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 ближньо/середньо-магістрального пасажирського літака»

Виконав: __________ **Ксенія ПОСИПАЙКО**

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 Passenger Aircraft for Short- and Medium-Haul Flights"

Fulfilled by:	_____________	**Kseniia POSYPAIKO**
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

ПОСИПАЙКО КСЕНІЇ РОМАНІВНИ

1. Тема роботи: «Аванпроект ближньо/середньо-магістрального пасажирського літака», 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 88, дальність польоту з максимальним комерційним навантаженням 3500 км, крейсерська швидкість польоту 820 км/год, висота польоту 10.7 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 удосконалень витривалості та міцності внутрішніх деталей конструкції пасажирського крісла.

5. Перелік обов'язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (A1×1), компонувальне креслення фюзеляжу (A1×1), креслення внутрішньої конструкції крісла (A1×1).

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 ____________ Ксенія ПОСИПАЙКО

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

Kseniia POSYAPIKO

1. Topic: "Preliminary design of Passenger Aircraft for Short- and Medium-Haul Flights", 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}=820 kmph, flight range L=3500 km, operating altitude H_{op}=10.7 km, 88 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 an improvement of the durability and strength of the internal structure of the passenger seat.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), design of internal structure of the passenger seat (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: ____________ Kseniia POSYPAIKO

РЕФЕРАТ

Кваліфікаційна робота «Аванпроект ближньо/середньо-магістрального пасажирського літака»:

47с., 5 рис., 6табл., 11 джерел

Представлена кваліфікаційна робота присвячена проектуванню ближньо/середньо-магістрального пасажирського літака для перевезення 88 осіб.

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 розробити концепцію удосконалення витривалості та міцності внутрішніх деталей конструкції пасажирського крісла.

Актуальність роботи полягає у підвищенні циклу життя та міцності внутрішніх деталей конструкції пасажирського літака без втрати комфорту для пасажирів, зменшення вартості обслуговування для компанії пасажирських крісел.

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, удосконалення витривалості та міцності внутрішніх деталей конструкції пасажирського крісла.

ABSTRACT

Bachelor degree thesis " Preliminary design of Passenger Aircraft for Short- and Medium-Haul Flights "

47 pages, 5 figures, 6 tables, 11 references

The bachelor degree thesis presents a preliminary design of passenger aircraft for short- and medium-haul flights that can transport 88 passengers.

The design methodology relies on the analysis of prototypes, advanced technical solutions and engineering calculations to obtain the technical specifications of the aircraft. A special part of the thesis focuses on the design of an improvement of the durability and strength of the internal part structure of the passenger seat

The relevance of the work is to increase the life cycle and durability of internal parts of the passenger aircraft structure without losing comfort for passengers, reducing the cost of maintenance for the passenger seat company.

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, passenger seats.

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 23 09P 00 00 00 80 TW	Task for work	1	
	2	NAU 23 09P 00 00 00 80	Short- and Medium-Haul Flight passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 23 09P 00 00 00 80 EN	Short- and Medium-Haul Flight passenger aircraft	47	
			Explanatory note		
A1	4	NAU 23 09P 00 00 00 80	Design of internal part of passenger seat	1	

	Sh.	№ doc.	Sign	Date	NAU 23 09P 00 00 00 80 EN
Done by	Posypaiko K.R.				Preliminary design of Passenger Aircraft for Short- and Medium-Haul Flight
Supervisor	Maslak T.P.				list: Q; sheet: 9; sheets: 47
St.control.	Krasnopolskyi V.S.				402 ASF 134
Head of dep.	Ignatovich S.R.				

CONTENT

INTRODUCTION

Looking at the current situation in the country, we can see the results of the negative impact of the war on all structures of the country. The country's aviation sector is particularly affected, as the country's airspace is closed and this infrastructure suffers huge losses.

In today's world, aviation is at the forefront of global transport and the economy. This industry is improving the technical characteristics of aircraft every year, increasing their transport capabilities, comfort and safety.

The main focus of this thesis is to improve and increase the life cycle of the internal parts of the passenger seat structure. The purpose of this thesis is to develop a modified aircraft based on the data of Ukrainian-made prototype aircraft.

The work will analyses current trends and innovations in the aviation manufacturing industry. The focus will also be on various aspects that affect the design of the aircraft, namely: fuselage, wing, and engine design.

The thesis includes the design of a short-medium-haul aircraft with a capacity of up to 88 passengers.

