168.08	25	4202.05
Airconditioning system, 40%	0.0098	336.16	15	5042.46
Passenger seats	0.0178	612.00	13.8	8445.60
Seats of flight attendence	0.0002	8.00	4.5	36.00
Seats of pilot	0.0009	30.00	2.8	84.00
Emergency equipment	0.0001	28.00	6	168.00
Lavatory, galley	0.0057	60.00	23.5	1410.00
Operational items	0.0176	606.54	27	16376.61
Equipped fuselage without payload	0.2892	9849.55	16.41247	161655.46
Passengers(economy)	0.1788	6160.00	13.8	85008.00
On board meal	0.0038	132.00	23.5	3102.00
Baggage	0.0511	1760.00	26	45760.00
Cargo, mail	0.0000	0.00	26	0.00
Flight attend	0.0035	120.00	4.5	540.00
Crew	0.0044	150.00	2.8	420.00
TOTAL	0.5309	18171.55	16.32	296485.46

The list of all object's masses from the wing and from the fuselage for the center of gravity calculation are given in table 1.6 and center of gravity calculation variants for different load cases are presented in the table 1.7.

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

Name of the object	Mass, m_i kg	Coordinate X_i, м	Mass moment, kgm
Equipped wing (without fuel and landing gear)	9292.38	15.3	142053
Nose landing gear (extended)	227.94	5.8	1319
Main landing gear (extended)	1291.68	17.1	22073
Reserve fuel	1224.79	16.7	20394
Fuel for flight	4187.58	16.7	69729
Equipped fuselage (without payload)	9849.55	16.4	161655
Passengers	6160	13.8	85008
On board meal	132	23.5	3102
Baggage	1760	26	45760
Cargo, mail	0	26	0
Flight attend	120	4.5	540
Crew	150	2.8	420
Nose landing gear (retracted)	227.94	3.3	750
Main landing gear (retracted)	1291.68	17.1	22073

Table 1.7 – Aircraft center of gravity position variants

Name	Mass m_i kg	Mass moment	Center of mass	Centre of gravity position
Take off mass (L.G. extended)	34395.93	552054.10	16.05	0.241
Take off mass (L.G. retracted)	34395.93	551484.24	16.03	0.2363
Landing weight (LG extended)	30208.35	482325.32	15.97	0.2164
Ferry version	26073.93	417074.24	16.00	0.2251
Parking version	21886.35	347495.32	15.88	0.1898

Conclusions to the part

In this work a preliminary design of a short-range aircraft for 80 passengers was made, taking as a the regional aircraft of Japanese production as a prototype, which is still undergoing on flight tests. The design of a low-level wing with a sweep angle of 27 degrees is accepted.

The layout of the fuselage is completely in economy class with spacious hand baggage, but much more convenient than other aircraft with economy class. The main cargo compartment is in the tail and not under the passenger deck, as in the most aircraft. This allows to place more fuel, and develop a version of the aircraft for medium range. The tricycle landing gear is taken for the aircraft. The new turbofan engines Pratt & Whitney 1217G with thrust in 78 kN are chosen for the designing aircraft.

The centre of gravity calculation was performed for some loading cases. The most forward c.g. position is 0,19 and the most aft c.g. position is 0,24.

2. CONCEPTUAL DESIGN OF THE PASSENGER SEAT CUSHION ADJUSTMENT

2.1. Requirements of the passenger seat

The seat design process of the passenger seat usually includes the following stages:

- the construction and development of the seats meet the requirements to the geometric parameters and safety;

- the block of seats has to be subjected to the static and dynamic tests to prove the strength of seat and device, to check the strength of the attachments of the seats to the floor at the emergency conditions;

- experimental tests of the material flammability and toxic.

As a result of such “crash” tests, the head injury criteria (HIC) has to be evaluated and manufacturer has to obtain approval documents for the equipment on aircraft.

Seat is exposed to two types of loads during the flight. The first is static load, this loads acts on the seat and device are not allowed to exceed the yield strength of the material. Under the load below yield strength, all structural members of the structure work in the elastic deformation zone with no plastic deformation after unloading.

The specified load factors in all directions according to FAR 25 are as follows: forward – 3g; side – 4g; up – 3g; down – 6g; back – 2.5g.

The other type of load is the dynamic load (HIC test).

Since the maximum equivalent stress generated by the structure in the design must not exceed the tensile strength of the material, there should be no damage to the material or failure of the structure under dynamic load.

The main requirement of the Federal Aviation Regulations (FAR) to passenger seat is – each seat can provide protection to the passenger during air crash, which requires seats to pass the load factor test: static load factor - 9g; dynamic load factor - 16g.

Seat material must be flame-retardant which can avoid excess damage to passenger due to seat on fire. And it required to provide guidance material for demonstrating compliance with the Federal Aviation Regulations (FAR) pertaining to flammability of aircraft seat cushion.

