МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
Національний авіаційний університет
Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, д.т.н., проф.
___________ Сергій ІГНАТОВИЧ
«___» ____________ 2023 р.

КВАЛІФІКАЦІЙНА РОБОТА

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ

«БАКАЛАВР»

Тема: «Аванпроект середньомагістрального літака пасажиромісткістю 80 чоловік»

Виконав:	__________	**Назарій ТКАЧЕНКО**
Керівник: к.т.н., доц.	__________	**Тетяна МАСЛАК**
Нормоконтролер: к.т.н., доц.	__________	**Володимир КРАСНОПОЛЬСЬКИЙ**

Київ 2023

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aviation University
Department of Aircraft Design

PERMISSION TO DEFEND
Head of the department,
Professor, Dr. of Sc.
_________ Sergiy IGNATOVYCH
"___" ____________ 2023

BACHELOR DEGREE THESIS

Topic: "Preliminary Design of a Mid-Range Aircraft with 80 Passenger Capacity"

Fulfilled by: ____________ **Nazarii TKACHENKO**

Supervisor:
PhD, associate professor ____________ **Tetiana MASLAK**

Standards inspector
PhD, associate professor ____________ **Volodymyr KRASNOPOLSKYI**

Kyiv 2023

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
«___» ____________ 2023 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

ТКАЧЕНКА НАЗАРІЯ РОСТИСЛАВОВИЧА

1. Тема роботи: «Аванпроект середньомагістрального літака пасажиромісткістю 80 чоловік», затверджена наказом ректора від 1 травня 2023 року № 624/ст.

2. Термін виконання роботи: з 29 травня 2023 р. по 25 червня 2023 р.

3. Вихідні дані до роботи: максимальна кількість пасажирів 80, дальність польоту з максимальним комерційним навантаженням 3400 км, крейсерська швидкість польоту 850 км/год, висота польоту 10.5 км.

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

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

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	29.05.2023 – 31.05.2023	
2	Вибір та розрахунок параметрів проєктованого літака.	01.06.2023 – 03.06.2023	
3	Виконання компонування літака та розрахунок його центрування.	04.06.2023 – 05.06.2023	
4	Розробка креслень по основній частині дипломної роботи.	06.06.2023 – 07.06.2023	
5	Огляд літератури за проблематикою роботи.	08.06.2023 – 09.06.2023	
6	Розробка креслень по спеціальній частині дипломної роботи.	10.06.2023 – 11.06.2023	
7	Оформлення пояснювальної записки та графічної частини роботи.	12.06.2023 – 14.06.2023	
8	Подача роботи для перевірки на плагіат.	15.06.2023 – 18.06.2023	
9	Попередній захист кваліфікаційної роботи.	19.06.2023	
10	Виправлення зауважень. Підготовка супровідних документів та презентації доповіді.	20.06.2023 – 22.06.2023	
11	Захист дипломної роботи.	23.06.2023 – 25.06.2023	

7. Дата видачі завдання: 29 травня 2023 року

Керівник кваліфікаційної роботи ____________ Тетяна МАСЛАК

Завдання прийняв до виконання ____________ Назарій ТКАЧЕНКО

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of Aircraft Design
Educational Degree "Bachelor"
Specialty 134 "Aviation and Aerospace Technologies"
Educational Professional Program "Aircraft Equipment"

APPROVED BY
Head of Department,
Professor Dr. of Sc.
________ Sergiy IGNATOVYCH
«___» ____________ 2023

TASK

for the bachelor degree thesis

Nazarii TKACHENKO

1. Topic: "Preliminary design of a mid-range aircraft with 80 passenger capacity", approved by the Rector's order № 624/ст from 1 May 2023.
2. Period of work: since 29 May 2023 till 25 June 2023.
3. Initial data: cruise speed V_{cr}=850 kmph, flight range L=3400 km, operating altitude H_{op}=10.5 km, 80 passengers.
4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, a special part that contains the design of a personal place for hand luggage.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), design of adjustable headrest (A1×1).

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	29.05.2023 – 31.05.2023	
2	Selection and calculation of the aircraft designed parameters.	01.06.2023 – 03.06.2023	
3	Performing of aircraft layout and centering calculation.	04.06.2023 – 05.06.2023	
4	Development of drawings on the thesis main part.	06.06.2023 – 07.06.2023	
5	Review of the literature on the problems of the work.	08.06.2023 – 09.06.2023	
6	Development of drawings for a special part of the thesis.	10.06.2023 – 11.06.2023	
7	Explanatory note checking, editing, preparation of the diploma work graphic part.	12.06.2023 – 14.06.2023	
8	Submission of the work to plagiarism check.	15.06.2023 – 18.06.2023	
9	Preliminary defense of the thesis.	19.06.2023	
10	Making corrections, preparation of documentation and presentation.	20.06.2023 – 22.06.2023	
11	Defense of the diploma work.	23.06.2023 – 25.06.2023	

7. Date of the task issue: 29 May 2023

Supervisor: ___________ Tetiana MASLAK

Student: ___________ Nazarii TKACHENKO

РЕФЕРАТ

Кваліфікаційна робота «Аванпроект середньомагістрального літака пасажиромісткістю 80 чоловік»:

46 с., 1 рис., 6 табл., 13 джерел

Дана кваліфікаційна робота присвячена проектуванню середньомагістрального пасажирського літака для перевезення 80 осіб з можливістю регулювання підголовника в пасажирському сидінні.

В роботі застосовано метод порівняльного аналізу літаків-прототипів для вибору найбільш обґрунтованих параметрів проектованого літака, а також методи інженерних розрахунків для отримання основних геометричних та компонувальних параметрів проектованого літака, визначення основних технічних рішень. В спеціальній частині необхідно зробити концепцію регульованого підголовника в пасажирському сидінні.

Актуальність роботи полягає у підвищенні комфорту пасажирів, а саме спроектований регульований підголовник забезпечить більший комфорт під час польоту, що зменшить неприємні відчуття від довгого сидячого положення.

Практичне значення дипломної роботи полягає в підвищенні комфорту та ефективності пасажирських перевезень. Представлені результати роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

Кваліфікаційна робота, аванпроект літака, компонування пасажирської кабіни, центрування літака, регульвоний підголовник

ABSTRACT

Bachelor degree thesis "Preliminary design of a mid-range aircraft with 80 passenger capacity"

46 pages, 1 figure, 6 tabels, 13 references

The bachelor degree thesis presents a preliminary design of a mid-range aircraft that can transport 80 passengers with the possibility of adjusting the headrest in the passenger seat.