1. ANALYSIS OF PROTOTYPES AND CHOICE OF THE PARAMETERS FOR DESIGNING AIRCRAFT

1.1 Analysis of prototypes

The primary objectives of modern aircraft design revolve around ensuring utmost safety, comprehensive functionality, a comfortable flying experience, and significant economic advantages. Achieving these goals involves a highly intricate process comprising the following key steps:

1. Conceptual design
2. Preliminary design
3. Scheme review
4. Detailed design
5. Design review
6. Pilot production testing
7. Design finalization
8. Obtaining airworthiness license
9. Test flight
10. Mass production

This thesis primarily focuses on completing the preliminary design phase of an aircraft, which marks the initial stage of the entire aircraft design process. The purpose of this phase is to create an initial design encompassing the aircraft's objectives, aerodynamic shape, main components, and internal layout. Subsequently, the aerodynamic shape undergoes experimental testing and necessary modifications based on the experimental data to achieve an optimized design.

The selection of aircraft parameters holds immense significance in the aircraft design process, as each parameter interacts with others. For instance, a higher take-off weight necessitates a larger wing area. Therefore, in order to successfully accomplish the concept and preliminary design of the aircraft, it becomes crucial to choose appropriate parameters during the initial stages.

The first step in this thesis is to select suitable prototypes, collect their data, and then use a computer program to obtain initial data for the aircraft to be designed. My purpose is to design a short-mid-range aircraft, so I chose to use Antonov 158, Antonov 72 and A1 as prototypes, all of which are mid-range aircraft. Through a computer program, the initial data I obtained was a mid-range aircraft with a capacity of 90 passengers and a range of 3 000 kilometers.

The A1 aircraft is specifically designed for transporting passengers on regional and short-haul routes spanning up to 3,100 km. It possesses the capability to operate from both artificially paved runways and prepared unpaved strips, located at elevations of up to 1,500 meters above sea level, and can function effectively in diverse climatic conditions. With a cruising speed ranging from 780 to 850 km/h and a maximum cruising altitude of 12,200 meters, the aircraft offers efficient performance.

The passenger compartment of the A1 aircraft is designed to accommodate various seating arrangements, allowing the operator to configure it for single-class or mixed configurations. The available seating options range from 68 to 80 passengers and include economy, business, and first-class cabins. In the economy class, the cabin layout consists of rows with a 2+3 seating arrangement.

To ensure safe and reliable operations, the aircraft is equipped with state-of-the-art flight navigation and radio communication equipment that adheres to international standards set by ICAO (International Civil Aviation Organization). The flight information is presented on five multifunctional liquid crystal displays. The advanced electronic equipment enables the aircraft to perform landings in challenging weather conditions and during nighttime, meeting the criteria specified in ICAO Category IIIA. The specific data of the prototype is shown in Table 1.1.

Table 1.1

Aircraft performance database

Parameter	Planes		
	An-158	An-72	A1
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attend. persons	2-5	3-5	2+2
Maximum take-off weight, kg	43700	30500	43700
Max. payload, kg	9800	7500	8514
Passenger's seat	80-99	56	86
The height of the flight, m	3100	1000	3000
Range max, km	2970	3300	2600
Take off distance, m	1900	620	1900
Number and type of engines	2×D-436-148	2×D-36	2×D-436-148
The form of the cross-section fuselage	Circular	Circular	Circular
Fineness ratio of the fuselage	9.4	9.9	9.4
Wingspan, m	28.6	35.8	28.6
Sweepback on 1/4 chord, °	25	17	25

The AN-148 airplane is equipped with two twin-circuit turbojet engines D-436-148 developed by ZMKB Progress and manufactured by Motor Sich OJSC. Fuel consumption is 1458 kg/h at maximum commercial load. Additionally, an auxiliary power unit AI-450-MS is used. Also, Oleg Antonov ASTC is additionally working on options for installing a foreign CF34-10 engine on the aircraft. Fuel efficiency of the A1 is 22.0 g/km.

Among the competitive advantages of the airplane, experts note the traditional high engine location for the ANTONOV Company, which allows the airplane to land even on unpaved runways, reducing the risk of debris entering the engine.

1.2 The brief description of the aircraft

Layout means the process of spatial linkage of aircraft parts (wings, engines, tail unit, landing gear), structural and power schemes into a single whole, and the arrangement of passenger and fuselage equipment, cargo and equipment. Airplane layout can be divided into the following interrelated processes: aerodynamic, volumetric, mass, and structural and power. Each of them is aimed at achieving high economic efficiency of the aircraft.