2.2 Design of the passenger seat device

Office of the Auditor of the Commission (OCA) conducted research on the placement of passengers on commercial flights as for seat pitch, seat size and legroom; and how they affect the comfort, health of passengers, and safety, or more precisely, whether some of these studies support seats of a certain size passengers. The main criteria is the tilt of the seat back, seat size and legroom volume for the accommodation of passengers. The more volume and the sixe of the seat, the more legroom it increases conviences for the health and safety of passengers.

Shrinking aircraft accommodations in commercial airlines has been part of the national conversation for decades. The main issue being discussed stems from customer perception that the airline industry has been reducing seat pitch, seat size and legroom in order to add more seats and passenger capacity, which has conveyed the impression over time that airlines have lowered passengers' comfort and may have contributed to health and safety concerns during flights. Changes to passengers’ accommodation started after the deregulation of the airline industry by Congress in 1978.

It also gave airlines more considerable latitude in the way they manage cabin space in the pursuit of profitability. As a result, in their efforts to make the most efficient ergonomic use of cabin space, some airlines have reduced seat pitch (the distance between one point of a seat to the same point in the seat in front of it) from 34/35 inches to 30/31 inches, and as low as 28 inches on some domestic flights depending on the type of airline and the fare class purchased, which has prompted concerns of comfort, health, and safety for passengers from consumer advocates and others.

Figure 2.1 shows the difference between the minimum seat pitch and the standard for economy class approved in this case. You can see that at 28 inches the legs are almost pinched, and for tall people this is a big problem.

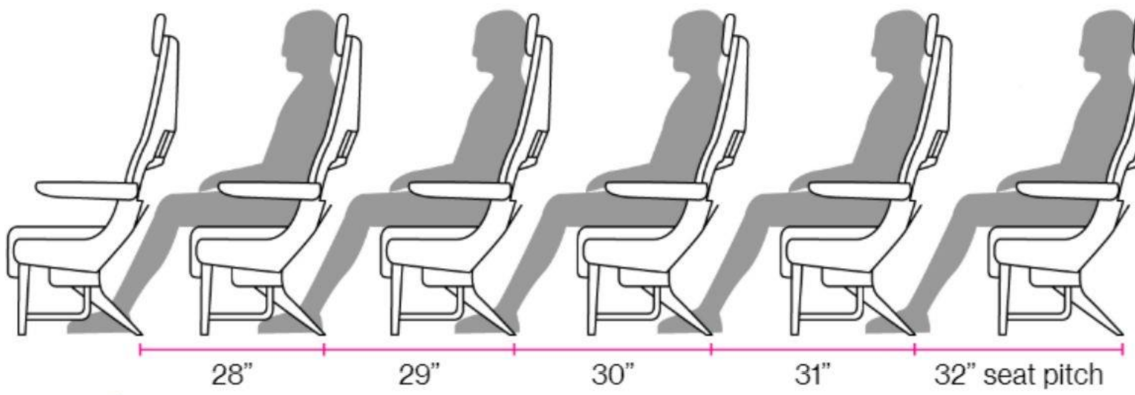

Figure 2.1 – Seat pitch from 28 to 32

At the core of the issue of passengers’ seating accommodation, is the topic of passenger seating configurations, which involves considerations for seat width, padding, reclining, pitch, legroom and aisle width as they relate to anthropometry – the scientific study of the measurements and proportions of the human body. Depending on how the airlines adjust these factors in seat design, passengers might end up with less or more space for comfort. Congress took on the airlines practice of reduced aircraft accommodation a few years ago; and consequently, in its Federal Aviation Authority (FAA) Reauthorization Act of 2018, it mandated the FAA to, among other things, issue within one year, a rule that sets minimum standards for airline seat pitch, seat size and legroom (the distance from the middle point of a seat cushion to the furthest point on the back of the seat in front of it) while simultaneously ordering a study of plane evacuations, including the effect seat size and legroom have on emergency evacuations.

To compare passengers' comfort, health, and safety with the need to carry the maximum number of passengers to ensure profitability will require the airline industry to find the optimal balance. Although some passengers can afford to pay for the more spacious seats that fulfill their comfort, safety, and health needs, that does not preclude the need for a minimum standard for seat pitch, seat size, and legroom since more passengers fly low-class carriers due to the affordability. Although the studies reviewed did not finalize any experiment into a specific level of seat pitch, seat size, and legroom that leads to increased health and safety, this concern cannot be dismissed entirely since at least one expert warns that a shrinking seat pitch below 30 inches is dangerous.

As shown in figure 2.2 , the seat pitch is 870 cm, which is equivalent to 34.5 inches. Some will say that it is a luxury for economy class, but it consider as necessity.