The design methodology relies on the analysis of prototypes, advanced technical solutions and engineering calculations to obtain the technical specifications of the aircraft. In a special part, it is necessary to make the concept of an adjustable headrest in the passenger seat.

The relevance of the work is to increase the comfort of passengers, namely the designed adjustable headrest will provide greater comfort during the flight, which will reduce unpleasant sensations from a long sitting position.

The practical results of the work include the improvement of passenger comfort and transportation efficiency. The work can be applied in the aviation industry and in the education of aviation specialties.

Bachelor degree thesis, prelimininary design of the aircraft, passenger cabin layout, center of gravity position, adjustable headrest

1. ANALYSIS OF PROTOTYPES

The designed airplane is a narrow-body twinengine turboprop midrange airliner. The aircraft is a lowwing airplane intended for flights on mediumhaul routes.

1.1 Choice of the projected data

The location of the aircraft is determined by the location, number and shape of its components. The aerodynamic, technical, and operational properties of an aircraft depend on its design and aerodynamic layout. A welldesigned layout can improve flight safety, regularity, and cost-effectiveness.

The proposed aircraft is made according to the scheme of the low location of the wing, which is the least favorable from the point of view of aerodynamics and layout due to the violation of smoothness of the flow and increased resistance at the junction of the wing with the fuselage. However, this disadvantage can be reduced by adding fairings to create a diffuser effect. From a layout perspective, the low-wing design results in the lower fuselage contour being higher above the ground, making it difficult to load and unload cargo and passengers. This design is necessary so that when landing with a roll, the wing tip does not touch the surface of the runway.

The aircraft has a three-wheel stable chassis with a nose support, which provides high stability during take-off and landing, good controllability on the ground, and effective braking due to the absence of a hood. The horizontal position of the longitudinal axis of the aircraft during parking and movement on the airfield improves the visibility of the pilot and the comfort of passengers. The three-support scheme of the landing gear with the nose leg allows for easier takeoff and landing in crosswind conditions if all three landing gear is self-orienting and equipped with self-oscillation dampers.

As a design basis, I will take a prototype of the aircraft such as Fokker70, MRJ90, ERJ175. On the basis of these aircraft, I will try to create a competitive aircraft. Statistic data of prototypes are presented in table 1.1.

Table 1.1

Operational-technical data of prototypes

Parameter	Planes		
	MRJ-90	ERJ-175	Fokker-70
The purpose of airplane	Passenger	Passenger	Passenger
Crew / flight attendance	2/2	2/2	2/2
Maximum take-off weight, kg	42800	40370	43588
Maxinum payload, kg	11650	10094	7920 kg
Passengers	88	88	80
The altitude of flight, m	11900	11500	10500
Flight range, km	3770	4074	3400 km
Take off distance, m	1740	2244	1028 m
Number and type of engines	2×PW1217G	2×GE CF34-8E	2×RRRB.183
Fuselage cross-section	circular	double-bubble	circular
Sweepback on 1/4 chord, °	28	28	28

1.2 Brief description of the main parts of the aircraft

1.2.1 Fuselage

One of the main advantages of modern aircraft is the way parts are manufactured. In the design of the aircraft, composite materials and strong light metal alloys are used. Composite materials have a number of advantages, such as: weight, strength, cost of components, etc.

1.2.2 Wing

My airplane's wing has a supercritical airfoil. The plane uses a lowwing. The use of a supercritical wing profile has a number of advantages such as:

Increased lift the aircraft can generate more lift and potentially carry more weight.

Reducing the noise level the planar contour of the supercritical profile reduces the noise level created by the aircraft, which will have a positive effect on passengers and people living near airports.

Higher cruising speed the supercritical airfoil creates shock waves further than traditional airfoils.

Improved stability a supercritical airfoil can improve the stability of the aircraft, which can improve handling in flight.

1.2.3 Tail unit

The tail unit is an important component of the aircraft structure. It is located at the rear of the aircraft and performs numerous functions that contribute to the stability and control of the aircraft during flight. Tail feathers consist of the following parts: horizontal stabilizer, elevator, vertical stabilizer, rudder. The tail unit plays a crucial role in maintaining the aircraft's stability, maneuverability, and control during various flight phases, including takeoff, climb, cruise, descent, and landing. It works in conjunction with other control surfaces, such as the ailerons and flaps, to ensure safe and precise flight operations.

1.2.4 Crew cabin

The cockpit is located in the forward part of the fuselage, in the middle it is equipped with advanced technologies, advanced avionics, flight controls, digital displays, autopilot and flight control system. There are all amenities for pilots, comfortable seats, an excellent air conditioning system, good visibility, low noise level.

1.2.5 Landing gear

The landing gear consists of three pairs of wheels, two main landing gear located under the wings and a nose landing gear located under the cockpit. The main landing gear rack is designed for take-off and landing and during ground operations. The nose landing gear is used to control the aircraft on the ground, supports the weight of the front part of the aircraft. the main landing gear rack is designed for take-off and landing and during ground operations. The chassis system is equipped with a hydraulic system that activates the extension or folding of the chassis during takeoff or landing.

Conclusions to the analytical part

In this section, I selected prototypes for aircraft design such as MRJ90, ERJ-175, Fokker70, and added a small description of each of the selected prototypes. Based on the prototypes I selected, I described the design of the aircraft, which is a low-wing monoplane equipped with two turbofan engines. I also added a small description of such parts as fuselage, wing, tail unit, crew cabin, landing gear.

2. PRELIMINARY DESIGN OF A MID-RANGE PASSENGER AIRCRAFT

2.1.1 Geometry calculations for the main parts of the aircraft

The layout of an airplane entails arranging the placement of all of its components and structures in relation to the various loads (passengers, baggage, cargo, fuel, and so on).

The aircraft's design and scheme selection should best satisfy the operating needs.

Calculating the primary components that are being designed is crucial for aircraft design. This section will include calculations for the wing design, fuselage geometry, cockpit layout, landing gear, and tail design. The aircraft's engines will be chosen among ones that are currently in use.

2.1.2 Wing geometry calculation

Initial data for developing aircraft has been calculated using a specialized computer program created at NAU Aircraft Design Department. The information is included in Appendix A, entitled "Aircraft Initial Data."

For designing aircraft the supercritical airfoil was taken. It has some advantages - maximum lift generation at low speed and also less drag at high speed.

Designing aircraft according the initial data has thing profile of a wing, the maximum thickness to chord ratio is 0.110.