The main layout tasks to be solved in the course of the design process are: placement of units, target load on the aircraft, provided that the required operating range of centerlines is ensured; development and interconnection of structural and power schemes of aircraft parts (fuselage, wings, tail unit, landing gear, etc.).

The requirements for aircraft layout are usually contradictory. For example, the requirements to ensure ease of maintenance require a large number of cutouts and operational joints in the airframe structure, which means that to ensure the required structural strength, these areas must be additionally strengthened, which in turn increases the weight of the structure, complicates production and leads to an increase in the cost of the aircraft. Therefore, to meet these conflicting requirements, compromise decisions must be made.

When designing an airplane, whenever possible, well-known technical solutions are used that have been successfully applied to other aircraft. In this case, it is only necessary to make minor changes to the design of the units (wing, landing gear, tail unit, fuselage) in accordance with specific technical, economic and other requirements. It is also necessary to use the principle of combining several functions performed by the same structural element or unit. For example, hatches are made in such a way that they perform both technological and operational functions; the same power frames of the fuselage tail section were used both for attaching vertical winglets to the fuselage and for engines. This approach allows not only to reduce the weight of the structure, but also to obtain larger volumes inside the aircraft to accommodate the target load.

When developing the structural and power scheme of an aircraft, the following approaches should be implemented:

- transfer and balancing of concentrated loads over structural elements should be carried out as far as possible along the shortest path;

- it is desirable to transfer bending moments over the largest possible building height, and torque moments over a closed loop of the largest possible area.

Conclusion to the analytical part

During the aircraft design process, specific layout tasks need to be addressed. These include determining the optimal placement of components to ensure the desired balance and load distribution while maintaining the required centerline operation range. Additionally, the structural and power schemes of different aircraft parts, such as the fuselage, wing, tail unit, and landing gear, must be developed and interconnected. Aircraft layout requirements often present conflicting demands. For example, while the need for easy maintenance may necessitate numerous cutouts and joints in the airframe, ensuring structural integrity requires additional reinforcement in these areas, leading to increased weight, production complexity, and cost. Consequently, compromise solutions must be found to reconcile these conflicting requirements. When designing an aircraft, existing successful technical solutions from previous aircraft are often employed with minor modifications to meet specific technical, economic, and other criteria.

Another principle applied is the integration of multiple functions within a single structural element or component. This approach allows for weight reduction and increased internal volume for accommodating the desired load. For instance, hatches can serve both technological and operational purposes, and power frames in the fuselage tail section can be utilized for attaching winglets and engines. In developing the structural and power scheme of an aircraft, certain approaches should be followed.

Basing on the analysis on prototypes the main flight performances for the designing aircraft are the next: cruise speed 820 kmph, flight altitude 3500 km, number of passengers 88, number of engines 2, fuselage diameter 3.4 m, aspect ratio of a wing 9.6 m.

2. PRELIMINARY DESIGN OF A MID-RANGE AIRCRAFT

2.1. Geometric calculations of major aircraft components

The geometric calculation of the aircraft should include the calculation of the main structural parts of the aircraft, the loads on the main parts of the aircraft (such as landing gear, etc.), and the calculation of the overall center of gravity of the aircraft. Also, here need to finish designing the interior layout of the aircraft.

The parameters and layout of aircraft components should be designed in accordance with airworthiness regulations.

Through the analysis of the parameters of the prototype, the initial data here obtained through the computer program are in Appendix A, and here was completed the geometric calculation of the aircraft and the calculation of the center of gravity based on these initial data.

2.1.1 Wing geometry calculation

The preliminary aircraft design process involves utilizing a specialized computer program developed at the Aircraft Design Department of NAU to calculate the initial data. These data, which can be found in Appendix A (Initial data of aircraft), are crucial for the design process.

In the preliminary design stage, it is common practice to select the airfoil from a wide range of options available in aeronautical literature. These airfoils possess known geometric and aerodynamic characteristics, making them suitable for consideration during this stage. Based on a case data for designing aircraft was taken that parameters: aspect ratio of a wing equal to 9.6. Taper ratio of a wing equal to 3.8. Sweep back angle of a wing is taken 25. Relative chord of a wing equal to 0.11. The wing position to the fuselage is a high-wing.