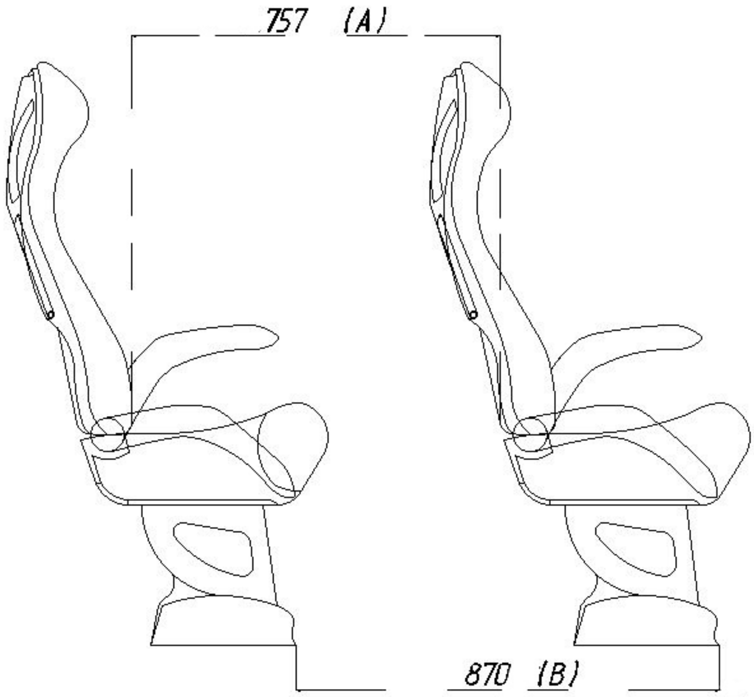

Figure 2.2 – Seat pitch (B) and legroom (A)

But this is not the only difference from standard passenger seats. Common here are a table behind the reclining chair, a footrest that folds under the bottom of the chair, and the back of the chair that tilts (figure 2.3), armrests are also standard, but only at the edges, between the seats they are connected (paired), and are one whole. This allows electronics to be installed so that passengers can charge their gadgets, because sometimes people stay at airports for a long time and phones can be quickly discharged, and when they get on a plane, they can recharge it. In the future, it will be possible to add a control panel to the device in the paired armrest, but this will require the addition of an electric motor, currently the mechanism controlled manually.

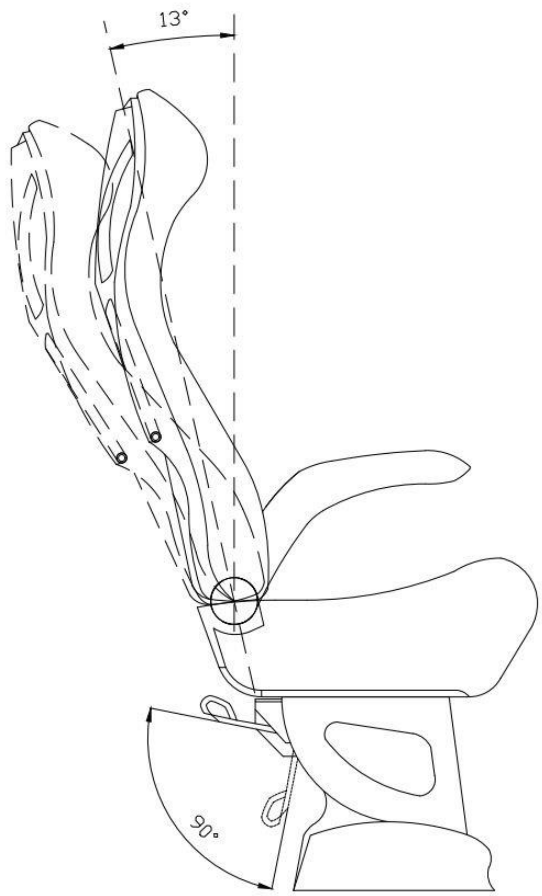

Figure 2.3 – Adjustable angle of the seat back.

As mentioned earlier, not everyone can withstand even short flights. Take myself, for example, in a short life It manage to get a lot of professional injuries that have changed skeleton, and can not physically sit still, even in a perfect chair for more than 10 minutes. But standing by plane during flight, unfortunately, too dangerous. Because I am sure that I am not the only one with such defects, so my device is made in the first place for such people.

What is this miracle device, which I called "mechanized ottoman". Thanks to this mechanism, the passenger will be able to completely change the configuration of seat bottom cushion. This design has two components: the first - the lever system, on which there are little pillows for support seats covering; the second component - is the gear mechanism to increase torque and reduce the load on the lever. In order to change the configuration of the chair, you need to turn the wheel under the thigh. Some will say that a similar feature is in the pilot's seat, but in fact it is a completely different device. If in the pilot's seat you can change only the seat angle of the thigh support, then in my seat changes not the angle but the height of the support, thus allowing you to take any position (figure 2.4)