As for the wing configuration based on mounting position, the aircraft has low wing design. This wing layout is more comfortable for pilot with good overview to the left, right, ahead, and up, and also it makes planes easier to handle.

The aspect ratio impacts the wing's lift and drag characteristics, making it a crucial aerodynamics variable.

The calculated aspect ratio in my case is equal to 8.45.

The Taper ratio of the wing is a parameter describing the change in the wing chord from the beginning to the end of the wing. This parameter shows the ratio of the chord length at the end of the wing to the chord length at the beginning of the wing. In my calculations, the taper ratio of the wing is equal to 3.3.

Sweep back angle of a wing in my case is equal to 28 degrees, but in different cases the sweep back angle of the wing is different, depending on the future task of the aircraft, its sweep is determined.

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:

$$S_w = \frac{m_0 \cdot g}{p_0} = \frac{43588 \cdot 9.8}{4.712} = 90.654 \text{ m}^2$$

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

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{90.654 \cdot 8.45} = 27.67 \text{ m}$$

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

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l} = \frac{2 \cdot 90.654 \cdot 3.3}{(1+3.3) \cdot 27.67} = 5.02 \text{ m}$$

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

Tip chord is:

$$b_{tip} = \frac{C_{root}}{\eta_w} = \frac{5.02}{3.3} = 1{,}5 \text{ m}$$

where b_t – tip chord, m.

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

$$c_i = c_w \cdot b_t = 0.110 \cdot 1.5 = 0.165 \text{ m}$$

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

On board chord for trapezoidal shaped wing is:

$$b_b = b_0 \cdot \left(1 - \frac{(\eta_w - 1)\cdot D_f}{\eta_w \cdot l_w}\right) = 5.02 \cdot \left(1 - \frac{(3.3-1)\cdot 3.30}{3.3 \cdot 27.69}\right) = 4.603 \text{ m}$$

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

We consider the necessary number of spars and where they must be placed when selecting a wing propulsion system.

Mean aerodynamic chord definition.

The geometrical method of mean aerodynamic chord determination has been taken, which is presented at fig. 1.1. Mean aerodynamic chord is equal to b_{MAC} = 3.58 m.

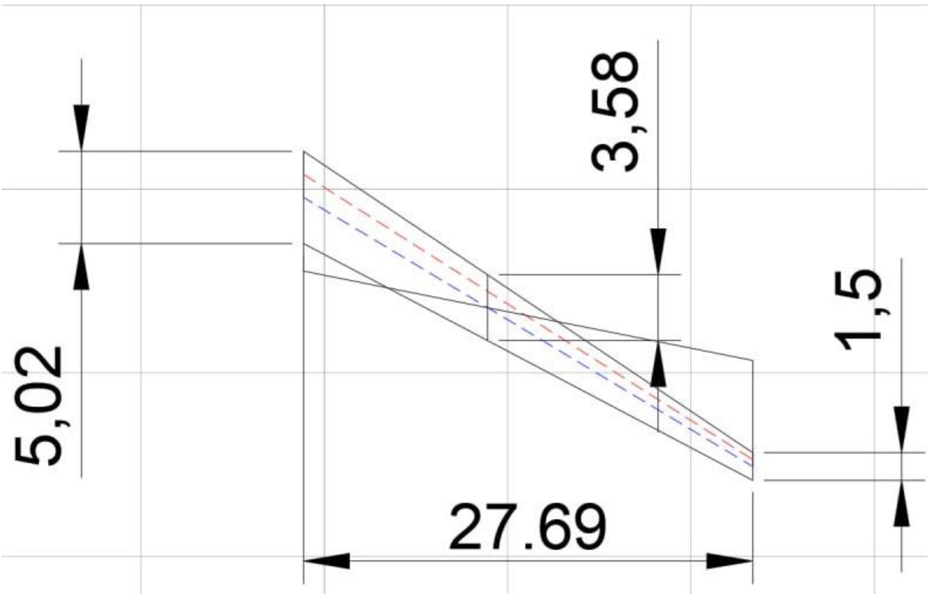

Fig. 1.1. Determination of mean aerodynamic chord.

To check the correctness of the drawing, we will also calculate MAC according to the formula:

$$b_{MAC} = \frac{2}{3}\frac{C_{root}^2 + C_{root}C_{tip} + C_{tip}^2}{C_{root} + C_{tip}} = \frac{2}{3}\cdot\frac{5.028^2 + 5.028\cdot 1.52 + 1.52^2}{5.028 + 1.52} \approx 3.58$$

From the drawing we can see that mean aerodynamic chord is equal b_{MAC} = 3.58 m.

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:

$$l_{ai} = \frac{0.35 \cdot l_w}{2} = \frac{0.35 \cdot 27.69}{2} = 4.84 \text{ m}$$

Aileron area:

$$S_{ai} = \frac{0.065 \cdot S_w}{2} = \frac{0.065 \cdot 90.654}{2} = 2.94 \text{ m}^2$$

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

Ailerons have only axial balance.

$$S_{ail} = 0.25 \cdot 2.94 = 0.735 \text{ m}^2$$

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} = 5.02 m) the flaps start, so the chord of the flap in this cross-section is:

$$b_f = 0.28 \cdot 5.02 = 1.4 \text{ m}$$

2.1.3 Fuselage layout calculation

In aircraft development and construction, one of the approaches involves calculating and defining the shape of the fuselage. The fuselage, which is the most critical structural component of the aircraft, is essential for passenger safety and comfort, as well as determining key aircraft characteristics such as weight, aerodynamic properties, and interior space. Various factors are considered when determining the fuselage shape, including internal and external loads, aerodynamic requirements, and ergonomic and functional considerations. The requirements and objectives of the aircraft's airframe are analyzed, such as the number of passengers, flight range, and other factors.

During the calculation of the airframe, factors such as static and dynamic resistance, aerodynamic stability and controllability, as well as noise and vibrations, need to be taken into account.

In our case, we will determine specific geometric features of the fuselage using standard formulas.

By substituting our values into the formula for obtaining the length of the fuselage, we have obtained:

$$l_f = \lambda_f \cdot D_f = 8.5 \cdot 3.3 = 28.05 \text{ m}$$

where D_f – fuselage diameter, m; – length of fuselage, m; – fuselage fineness ratio.

According to our calculations the fuselage nose part fineness ratio is equal to:

$$\lambda_{fnp} = 1.2...2.5$$

According to our calculations the fuselage rear part fineness ratio is equal to:

$$\lambda_{fnp} = 2...5$$

The estimated length of the nose part of the aircraft fuselage is equal to:

$$l_{fnp} = \lambda_{fnp} \cdot D_f = 1.75 \cdot 3.3 = 5.7 \text{ m}$$

where l_{fnp} – length of fuselage nose part, m; fuselage nose part fineness ratio.