The geometric characteristics of the wing are determined based on the takeoff weight m_0 and the specific load on the wing P_0.

First, find the wing area:

$$S_W = \frac{m_0 \cdot g}{P_0} = \frac{43700 \cdot 9.8}{5000} = 85.652 \text{ m}^2$$

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

The wingspan is calculated by the formula:

$$l_w = \sqrt{S_W \cdot \lambda_W} = \sqrt{85.625 \cdot 9.6} = 28.8 \text{ m}^2$$

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

By the geometric method we could perform the drawing of the mean aerodynamic chord length in fig. 2.1.

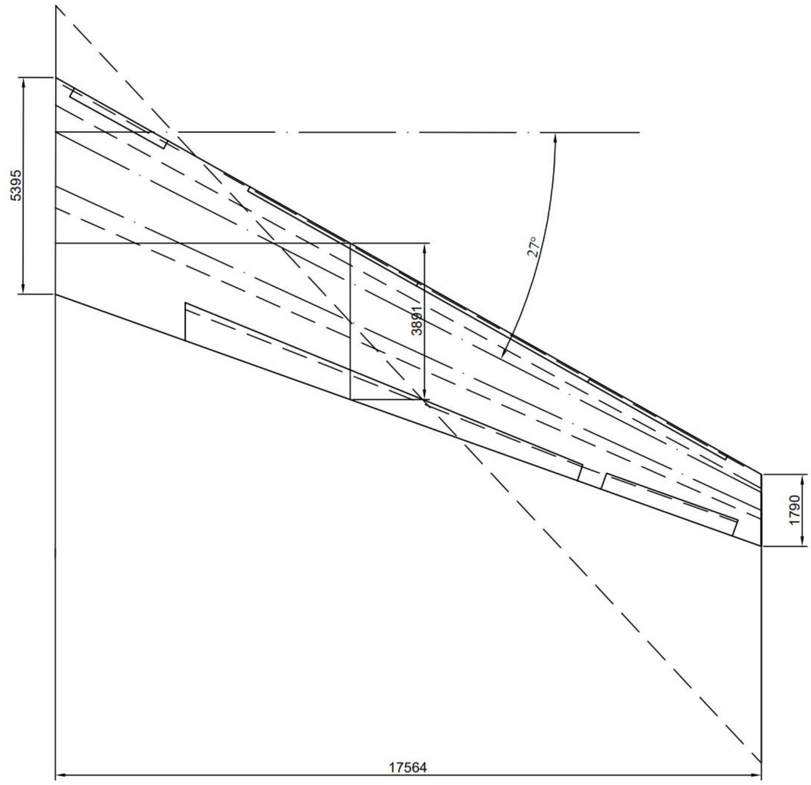

Fig. 2.1. Determination of mean aerodynamic chord.

The root chord is:

$$C_{root} = \frac{2 \cdot S_W \cdot \eta}{(1+\eta) \cdot l} = \frac{2 \cdot 85.652 \cdot 3.8}{(1+3.8) \cdot 28.8} = 4.7 \text{ m}$$

where C_{root} – root chord, m; η_w – wing taper ratio

The tip chord could be calculated by:

$$C_{tip} = \frac{C_{root}}{\eta_w} = \frac{4.7}{3.8} = 1.2 \text{ m}$$

where C_{tip} – tip chord, m

The mean aerodynamic chord also could be calculated by the formula:

$$b_{MAC} = \frac{2}{3} \cdot \frac{C_{root}^2 + C_{root} \cdot C_{tip} + C_{tip}^2}{C_{root} + C_{tip}} = \frac{2}{3} \cdot \frac{4.7^2 + 4.7 \cdot 1.2 + 1.2^2}{4.7 + 1.2} = 3.296 \text{ m}$$

The main parameters of the ailerons are performed basing on the statistic data of prototypes.