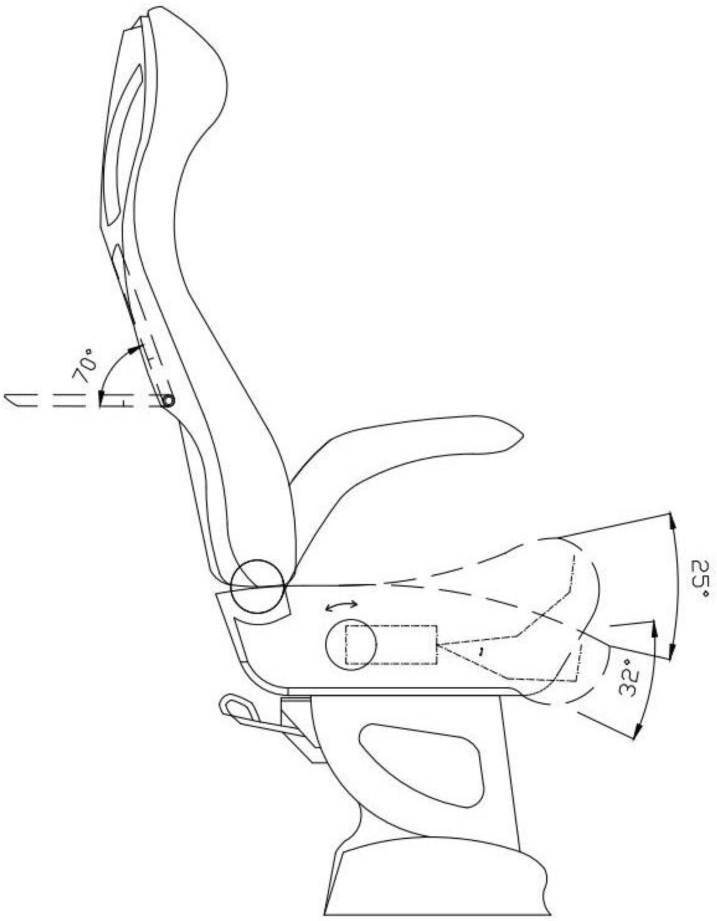

Figure 2.4 – The principle of operation of the mechanism

The original box with gears is quite small and takes 12x5x4 cm. There are 5 pairs in it. In this work chose straight gears with parallel axes (figure 2.5) because they have the following advantages: stability and a fairly wide range of gear ratios, high reliability, durability, compactness, wide load range, low loads on shafts and supports, can be conveniently arranged in separate units.

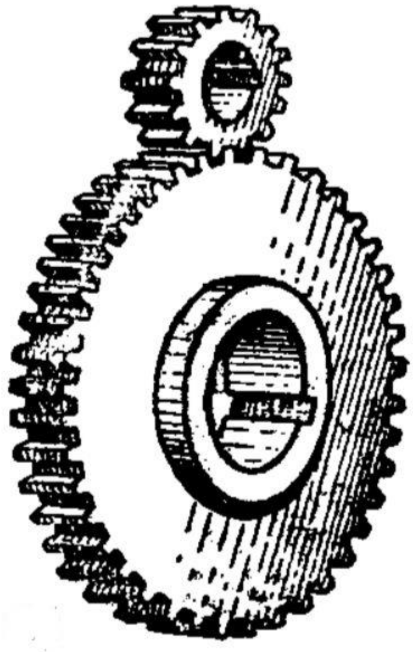

Figure 2.5 – Cylindrical gears

Carbon steels 40, 45 with heat treatment H <350 HB are suitable for their production. This will ensure sufficient accuracy, good efficiency, no need for expensive finishing operations. The hardness of the gear is greater than the hardness of the wheel ($H_1 = H_2 + (25...30)$ HB). In this case, the wheels work better. Usage: individual and small-scale production, small and medium-sized transmissions.

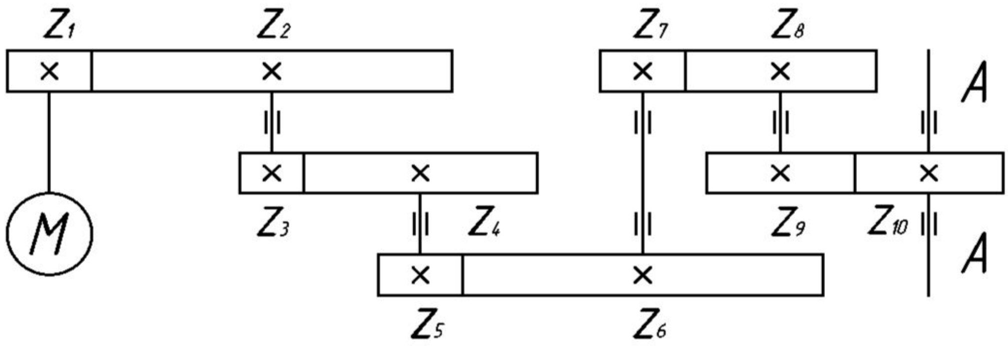

Figure 2.6 – Top view of gear mechanism:
M – input moment, z_1, z_5, z_7 – 12 teeth, z_2, z_6 – 36 teeth, z_3 – 8 teeth,
z_4 –special safe gear with 24 teeth, z_8 – 20 teeth, z_9, z_{10} – 14 teeth, A- lever.