Calculated length of the fuselage rear part is equal to:

$$l_{frp} = \lambda_{frp} \cdot D_f = 3 \cdot 3.3 = 9.9 \text{ m}$$

where – length of fuselage rear part, m; fuselage rear part fineness ratio.

For passenger and cargo aircraft, the size of the passenger lounge or cargo cabin plays a significant role in determining the center section of the fuselage. The height of the passenger cabin is one of the primary parameters that determines the middle portion of the airliner.

$$B_{cabin} = n_2 b_2 + n_3 b_3 + n_{aisle} b_{aisle} + 2\delta + 2\delta_{wall} = 3230$$

where – number of three-seat blocks; – width of three-seat blocks for economy class, mm; – number of aisles; – width of aisle, mm; – distance from the outside of the seat handle to the inside of the wall, mm; – distance between the inner and outer wall, mm.

2.1.4 Luggage compartment

The luggage compartment of an aircraft is an enclosed area where checked baggage, cargo, and other passenger belongings are stowed during flight. It is typically located beneath the primary passenger cabin on commercial aircraft, although some aircraft may have overhead bins or other storage areas.

K = 400... 600 kg/m2 is the standard floor load unit.

Then, the cargo hold's calculated area equals:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo\&mail}}{0.6K} = \frac{20 \cdot 80}{0.4 \cdot 500} + \frac{15 \cdot 80}{0.6 \cdot 500} = 12\ \text{m}^2$$

where S_{cargo} – cargo compartment volume, m^3; M_{bag} – mass of the baggage, kg; – mass of the cargo and mail, kg.

The estimated volume of the cargo compartment in our case is equal:

$$\nu = \upsilon \cdot n = 0.2 \cdot 80 = 16\ \text{m}$$

where V_{cargo} – cargo compartment volume, m^3; υ – cargo volume coefficient, m^3; n_{pass} – number of passengers.

2.1.5 Galleys and wardrobes

Galleys and closets are essential aircraft components. Aircraft galleys serve as kitchens and provide a variety of facilities and equipment for preparing and serving passengers and personnel with food and refreshments. These kitchens feature compact furnaces, ranges, and other heating and culinary appliances. Food and beverage storage facilities, including refrigerators and freezers, are also available. Trolleys, trolleys, and platters are utilized on board for serving prepared meals, beverages, and other necessities.

2.1.6 Lavatories

Lavatories or washrooms are an essential component of the interior design of an aircraft in order to satisfy the requirements of passengers during the flight. Typically, there are restrooms located throughout the aircraft interior. Depending on the size and configuration of the aircraft, the quantity and location of restrooms will vary. Aircraft lavatories are compact and space-efficient. Typically, they include a toilet, a basin, and a mirror.

The number of restrooms depends on the number of passengers and the duration of the flight.

Calculated area of lavatory is equal to:

$$n_{lav} = \frac{n_{pass}}{40} = \frac{80}{40} = 2$$

where n_{lav} – number of lavatories.

2.1.7 Layout and calculation of basic parameters of tail unit

One of the key factors in aerodynamic design is determining the optimal positioning of the tail. To ensure longitudinal stability during flight, it is important to place the center of gravity in front of the aircraft's focal point. The longitudinal stability index is calculated based on the distance between these points relative to the average value of the wing's aerodynamic chord. By analyzing statistical data on the static moment coefficient for the horizontal tail (A_{htu}) and the vertical tail (A_{vtu}), along with typical correlations for their respective distances (H_{tu} and V_{tu}), we can make an initial estimation of the geometric parameters.

L_{HTU} and L_{VTU} values depend on a number of variables. First, they are affected by the length of the nose and rear sections of the fuselage, along with the sweptback configuration and location of the wing. In addition, the aircraft's stability and control conditions play a role in determining these values.

Area of horizontal tail unit is equal:

$$S_{HTU} = 0.19 \cdot S_w = 0.19 \cdot 90.654 = 17.22 \text{ m}^2$$

where S_{HTU} – area of horizontal tail unit, m^2;

Area of vertical tail unit is equal:

$$S_{VTU} = 0.2 \cdot S_w = 0.2 \cdot 90.654 = 18.13\,\text{m}^2$$

where S_{VTU} – area of vertical tail unit, m^2;

Determination of the elevator area:

$$S_{el} = 0.27 \cdot S_{HTU} = 0.27 \cdot 17.22 = 4.64\,\text{m}^2$$

where S_{el} – elevator area.

Rudder area:

$$S_{rud} = 0.23 \cdot S_{VTU} = 0.23 \cdot 18.13 = 4.1\,\text{m}^2$$

where S_{rud} – rudder area, m^2.

2.1.8 Landing gear design

The distance between the center of gravity and the primary landing gear is calculated using the following formula.

$$B_{\text{m}} = (0.15...0.2) b_{MAC} = 0.17 \cdot 3.58 = 0.608\,\text{m}$$

where B_m – main wheel axes offset, m.

The estimated wheel base is equal to:

$$B = (0.3...0.4) l_f = 0.4 \cdot 28.05 = 11.22\,\text{m}$$

where B – wheel base, m.

We will calculate the wheel track according to the following formula:

$$T = (0.7...1.2) B = 0.9 \cdot 11.22 = 10.098\,\text{m}$$

where T – wheel track, m.

Nose wheel loading is calculated according to the following formula:

$$F_{\text{nose}} = \frac{Bm \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot z} = \frac{0.782 \cdot 43588 \cdot 9.81 \cdot 1.8}{11.22 \cdot 2} = 26822.07\,\text{N}$$

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

Main wheel loading is calculated according to the following formula:

$$F_{main} = \frac{(B - B_m)m_0 \cdot 9.81}{B \cdot n \cdot z} = \frac{(11.22 - 0.782) \cdot 101422 \cdot 9.81}{11.22 \cdot 2 \cdot 4} = 49725 \text{ N}$$

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

To select tires for an aircraft (table 1.1), we must know the masses on the main and nose wheels, as well as the takeoff and landing speeds.

According to the Goodyear aircraft tire data book I chose these tires:

Table 2.1

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
32×10.75-14	12	22×6.75-10	8

2.1.8 Choice of power plant

A well-chosen aircraft engine is very important. The engine plays a large role in determining the characteristics, range and capabilities of the aircraft. Aircraft power plants are becoming more and more efficient over time due to advances in current technology.