Ailerons span:

$$l_{aileron} = 0.35 \cdot \frac{l_W}{2} = 0.35 \cdot \frac{28.8}{2} = 5.04 \text{ m}$$

Aileron area:

$$S_{aileron} = 0.06 \cdot \frac{S_w}{2} = 0.06 \cdot \frac{85.652}{2} = 2.5 \text{ m}$$

Area of aileron’s trim tab for two engine airplane:

$$S_{trimtabs} = 0.06 \cdot S_{aileron} = 0.06 \cdot 2.5 = 0.15 \text{ m}^2$$

According to the task and first iteration of the geometry of a wing the top view of a half of a wing could be performed as the next view (fig. 2.2)

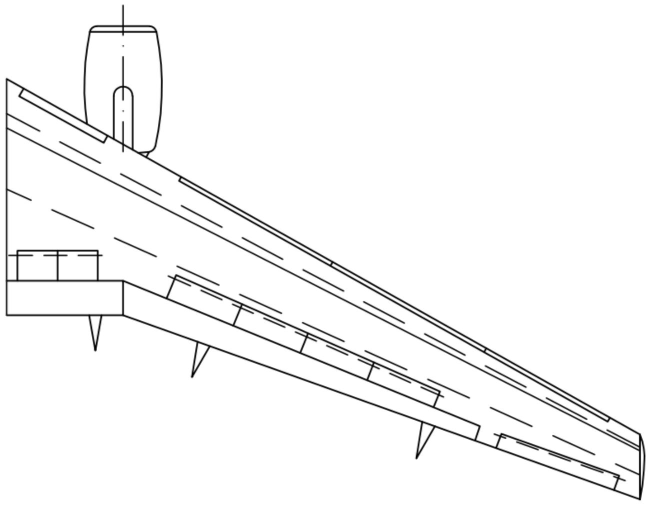

Fig. 2.2. Preliminary design of the wing.

The presented wing design has front and rear spars from 0,2 and 0,6 relative coordination to the leading edge of a wing. As for the high lift devices – it is equipped with slats and double-slotted flaps, also on upper section it has six section of spoilers.

2.1.2 Fuselage layout

When choosing the shape and dimensions of the fuselage cross-section, it is important to consider the aerodynamic requirements, such as streamlining and cross-sectional area. This is particularly crucial for passenger and transport aircraft operating at speeds below the speed of sound (V<800 km/h), as the impact of wave resistance on their performance is negligible.

Initial data of the fuselage: fineness ratio of fuselage equal to 9.4; fuselage diameter equal to 3.4 m; fineness ratio of nose part equal to 1.5; fineness ratio of tail part is equal to 2.5.

The length of the aircraft fuselage:

$$L_{fus} = FR_f \cdot D_{fus} = 9.4 \cdot 3.4 = 31.96 \text{ m}$$

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

The length of the fuselage forward part:

$$L_{fwd} = FR_{np} \cdot D_{fus} = 1.5 \cdot 3.4 = 5.1 \text{ m}$$

The length of the fuselage tail part:

$$L_{tailpart} = FR_{tu} \cdot D_{fus} = 2.5 \cdot 3.4 = 8.5 \text{ m}$$

Cabin width:

For passenger cabin I choose this configuration of the spit of passenger's seats: business class – 2+2 and for economy class – 2+3.

Initial data for passenger cabin: cabin height equal to 2.1m; seat pitch equal to 860; aisle equal to 0.5

For economy class:

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

$$= 1 \cdot 1000 + 1 \cdot 1500 + 1 \cdot 510 + 2 \cdot 50 + 2 \cdot 120 = 3350 \text{ mm}$$

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.

For business class:

$$B_{cab} = n_2 \cdot b_2 + n_{aisle} \cdot b_{aisle} + 2\delta + 2\delta_{\text{wall}} = 2 \cdot 1200 + 1 \cdot 550 + 2 \cdot 50 + 2 \cdot 120 = 3350 \text{ mm}$$

Cabin height:

Initial data we got the narrow body plane and with number of seats in one row less than 6. So we use that formula:

$$H_{cab} = 1.48 + 0.17 \cdot B_{cab} = 1.48 + 0.17 \cdot 3.35 = 2.04 \text{ m}$$

Length of the passenger cabin. In my configuration I had economy and business class.

The length of the economy class. Based on that data: seat pitch equal to 860, number of row equal to 16; and recommended parameters of length for economy class:

$$L_{econ} = L_1 + (N-1) \cdot L_{seatpitch} + L_2 = 1200 + (16-1) \cdot 860 + 300 = 14400 \text{ mm}$$

The length of the business class:

$$L_{busi} = L_1 + (N-1) \cdot L_{seatpitch} + L_2 = 1200 + (2-1) \cdot 860 + 300 = 2360 \text{ mm}$$

2.1.3 Luggage compartment

K equal to 400…600 kg/m^2

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo/mail}}{0.6K} =$$
$$= \frac{20 \cdot 88}{0.4 \cdot 600} + \frac{15 \cdot 88}{0.6 \cdot 600} = 11 \text{ m}^2$$