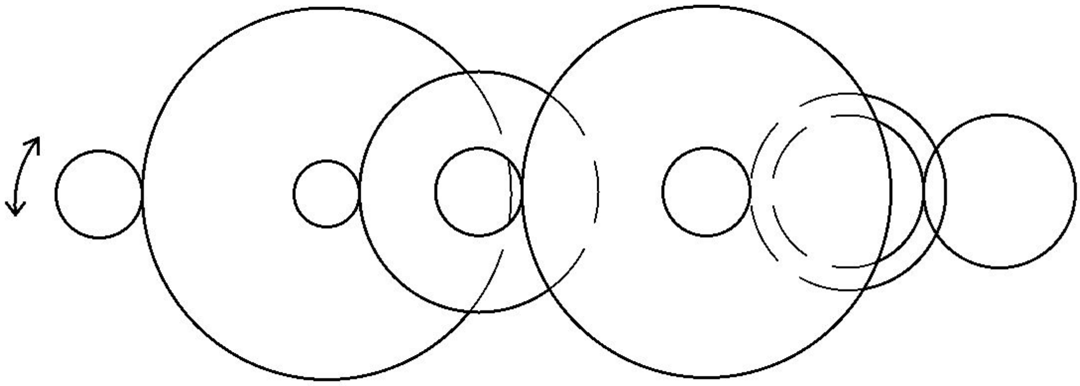

Figure 2.7 – Side view of gear mechanism

Some pairs have the same gear ratio (3:1), but have different gears, this was done so that the axes were at a sufficient distance from each other, but if you replace large gears with smaller ones, there will be an overlay and the axles will not fit.

As for the unique safety gear (figure 2.8), it goes in the second pair and has an internal clutch. It is set so that when the lever reaches the limit in space, and the load on gear that will continue to go does not break either the lever or the gear. This way clutch inside in gear will just scroll without moving the gear. It remains to calculate the output force, and put the coupling less than this force.

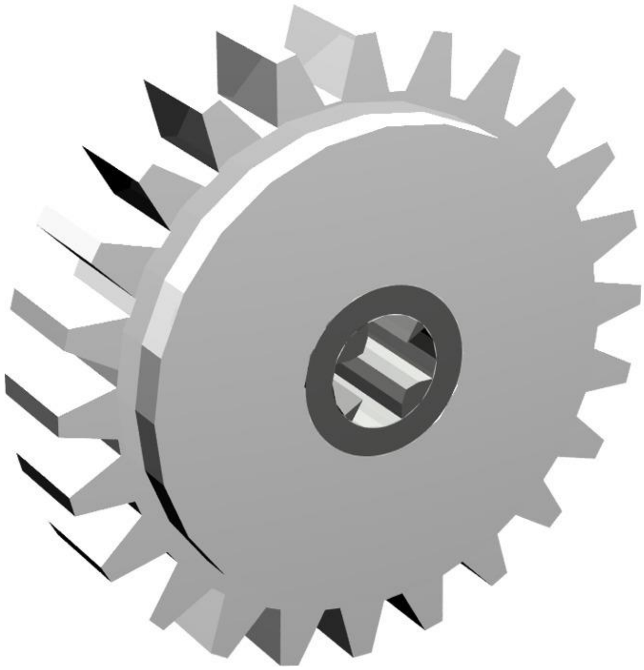

Figure 2.8 – Safe gear with internal clutch

Now let's move on to the second part of the device design - the lever system of kinematic chain (figure 2.9). It has 3 ground point and 7 links, namely a crank and a rocker joint.