This aircraft will be equipped with a Rolls-Royce RB.183 Tay powerplant. The Rolls-Royce RB.183 Tay is a medium-bypass turbofan engine with a bypass ratio of 3.1:1 or greater.

2.2 Center of gravity calculation

2.2.1 Trim-sheet of the equipped wing

A fitted wing's total weight is made up of the weight of the wing's structure, the weight of whatever equipment it is carrying, and the weight of fuel. The main gear and rear wheel are factored into the weight calculation for the equipped wing regardless of whether the attachment point is the wing or the fuselage. The names of the items, their individual weights, and the coordinates of their center of gravity are all included in the weight computation. Projecting the nose point onto the mean aerodynamic chord (MAC) of the XOY surface yields the reference point for the center wing section coordinates. Positive center of gravity coordinate values are taken into consideration for the aircraft's tail.

Table 2.2

Trim-sheet of equipped wing

Object name	Unit mass, %	Mass, kg	CG coordinates, m	Moment of mass, kgm
Wing (structure)	0.1105	4816	1.611	7758.64
Fuel system, 80-100%	0.0058	255	1.289	328.07
Control system, 30%	0.0130	567	2.148	1217.15
Electrical equipment, 20%	0.0337	1469	0.358	525.87
Anti-icing system, 70%	0.0106	463	0.358	165.88
Hydraulic system, 30%	0.0058	251	2.148	539.29
Power plant	0.0960	4183	5.000	20913.52
Equipped wing without landing gear and fuel	0.2754	12003	2.620	31448.42
Nose landing gear	0.0120	523	-12.345	-6457.13
Main landing gear	0.0283	1234	3.234	3990.68
Fuel for flight	0.2095	9130	1.074	9805.09
Reserve fuel	0.0443	1932	1.253	2420.57
Totally equipped wing	0.5695	24822	1.660	41207.63

The following formulas are used to establish the coordinates of the equipped wing's center of gravity:

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

where X'_w – center of mass for equipped wing, m'_i – mass of a unit, kg; x_i – center of mass of the unit, m.

2.2.2 Trim-sheet of the equipped fuselage

A list of aircraft objects whose coordinate origins are determined by the projection of the fuselage's nose portion onto the horizontal axis is provided in table 2.2. The structural portion of the hull is represented by the X axis.

CG coordinates for the FEF are calculated using the following formulas

$$X'_f = \frac{\sum m'_i x'_i}{\sum m'_i}$$

where X'_f – center of mass for equipped fuselage, m; m'_i – mass of a unit, kg; x_i – center of mass of the unit, m.

Table 2.3

Trim-sheet of equipped fuselage

Object name	Unit mass, %	Mass, kg	CG coordinates, m	Moment of mass, kgm
1	2	3	4	5
Fuselage	0.1203	5241	14.250	74690.76
Horizontal tail unit	0.0151	659	24.980	16452.19
Vertical tail unit	0.0185	805	22.815	18357.74
Radiolocation equipment	0.0052	227	0.110	24.93
Dashboard and instrument equipment	0.0060	262	2.350	614.59
Aero navigation equiment	0.0052	227	2.134	483.69
Radio equipment	0.0026	113	2.134	241.84
Fuel system, 0-20%	0.00073	32	2	63.64
Control system, 70%	0.0074	323	15.675	5055.99
Electrical system, 80%	0.0269	1173	14.250	16708.37
Hydraulic system, 70%	0.0134	586	15.000	8787.34
Anti-ice system, 30%	0.0045	196	24.620	4829.11
Air-conditioning system	0.0065	284	12.825	3639.19
Emergency equipment	0.0025	109	7.000	762.79
Tools	0.0002	11	5.000	53.05
Water and liquid	0.0009	40	6.000	240.00
Lavatory 1	0.0046	200	4.000	800.00
Lavatory 2	0.0000	0	0.000	0.00
Lavatory 3	0.0000	0	0.000	0.00
Wardrobe 1	0.0000	0	0.000	0.00
Wardrobe 2	0.0000	0	0.000	0.00
Wardrobe 3	0.0000	0	0.000	0.00
Galley 1	0.0055	240	5.000	1200.00

Ending of table 2.3

1	2	3	4	5
Galley 2	0.0000	0	0.000	0.00
Galley 3	0.0000	0	0.000	0.00
Baggage equipment	0.0155	675	14.000	9450.00
Interior panels, lining and insulation	0.0085	370	12.825	4751.64
Passenger's seats 1	0.0080	350	8.000	2800.00
Passenger's seats 2	0.0000	0	0.000	0.00
Passenger's seats 3	0.0000	0	0.000	0.00
Pilot's seats	0.0009	40	2.500	100.00
Non-typical equipment	0.0023	100	7.050	706.78
Equipped fuselage without commercial load	0.2813	12261	13.932	170813.65
Passengers 1	0.1285	5600	14.000	78400.00
Passengers 2	0.0000	0	0.000	0.00
Passengers 3	0.0000	0	0.000	0.00
Passenger baggage	0.0138	600	14.000	8400.00
Cargo, mail	0.0000	0	0.000	0.00
On board meal	0.0006	25	3.000	75.00
Flight attendants	0.0028	120	3.000	360.00
Crew	0.0037	160	2.000	320.00
Totally equipped fuselage	0.4305	18766	13.768	258368.65

We constructed the moment equilibrium equation relative to the fuselage nose after determining the C.G. of fully equipped wings and fuselage:

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

where m_0 – aircraft takeoff mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; C – distance from MAC leading edge to the C.G. C = (0,22...0,25) B_{MAC} –low wing.