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

The volume of cargo compartment is equal:

$$V_{cargo} = V \cdot n_{pass} = 0.1 \cdot 88 = 17.6 \text{ m}^3$$

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

2.1.4 Galleys and buffets

To international standards, the volume of the galleys should be about 0.1 cubic meter per passenger, so the volume of galley should be:

$$V_{galley} = 0.1 \cdot n_{pass} = 0.1 \cdot 88 = 8.8 \text{ m}^3$$

Total area:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{8.8}{2.04} = 4.3 \text{ m}^2$$

2.1.5 Lavatories

The number of lavatories depend of that data – number of passenger and range of the aircraft:

$$t = \frac{Range_{flight}}{V_{cruise}} + 0.5 = \frac{3500}{820} = 4.7 \text{ h}$$

$$N_{Lavatory} = \frac{N_{pass}}{40} = \frac{88}{40} \geq 4$$

where n_{lav} – number of lavatories

The design of lavatories we used as a prototype aircraft used. Based on these calculations we get – number of the lavatories is 2; area of the lavatories equal to standard equal to 1.5 m^2

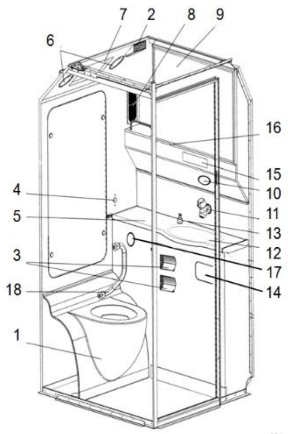

Fig.2.3 Elements of the toilet room
1 – toilet bowl; 2 – ventilation grilles; 3 – paper holders; 4 – drain button; 5 – table; 6 – lighting lamps; 7 – oxygen mask; 8 – sound speaker; 9 – mirror; 10 – napkin dispenser; 11 – tap; 12 – sink sink; 13 – soap dispenser; 14 – garbage container; 15 – information panel; 16 – locker; 17 – individual ventilation nozzle; 18 – handrail

2.1.6 Design and calculation of main characteristics of the tail unit

Calculation of the tail unit one of the important parts.

Area of the horizontal tail unit:

$$S_{HTU} = 0.19 \cdot S_W = 0.19 \cdot 85.652 = 16.27 \text{ m}^2$$

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

Area of the vertical tail unit:

$$S_{VTU} = 0.2 \cdot S_W = 0.2 \cdot 85.652 = 17.13 \text{ m}^2$$

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

Area of the elevator:

$$S_{el} = 0.27 \cdot S_{HTU} = 0.27 \cdot 17.13 = 4.67 \text{ m}^2$$

where S_{el} – elevator area.

Area of the rudder:

$$S_{rud} = 0.23 \cdot S_{VTU} = 0.23 \cdot 16.27 = 3.74 \text{ m}^2$$

where S_{rud} – rudder area, m^2.

Area of the elevator trim tab:

$$S_{te} = 0.08 \cdot S_{el} = 0.08 \cdot 4.67 = 0.37 \text{ m}^2$$

where S_{te} – elevator area, m^2.

Area of the rudder trim:

$$S_{tr} = 0.06 \cdot S_{rud} = 0.06 \cdot 3.74 = 0.2 \text{ m}^2$$

where S_{tr} – rudder trim area, m^2.

Span of the tail unit:

$$L_{\gamma_0} = 0.4 \cdot L_W = 0.4 \cdot 28.8 = 11.52 \text{ m}$$

2.1.7 Landing gear design

The distance from center of gravity to the main landing gear is determined by using of the main aerodynamic chord:

$$B_m = 0.185 \cdot b_{MAC} = 0.185 \cdot 3.296 = 0.609 \text{ m}$$

where B_m – main wheel axes offset, m.

The estimated wheel base:

$$B = 0.35 \cdot L_f = 0.35 \cdot 31.96 = 11.18 \text{ m}$$

where B – wheel base, m.