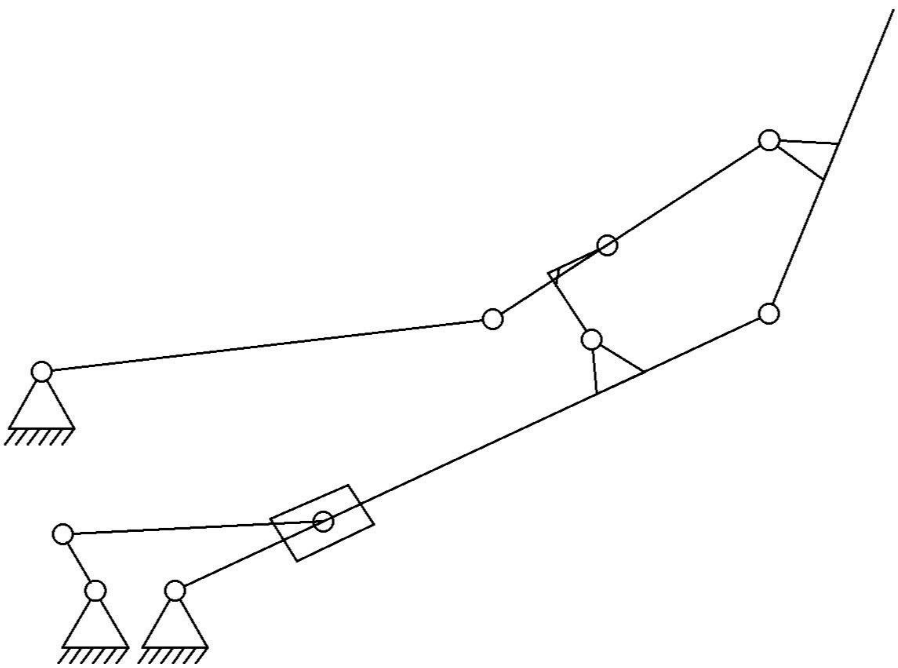

Figure 2.9 – Lever system

The mechanism consists mainly of the 2nd and 3rd class RRR, RTR of the kinematic link (figure 2.10)

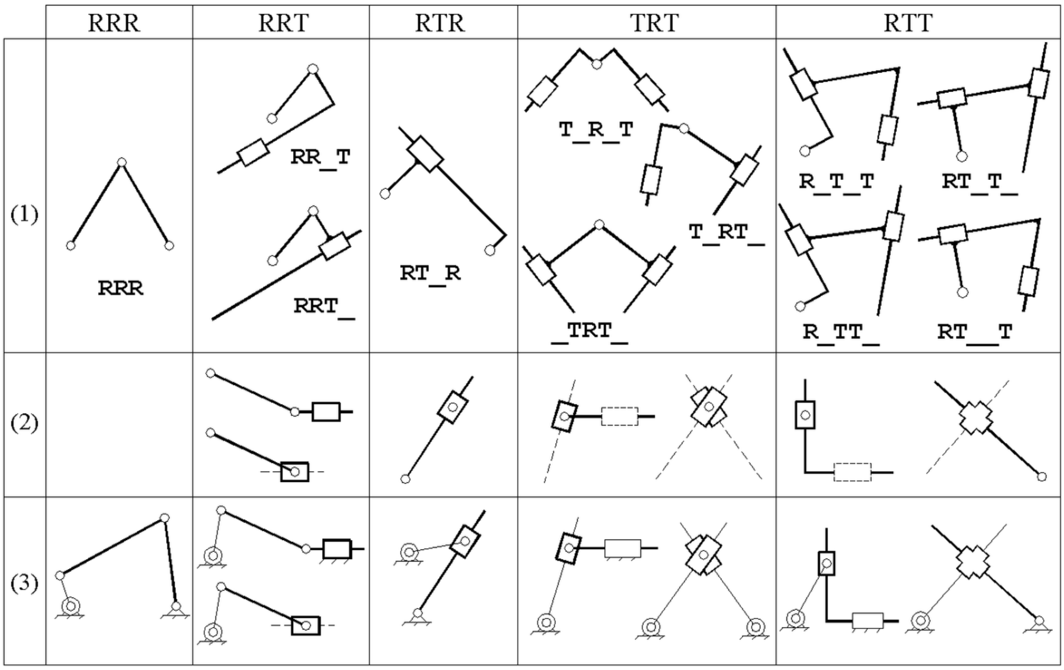

Figure 2.10 – Types of kinematic link

It may seem that the mechanism looks complicated and unreliable, and that it can break with unconsiderable g loads. But in fact, for a long time the aircraft uses a larger mechanism with the same principle of operation, namely the main landing gear. Since my mechanism is much smaller than the main chassis and weighs no more than 3 kg maximum, it must withstand testing for different types of loads.

2.3 Analysis of the components for the device

The aircraft has 80 passenger seats (n). With a maximum weight of 3 kg, we can determine how much the weight of the aircraft will increase:

$$W_m = n * 3$$

$$W_m = 80 * 3 = 240kg$$

This is the weight we can afford.

Basic parameters of involute engagement are shown on Figure 2.11.