2.2.3 Calculation of center of gravity positioning variants

Table 2.3

Calculation of C.G. positioning variants

Object name	Mass, kg	CG coordinates, m	Moment of mass, kgm
Equipped wing without landing gear and fuel	12003	16.754	201104.07
Nose landing gear (retracted)	523	1.789	935.81
Main landing gear (retracted)	1234	17.368	21431.86
Fuel for flight	9130	15.208	138842.70
Reserve fuel	1932	15.387	29725.16
Equipped fuselage	12261	13.768	168807.53
Passengers 1	5600	14.000	78400.00
Passengers 2	0	0.000	0.00
Passengers 3	0	0.000	0.00
Baggage of passengers	600	14.000	8400.00
Cargo, mail	0	0.000	0.00
On board meal	25	3.000	75.00
Flight attendants	120	3.000	360.00
Crew	160	2.000	320.00
Nose landing gear (extended)	523	1.444	755.36
Main landing gear (extended)	1234	17.368	21431.86

Table 2.4

Airplanes C.G. position variants

Variant of loading	Mass, kg	Moment of mass, kgm	CG coordinates, m	Centering, %
Take-off mass (landing gear extended)	43587	648402.13	14.876	20.72
Take-off mass (landing gear retracted)	43587	648221.68	14.872	20.60
Landing variant (landing gear extended)	34433	509484.43	14.796	18.50
Transportation variant (without payload)	37242	560986.68	15.063	25.95
Parking variant (without fuel and payload)	26021	392279.27	15.075	26.29

Conclusions to the project part

In this project, I calculated an airplane with an economy class cabin, with a passenger capacity of 80 people. The plane is equipped with two Rolls-Royce RB.183 Tay turbofan engines with a take-off weight of 43,588 kilograms. Calculations were also done for the wing, fuselage, tail, and landing gear parameters. It is decided how many restrooms and kitchens there will be. Additionally, the aircraft's center of gravity and its drawings were determined.

3. IMPROVEMENT OF PASSENGER SEAT ERGONOMICS

3.1 Introduction

What is a passenger seat? The passenger seat is the place where a person spends 99 percent of his time. Thus, satisfaction and safety in a direct flight depends not only on the pilot, but also on the comfort of the seat, namely the passenger seat. Currently, few companies can show a new, safe and comfortable passenger seat design. That's why I think it's time to change something.

Improvement must include all the safety standards. Namely, impact resistance, fire resistance, comfortable ergonomics. Convenience during the flight is a combination of many factors.

3.2 Requirements to the design of the passenger seat

The main criterion when designing a chair is safety during flight. One of the main safety criteria is the fire resistance of the materials from which the chair is made.

Passenger planes use special fire-resistant fabrics that meet the safety and regulatory requirements of the aviation industry. One of the most common classifications of fire-resistant fabrics is the classification according to FAR/JAR 25.853, which establishes fire resistance requirements for materials used in aircraft cabins. According to this standard, fabrics for passenger seats must meet the requirements for combustion, smoke generation and heat release. Popular fabrics that meet FAR/JAR 25.853 standards:

Artificial fabrics, for example, polyesters, polyamides, reinforced with fibers, which have high resistance to burning and limited smoke generation. Fabrics that use special coatings that provide additional fire resistance, such as flame retardant coatings based on fluorine-containing compounds. Microfiber, which has fire-resistant properties and is an easy-to-clean material. Leather substitutes that undergo special treatment to ensure fire resistance.

3.3 Fire resistance

One of the most important regulations outlining the fire safety criteria for materials used in passenger airplane cabins is FAR 25.853 (Federal Aviation Regulations, Part 25, Section 853). As a foundation for establishing the fire safety criteria for the aviation sector, this standard was accepted in the United States and is widely utilized in many other nations.

FAR 25.853 specifies in great detail how various materials, such as textiles, foams, plastic parts, veneers, and other elements used in airplane cabins, must burn, smoke, and release heat.

The following are the primary requirements listed in FAR 25.853:

Combustibility: To reduce flame spread, materials must be properly fire treated. Burning time, flame spread, and self-ignition of materials are all covered under combustion criteria.

Smoke production: When materials burn, only a small amount of smoke should be produced. By measuring the optical density of the smoke that is created when the material is burned, smoke needs can be calculated.

Heat release: When burning, materials must emit as little heat as possible. By measuring the rate of heat from the material's surface, heat release needs are determined.

To ascertain if a material complies with the FAR 25.853 standard, special tests that subject the material to heat, open flames, and other circumstances are conducted. These tests are carried out in accredited labs, and all essential documentation and certificates are provided to back up the findings.

Aviation manufacturers and businesses must comply with FAR 25.853, it is mandatory. The use of fire-resistant materials increases safety during flight and during an emergency landing, thereby preventing the fire from quickly spreading throughout the cabin.

3.4 Impact resistance

A rather important criterion is the impact resistance of the passenger seat during the flight. When designing the passenger seat, various impact-resistant materials are used to ensure greater safety during the flight. Materials are selected for more effective absorption and dissipation of impact energy. There are different types of such materials, but here are some of them.

Aluminum and steel alloys are two materials that are frequently utilized to make airplane seats. Aluminum alloys with good strength-to-weight ratios, including aluminum-magnesium and aluminum-lithium, are perfect for lightweight seat frames. Steel alloys offer superior structural integrity and impact resistance, such as high-strength low-alloy (HSLA) steel. These metal alloys have the capacity to disperse and absorb impact energy during a collision or turbulent airflow.

Composite Materials: The design of airplane seats frequently makes use of composite materials, notably carbon fiber reinforced polymers (CFRP) and fiberglass. Composites are made of a strong fiber matrix, usually made of carbon or glass, and a polymer, such as epoxy resin. They are substantially lighter than conventional metal materials while providing great strength, stiffness, and impact resistance. To improve passenger safety, composites are frequently utilized for seat shells, backrests, and other structural elements.

Fire-Resistant Foam: Aircraft seats are cushioned and padded with fire-resistant foam, such as self-extinguishing or fire-block foam. In addition to offering comfort, this foam has impact-absorbing qualities. In the event of a fire, it is made to withstand burning or from releasing poisonous gases, improving passenger security.

The choice and mix of impact-resistant materials are dependent on a number of variables, such as legal constraints, weight limitations, and crashworthiness standards. Extensive testing and certification procedures guarantee that the selected materials adhere to strict safety requirements and provide passengers with the best protection possible in the case of an accident or turbulence

3.5 Ergonomic Airline Seat

One of the very important criteria when designing a passenger seat is its ergonomics. Ergonomics is a science that studies the peculiarities of human production activities to increase safety, comfort and productivity.

One of the main factors of passenger satisfaction during the flight is ergonomics, since a person spends almost the entire flight in the passenger seat. A person who likes sitting in a passenger seat is more likely to buy a new ticket from this airline.

At the moment, there are few airlines that can really offer a comfortable passenger seat during the flight. This is due to the fact that it is difficult to combine economy with safety and good ergonomics of the chair, but it seems to me that the time has come to change something and improve the concept of the previous chair and make it more technological and economically profitable.

The ergonomics of the passenger seat includes the construction and design taking into account the comfort and safety of the passengers. The ergonomics of the seat should combine the optimal position of the person during the flight, his safety in emergency situations, and reduce discomfort during a long stay in the seat. To combine all these aspects, it is necessary to follow the aviation rules when designing the passenger seat.