The distance between the center of gravity and nose landing gear:

$$B_n = B - B_m = 11.18 - 0.609 = 10.571 \text{ m}$$

The wheel track according:

$$T = 0.9 \cdot B = 0.9 \cdot 11.18 = 10.062 \text{ m}$$

where T – wheel track, m

For that step we will determine all of loading on wheels. Here we using parameter that calculated before. The loading on the nose wheel:

$$F_{nose} = \frac{B_m \cdot m_0 \cdot g \cdot K_g}{B \cdot z} = \frac{0.609 \cdot 43700 \cdot 9.8 \cdot 1.8}{11.18 \cdot 2} = 21016.8 \text{ N}$$

where – nose wheel load, N; – dynamics coefficient; z – number of wheels; K_g equal to 1.5…2.0 – dynamics coefficient. We used the average value is equal equal to1.8.

The loading on the main wheel:

$$F_{main} = \frac{(B - B_m) \cdot m_0 \cdot g}{B \cdot n \cdot z} =$$
$$= \frac{(11.18 - 0.609) \cdot 43700 \cdot 9.81}{11.18 \cdot 2 \cdot 4} = 50668.1 \text{ N}$$

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

For that case I chose the same tire as on my prototype. In prototype plane used of KN-35 for a non-brake wheel. The main technical data of KN-35: parking load, no more than – from MTOW (3400 kgf) and from the max landing weight of 2900 kgf; working gas in the wheel-tire compressed air or nitrogen; wheel-tire system – MPa (kgf/cm) – 1.05+0.05. And KT263A for a brake wheel with that technical data: parking loads – from MTOW (9500 kgf), from max landing weight of 8300 kgf; max takeoff speed – 335 km/h; max landing speed – 280 km/h; deceleration speed – 275 km/h; wheel tire system – MPa (kgf/cm^2) 1.15+0.05; max allowable temperature of the cylinder block – 150°C; melting temperature of the thermal witness: installed on the wheel with one notch on the hexagon - 125±5°C; with two – 150-10°C; with three – 170-10°C.

2.1.8 Choice and description of aircraft engine

In this case the main power plant of the aircraft construction – engine – that aircraft will be equipped by with two twin-circuit turbojet engines D-436-148 developed by ZMKB Progress and manufactured by Motor Sich OJSC. Perfect variant for short- and medium-haul flights. One of the main advantages of that engine is low specific consumption of fuel, as result it has lower level of emission; quite low noise level; it has a long service life at one hand and another low operating cost, which greatest variant for companies.

Technical characteristic of the turbojet engine D-436-148 shown in Table 2.1.

Table 2.1

Technical characteristic of engine

D-436-148	A	B
1	2	3
Aircraft range	Short range	Long range
Emergency mode (Hequal to0, Mequal to0, MCA)		
Temperature condition	t_n +37.5°C	t_n +30°C
Thrust	7280	790

Ending of the table 2.1

1	2	3
Takeoff mode (Hequal to0, PHequal to760 mm Hg, MPequal to0, MCA)		
Temperaturecondition	t_n +37.5°C	t_n +30°C

Thrust, kgf	6570	7010
Specific fuel consumption	0.35	0.35
Max cruising mode (Nequal to11000 m, MPequal to0.75, MCA)		
Thrust	1560	1560
Overall dimension	3829×1802×1949	3829×1802×1949
Specific fuel consumption	0.60	0.60
Dry weight kg	1400	1400
Engine resource, hours	40 000	40 00

2.2.1 Trim-sheet of equipped wing

The weight of an attached wing is defined as its structure, the weight of gear carried with it and the weight of fuel. The main gear and the rear wheel are included in the weight calculation of the equipped wing irrespective of whether it is an attachment point or a fuselage. The names of objects and their respective weights, as well as the center of gravity coordinates are included in the weight calculation. The reference point for the center wing section coordinates is determined by projecting the nose point onto the mean aerodynamic chord (MAC) of the XOY surface. For the tail of the aircraft, positive values of the center of gravity coordinates are considered.

Summary, you can see calculation or the aircraft center of gravity in the table 2.2 as special for their weights for aircraft with total weight equal to 43700 kg.