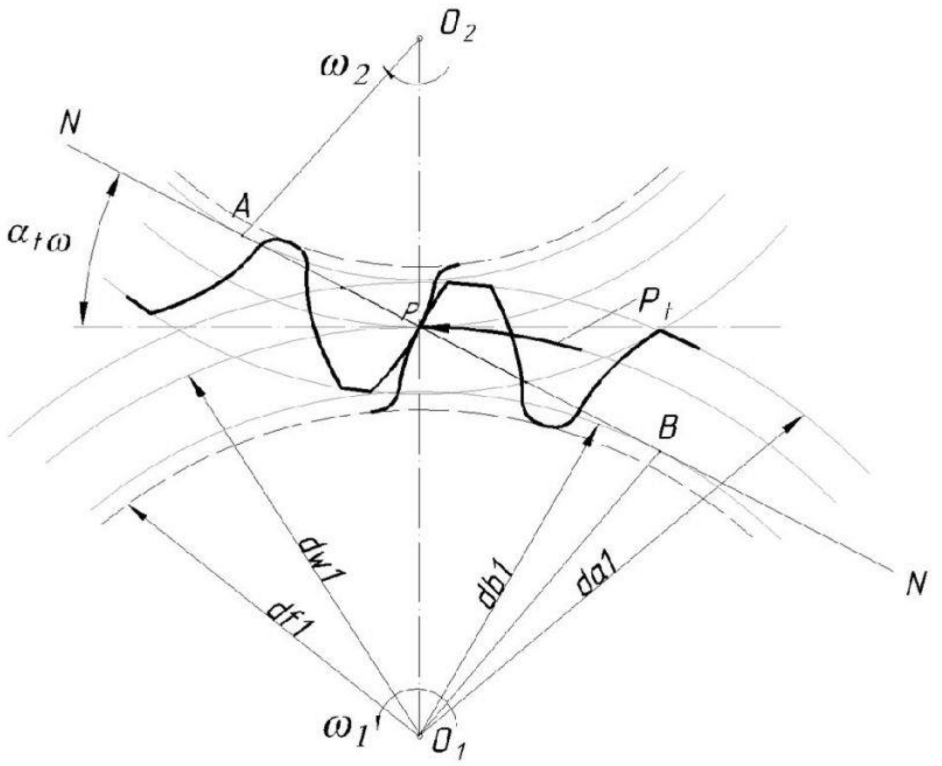

Fig 2.11 – O_1 – gear, O_2 – wheel

Where:

d_{b1}, d_{b2} - diameters of the main circles;

NN - reproducing; when moving on the main circles so *P* describes the involute;

P – gear pole – point of intersection *NN* and lines of centers O_1O_2;

AP and *BP* – radius of curvature involute in R;

NN – common normal to involute. The points of contact of the teeth of the wheels lie on the line *NN*, so *NN* – gear line;

α_{tw} - engagement angle;

d_{w1} d_{w2} − diameters of the initial circles. The initial circles roll one by one without slipping;

Gear ratio $i = \omega_1 / \omega_2 = d_{w1}/d_{w2}$;

d_1, d_2, - diameters of dividing circles. The dividing circle divides the tooth into two parts - the head and the leg. In wheels cut without offsetting the tool, $d_1 = d_{w1}$, $d_{b2} = d_{w2}$;

d_{a1}, d_{a2} - diameters of tooth vertices;

d_{f1}, d_{f2} - diameter of depressions.

The gear ration could be find by the next formular:

$$Gear\ ratio = \frac{teeth\ of\ driven\ gear}{teeth\ of\ driver\ gear} = \frac{z_2}{z_1} * \frac{z_4}{z_3} * \frac{z_6}{z_5} * \frac{z_8}{z_7} * \frac{z_{10}}{z_9}$$

$$Gear\ ratio\ = \frac{36}{12} * \frac{24}{8} * \frac{36}{12} * \frac{20}{12} * \frac{14}{14} = 45$$

So in output point we have moment 45:1. This means that even a child can easily turn the wheel to lift a person over 100 kg

Perform a strength calculation for steel 45 with H <350 HB.

Check the operating contact tension for first pair at:

$$b=0, \quad Z_H=1.76, \quad Z_M=2.74*10^3\ Pa$$

$$Ea = \left|1.88 - 3.2 * \left(\frac{1}{Z_1} + \frac{1}{Z_2}\right)\right| * cosB = \left|1.88 - 3.2 * \left(\frac{1}{12} + \frac{1}{36}\right)\right| * cos0$$
$$= 1.52 * 1 = 1.52$$

$$\text{Zr} = \sqrt{\frac{(4 - Ea)}{3}} = \sqrt{\frac{(4 - 1.52)}{3}} = 0.91$$

0.91<1. So, this gear is suitable for use.

Conclusions to the part

The special part of the diploma work presents the conceptual design of the mechanism for the passenger seat control. The position of the thigh pad of the seat cusion culd be operated by the special adjustment. The structure of the mechanism is the box with gears in the seat base, and kinematic chains to the mmechanized ottoman. The principle of operation of the device and its design are briefly described. Carbon steel 45 was taken as a material for the gears. The gear ratio 45:1 has a high efficiency, which has a positive effect on the operation of the mechanism.

Proposed design of the seat adjustment could provide more comfortable position of legs in legroom, and it has positive effect on blood circulation.

GENERAL CONCLUSIONS

The main task of the diploma was a sketch design of a short-range aircraft with 80 passenger capacity. The main prototype is Mitsubishi Regional Jet 90.

All geometric parameters for designing aircraft are calculated, such as geometry of the wing, the layout of the fuselage, the design of the tail unit, the design of landing gear. The Pratt & Whitney 1217 G turbofan engine is chosen.

The range of the center of gravity position under different loading conditions was estimated (for takeoff case, for landing case and case for the maximum flight range with maximum payload and without payload).