In-flight comfort can be greatly enhanced by the seat. The seat should be sufficiently wide and soft, and should provide adequate support for the back and seat. Also, do not forget about the adjustable headrests and footrests, which will allow passengers to choose the optimal position during the flight

Seats should provide the passenger with proper back support. Avoiding tiredness and discomfort is made possible by the ideal back form. Some chairs include adjustable backrests or built-in massage features that enhance blood flow and offer more comfort.

When constructing ergonomically sound seats, legroom is a crucial factor. The legroom promotes healthy blood flow and prevents compression. The seat's height and inclination should be adjusted so that people may put their feet up comfortably and without interference.

A modern seat cannot do without adjustment methods for greater passenger comfort. A modern chair cannot do without adjusting the angle of the backrest, headrest and footrest. This will provide more satisfaction to passengers, because they will be able to improve and adjust their seats for themselves if necessary, which will significantly affect flight satisfaction.

The key factor is safety. The seat must meet all safety standards. The seat must meet all standards of strength and fire resistance, in addition, the location of the passenger seats is very important to ensure maximum protection during emergency situations. The seat must have such details as: seat belts, airbags, a place for emergency equipment.

Ergonomics is an important factor in chair design. I want to consider economy class passenger seats. Most people fly on economy-class planes, because not everyone can afford to fly in business, and even more so in first class. A passenger seat in economy class is associated with small seats, uncomfortable ergonomics, hard, uncomfortable armrests and insufficient legroom.

If you look at the functionality of the economy class chair, you can immediately notice its lack of comfortable settings.

Of course, the current passenger seats have some advantages, namely their low functionality. The functionality of the chair is a rather difficult issue in design, because the more functional the chair, the more often it will need repair and, at the same time, it will be less economically profitable, but it will increase the convenience of use and allow passengers to feel more comfortable, and in the future, customers will only grow, because comfort is a very important factor when flying. There are also advantages in small functionality, such as a longer time in operation without the need for repairs, in addition, a lighter design and thereby increasing the economic profitability of such chairs. But is it necessary to sacrifice comfort in exchange for a higher profit and is it possible to find a compromise by making the seat more comfortable and economical for airlines.

If we talk about the improvement of the passenger seat in the economy class, I would like to start by discussing the main base that exists at the moment. If you take an ordinary passenger seat, you can notice that it is not comfortable and ergonomic enough, as I mentioned above. Conventionally, the passenger seat can be divided into such parts as: the seat itself, the back, the headrest, the armrest, and the footrest.

The seat is quite comfortable and does not have much room for improvement, but the parts of the chair are interconnected and depending on further improvements, the seat can change.

The back of the chair is very important for a comfortable flight. Depending on the form factor of the back of the passenger seat, the sensations after the flight will be very different. The passenger seats used in the economy class have a rather big drawback, namely, there is no support for the back. As we all know, a person's posture in a straight line depends on the health of his back, so when a person sits in an ordinary chair without support, after a long flight, it can lead to unpleasant sensations. Back support has quite a few benefits, namely: Pain reduction, injury prevention, improved body position, and fatigue reduction. Pain reduction is achieved due to proper fit.

The headrest in the passenger seat is designed to support the head and neck while sitting. The main function of a headrest is to provide comfort and support to the head, helping to reduce tension in the neck and shoulders. In economy class passenger seats, the headrest cannot be adjusted, which significantly reduces pleasant sensations.

The armrests are quite hard and rough. I suggest adding a little more softness to them by making the armrest softer than it is now. This will help to avoid painful sensations in the elbow area, which can increase the pleasant experience of flying.

The space for the legs is a rather controversial topic, because depending on the size of the person, the sensations may be different. The footwell has adjustable support and can be folded or opened, which adds to the variability of the passenger seat adjustment during the flight.

Having considered some shortcomings, I would like to dwell on such a part as the headrest. In my opinion, the passenger seat lacks a comfortable adjustable headrest. I want to propose the concept of a side adjustable headrest. After all, in my opinion, such a detail will greatly improve the feeling during the flight.

3.6 Headrests and their requirements

Headrests in aircraft have a number of requirements that ensure the safety and comfort of passengers during the flight. Here are some of the basic requirements for headrests:

Injury protection: Head restraints must be designed to prevent injury to the head and neck of passengers in case of turbulence, accidents or steep braking. They must provide support and shock absorption.

Adjustability: Headrests should be adjustable in height and angle to suit the individual preferences and physiology of passengers of different sizes and statures.

Comfort: Headrests should provide comfort on long flights. They should be soft enough to support the passenger's head in a natural position and not cause discomfort or fatigue.

Compatibility with safety systems: Head restraints must be compatible with safety systems such as seat belts and airbags. They must not interfere with the proper use of these systems and must be easy to integrate.

Fire resistance: Headrests must be made of fire-resistant materials to prevent the spread of fire in the event of an on-board fire.

Easy cleaning and care: Head restraints should be made of materials that are easy to clean and maintain in a hygienic condition. This is important for passenger safety and comfort.

Compliance with Regulations and Standards: Head restraints must comply with aviation regulations and standards, such as FAA or EASA requirements, to ensure safety and compliance with regulatory requirements.

3.7 Headrest with movable adjustment system

The new type of airline headrest with movable adjustment system described below is an innovative solution that provides additional comfort and support for passengers during the flight.

The new aviation headrest with movable adjustment system has the following features:

Multi-functionality: The headrest features a movable adjustment system that allows passengers to adjust its position according to their individual needs. Passengers can adjust the height, angle and depth of the headrest to achieve optimum support and comfort.

Softness and Adaptability: The headrest is made of soft materials that provide a comfortable feel and soft support for the passenger's head. The materials can be adaptive, responding to heat and pressure to ensure optimal head fit and minimize point pressure.

The passenger seat's ergonomics will be enhanced by this design. By accounting for the head and neck's shape, it will offer the best support and weight distribution. The headrest will play a crucial role in maintaining passenger safety during the flight since it can shield the head and neck from injury in the case of abrupt turbulence or an emergency landing.

Such a small detail as an adjustable side headrest can provide much more comfort. Passengers will be able to adjust it to themselves, which will allow them to sit more comfortably in the passenger seat. Passengers will no longer have to carry sleeping pillows with them.

Conclusion to the special part

In conclusion, the design of smart passenger seats should prioritize safety, comfort, and ergonomics. Meeting safety standards, such as fire resistance according to FAR/JAR 25.853, is crucial to ensure passenger protection during flights and emergency situations. The use of fire-resistant fabrics, coatings, microfiber, and treated leather substitutes can enhance fire safety in passenger seats.

To enhance safety and impact resistance, materials such as aluminum and steel alloys, composite materials like carbon fiber reinforced polymers (CFRP) and fiberglass, and fire-resistant foam are utilized. These materials provide strength, structural integrity, impact absorption, and weight efficiency.

Ergonomics is a vital consideration to improve passenger satisfaction. Designing seats with optimal positioning, back support, adjustable headrests, footrests, and legroom promotes comfort and reduces fatigue during long flights. Providing adjustable features, such as seat angle, headrest, and footrest adjustments, allows passengers to personalize their seating positions for enhanced comfort.

While economy class seats often face limitations due to cost considerations, it is important to strike a balance between functionality and profitability. The focus should be on designing seats that prioritize passenger comfort without compromising safety or economic viability. This could involve improving back support, offering adjustable headrests, softer armrests, and flexible legroom to accommodate various passenger sizes.

In particular, the concept of a side adjustable headrest can significantly enhance the flying experience. This design considers the shape of the head and neck, providing optimal support and load distribution. It serves as a safety element to protect passengers from potential neck and head injuries during turbulence or emergency landings.

By incorporating these improvements and adhering to safety standards, airlines can offer a more pleasant and comfortable flying experience for passengers, leading to increased customer satisfaction and loyalty.

GENERAL CONCLUSIONS

During the writing of the thesis, an analysis of selected prototypes was carried out, namely the Fokker-70, MRJ-90, ERJ-175. The aircraft's complete structure, safety, functionality and design were calculated. The project includes an analysis of economy class passenger seats and options for improving ergonomics for better passenger satisfaction with the flight. The concept of improving the adjustable side headrest was presented.

The work included research and calculations related to various aspects of aircraft performance. This included determining payload, flight range, fuel efficiency, speed, and other parameters necessary to ensure safe and efficient air travel. The results obtained allow us to evaluate the performance of the aircraft and make decisions for its improvement.

A novel headrest with a movable adjustment system was created as part of the work. In addition to taking passenger safety and comfort criteria into account, a number of design, construction, and material requirements were taken into account in order to build a headrest that offers the best support for the neck and shoulder area.

The research's findings make a substantial addition to the field of building aircraft and creating aviation parts. They can be employed in additional studies and initiatives aimed at enhancing aircraft performance and creating cutting-edge new options for passenger safety and comfort.

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Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	80
Flight Crew Number	2
Flight Attendant or Load Master Number	2
Mass of Operational Items	725.20 kg
Payload Mass	7920.00 kg

Cruising Speed	850 km/h
Cruising Mach Number	0.7924
Design Altitude	10.50 km
Flight Range with Maximum Payload	3400 km
Runway Length for the Base Aerodrome	2.20 km

Engine Number	2
Thrust-to-weight Ratio in N/kg	3.1500
Pressure Ratio	25
Assumed Bypass Ratio	5
Optimal Bypass Ratio	5
Fuel-to-weight Ratio	0.2500

Aspect Ratio	8.45
Taper Ratio	3.30
Mean Thickness Ratio	0.110
Wing Sweepback at Quarter Chord	28.0
High-lift Device Coefficient	1.050
Relative Area of Wing Extensions	0.080

Wing Airfoil Type supercritical
Winglets not installed
Spoilers installed

Fuselage Diameter	3.30 m
Finess Ratio	8.50
Horizontal Tail Sweep Angle	30.00
Vertical Tail Sweep Angle	45.0

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point 0.39248

Induce Drag Coefficient 0.00902

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

Cruising Mach Number	0.79237
Wave Drag Mach Number	0.80725
Calculated Parameter D_m	0.01488

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	4.876
At Middle of Cruising Flight	4.243
At the Beginning of Cruising Flight	4.712

Drag Coefficient of the Fuselage and Nacelles	0.01152
Drag Coefficient of the Wing and Tail Unit	0.00904

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.03145
At Middle of Cruising Flight	0.03045

Mean Lift Coefficient for the Ceiling Flight 0.39248

Mean Lift-to-drag Ratio	12.88887

Landing Lift Coefficient	1.593
Landing Lift Coefficient (at Stall Speed)	2.389
Takeoff Lift Coefficient (at Stall Speed)	1.971
Lift-off Lift Coefficient	1.439
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.722
Start Thrust-to-weight Ratio for Cruising Flight	2.862
Start Thrust-to-weight Ratio for Safe Takeoff	3.185

Design Thrust-to-weight Ratio = 3.312

Ratio $D_r = R_{cruise} / R_{takeoff=}$ 0.899

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

Takeoff	37.9840
Cruising Flight	61.2699
Mean cruising for Given Range	63.4747

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.04432
Block Fuel	0.20945

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.11049
Horizontal Tail	0.01511
Vertical Tail	0.01846
Landing Gear	0.04031
Power Plant	0.10326
Fuselage	0.12025
Equipment and Flight Control	0.13037
Additional Equipment	0.00964
Operational Items	0.01664
Fuel	0.25378
Payload	0.18170

Airplane Takeoff Weight	43588 kg
Takeoff Thrust Required of the Engine	72.18 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0217
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0151
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0085
Furnishing Equipment Weight Fraction	0.0062
Flight Control Weight Fraction	0.0074
Hydraulic System Weight Fraction	0.0192
Electrical Equipment Weight Fraction	0.0337
Radar Weight Fraction	0.0034
Navigation Equipment Weight Fraction	0.0052
Radio Communication Equipment Weight Fraction	0.0026
Instrument Equipment Weight Fraction	0.0060
Fuel System Weight Fraction	0.0073

Additional Equipment:

Equipment for Container Loading	
No typical Equipment Weight Fraction	0.0073
(Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0023

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	264.99 km/h
Acceleration during Takeoff Run	2.63 m/s*s
Airplane Takeoff Run Distance	1028 m

Airborne Takeoff Distance	578 m
Takeoff Distance	1607 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	251.74 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.38 m/s*s
Takeoff Run Distance for Continued Takeoff on Wet Runway	1602.67 m
Continued Takeoff Distance	2181.05 m
Runway Length Required for Rejected Takeoff	2257.86 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	36019 kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	19.9
Descent Distance	47.00 km
Approach Speed	246.19 km/h
Mean Vertical Speed	1.99 m/s
Airborne Landing Distance	515 m
Landing Speed	231.19km/h
Landing run distance	720 m
Landing Distance	1235 m
Runway Length Required for Regular Aerodrome	2063 m
Runway Length Required for Alternate Aerodrome	1754 m