Finally, the conceptual seat device was developed to provide the maximum comfort of all passengers, regardless of their preferences.

In the future, the more convenient seats can increase the comfort for long range flight of the aircraft. The presented engineering device could be modified by the input an electric motor in the seat to control the settings of the seat from the control panel on the side.

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Performed by:
Supervisor:

PRELIMINARY DESIGN OF THE AIRCRAFT
The main prototype is Mitsubish Regional Jet(MRJ)90

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	80.
Flight Crew Number	2.
Flight Attendant or Load Master Number	2.
Mass of Operational Items	606.45 kg.
Payload Mass	8360.00 kg.
Cruising Speed	830. km/h
Cruising Mach Number	0.7803
Design Altitude	11.90 km.
Flight Range with Maximum Payload	1780. km.
Runway Length for the Base Aerodrome	1.90 km.
Engine Number	2.
Thrust-to-weight Ratio in N/kg	3.3
Pressure Ratio	32.00
Assumed Bypass Ratio	9.00
Optimal Bypass Ratio	9.00
Fuel-to-weight Ratio	0.2400
Aspect Ratio	9.3
Taper Ratio	4.16
Mean Thickness Ratio	0.118
Wing Sweepback at Quarter Chord	27. degrees.
High-lift Device Coefficient	0.580
Relative Area of Wing Extensions	0.000

Wing Airfoil Type – supercritical
Winglets – не применяются
Spoilers - установлены

Fuselage Diameter	3.00 м.
Finess Ratio	11.00
Horizontal Tail Sweep Angle	30.0 degrees.
Vertical Tail Sweep Angle	35.0 degrees.

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	Cy	0.42483
Induce Drag Coefficient	Cx.	0.00911

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

Cruising Mach Number	0.78026
Wave Drag Mach Number	0.78629
Calculated Parameter D_m	0.00603

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	3.900
At Middle of Cruising Flight	3.575
At the Beginning of Cruising Flight	3.750

Drag Coefficient of the Fuselage and Nacelles	0.00961
Drag Coefficient of the Wing and Tail Unit	0.00913

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.02923

At Middle of Cruising Flight		0.02879
Mean Lift Coefficient for the Ceiling Flight		0.42483
Mean Lift-to-drag Ratio		14.75721
Landing Lift Coefficient		1.269
Landing Lift Coefficient (at Stall Speed)		1.904
Takeoff Lift Coefficient (at Stall Speed)		1.692
Lift-off Lift Coefficient		1.236
Thrust-to-weight Ratio at the Beginning of Cruising Flight		0.656
Start Thrust-to-weight Ratio for Cruising Flight		3.078
Start Thrust-to-weight Ratio for Safe Takeoff		3.447
Design Thrust-to-weight Ratio	Ro	3.622
Ratio $D_r = R_{cruise} / R_{takeoff}$	Dr	0.893

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

Takeoff	35.4243
Cruising Flight	56.8167
Mean cruising for Given Range	58.3111

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03556
Block Fuel	0.12158

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12587
Horizontal Tail	0.01653
Vertical Tail	0.01629
Landing Gear	0.04412
Power Plant	0.10818
Fuselage	0.12395
Equipment and Flight Control	0.14472
Additional Equipment	0.00280
Operational Items	0.01761
Fuel	0.15715
Payload	0.24272

Airplane Takeoff Weight = 34443. kg.
Takeoff Thrust Required of the Engine 62.34 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0244
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0190
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0116
Furnishing Equipment Weight Fraction	0.0057
Flight Control Weight Fraction	0.0087
Hydraulic System Weight Fraction	0.0221
Electrical Equipment Weight Fraction	0.0340
Radar Weight Fraction	0.0036
Navigation Equipment Weight Fraction	0.0053
Radio Communication Equipment Weight Fraction	0.0027
Instrument Equipment Weight Fraction	0.0062
Fuel System Weight Fraction	0.0045

Additional Equipment:

Equipment for Container Loading	0.0000
No typical Equipment Weight Fraction (Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0028

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	255.80 km/h
Acceleration during Takeoff Run	3.08 m/s*s
Airplane Takeoff Run Distance	816 m
Airborne Takeoff Distance	578 m
Takeoff Distance	1395 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	243.01 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.70 m/s*s
Takeoff Run Distance for Continued Takeoff on Wet Runway	1086.02 m
Continued Takeoff Distance	1663.4 m
Runway Length Required for Rejected Takeoff	1721.75 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	31778. kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	22.6 min.
Descent Distance	52.09 km.
Approach Speed	260.61 km/h
Mean Vertical Speed	2.08 m/s
Airborne Landing Distance	521 m
Landing Speed	245.61 km/чh
Landing run distance	849. m
Landing Distance	1370. m
Runway Length Required for Regular Aerodrome	2288. m
Runway Length Required for Alternate Aerodrome	1945.m

ECONOMICAL EFFICIENCY

THESE PARAMETERS ARE NOT USED IN THE PROJECT