Table 2.2

Trim sheet of equipped wing

N		Mass		

	Objects names	units	total mass	C.G coordinates Xi, m	Mass moment, Xi * mi
1	Wing (structure)	0.12624	5459.68	1.532	8335.442
2	Fuel system	0.00480	206.83	1.532	316.937
3	FCS, 30%	0.00234	100.83	2.189	220.724
4	Electrical equipment, 10%	0.00606	260.91	0.365	95.191
5	Anti-ice system	0.00132	56.74	0.365	20.699
6	Hydraulic systems , 70%	0.01414	609.29	2.189	1333.776
7	Power plant	0.09405	4052.61	-2.650	-10739.42
8	Equipped wing without LG	0.24894	10726.90	-0.039	-416.659
9	Nose LG	0.01002	431.93	-9.084	-3923.690
10	Main LG	0.04010	1727.74	2.181	3768.194
11	Fuel	0.16804	7240.84	1.532	11095.435
12	Total	0.46710	20127.41	0.523	10523.28

For determination of the coordinates of the center of gravity of the equipped wing – we got that formula:

$$X_w^{'} = \frac{\sum m_i^{'} x_i^{'}}{\sum m_i^{'}}$$

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 equipped fuselage

Table 2.3 shows a list of aircraft with engines located under the wing, where the origin is determined by the projection of the fuselage nose onto the horizontal axis. The X-axis represents the structural part of the hull.

Formula for determined of the CG coordinates of the FEF:

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

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

N	Objects names	Mass		C.G coordinates Xi, m	mass moment
		units	total mass		
1	Fuselage	0.17	7371.84	15.71	115822.6
2	Horizontal tail	0.015	679.53	29.8	20249.97
3	Vertical tail	0.018	789.41	31.5	24866.37
4	Radar	0.0059	254.23	3.7	940.65
6	Aero navigation equipment	0.0089	383.50	1	383.50
7	Radio equipment	0.0044	189.60	3.7	701.5
8	Lavatory	0.002	100	5.7	570
9	Galley	0.00023	10	3.98	39.8
10	Flight control system 70%	0.00546	235.27	15.71	3696.4
11	Electrical equipment	0.0	922.13	15.71	14487.9
12	Hydraulic system 30%	0.00606	261.13	18.85	4923.2
13	High-quality equipment	0.016	706.68	15.71	11102.9
14	Decorative lining	0.00267	115.05	15.71	1807.6

End of the table 2.3

	1	2	3	4	5
15	Thermal and acoustic insulation	0.00623	268.45	15.71	4217.7
16	Chemical liquid	0.00116	50	5.5	275
17	Aqua	0.00116	50	5.5	275
18	Oxygen equipment	0.00232	100	15.71	1571
19	Anti ice system, 30%	0.00056	24.32	1.09	26,61
20	Emergency equipment	0.00197	85	15.71	1335.35
21	Crew seat	0.00232	100	2.8	280
22	Flight attendant seat 1	0.00088	38	4.15	157.7
23	Flight attendant seat 2	0.00088	38	4.15	157.7
24	Additional eguipment	0.00464	200	29.6	5920
25	Not typical equipment	0.01	564.48	5.3	2991.73
Equipped fuselage without commercial payload		0,31	13593.49	12.81	172784.28
26	Commercial payload	0.00067	28.9	5.5	158.95
27	Crew	0.00395	170	2.55	433.5
28	Flight attendant	0.00395	170	4.35	739.5
Equipped fuselage with commercial payload		0,53	22962.71	12.68	302675.8

Next step is a construct the moment equilibrium equation relatively to the nose part of fuselage:

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

$$m_f X_f^{'} + m_w(X_{MAC} + x_w^{/}) = m_0(X_{MAC} + C)$$

After we must determine the wing MAC leading edge position relative to fuselage by this way:

$$X_{MAC} = \frac{m_f \cdot X'_f + m_w \cdot X'_w - m_0 \cdot C}{m_0 - m_w} =$$

$$= \frac{302675.8 + 10523.28 - 43700 \cdot 0.25 \cdot 3.296}{43700 - 20127.41} = 11.75901\,\text{m}$$

2.2.3 Calculation of center of gravity position variants

A list of mass objects to be taken into account for variant calculation of center gravity, as set out in Table 2.4 and Center Gravity Calculations option provided in Table 2.5, is completed on the basis of both earlier tables.

Table 2.4

Calculation of C.G. positioning variants

Name object	mass in kg m_i	Coordinate X_i, м	mass moment kgm
Equipped wing (without fuel and landing gear)	10726.89	11.04	118482.54
Nose landing gear (extended)	431.934	2.0	863.96
Main landing gear (extended)	1727.73	13.26	22918.79
Fuel	7240.84	12.61	91354.48
Equipped fuselage	13593.49	12.81	174177.24
Water	28.9	5.5	158.95
Commercial payload	1285	19.1	24543.5
Crew	170	2.55	433.5
Flight attend	170	4.35	739.5
Nose landing gear (retrected)	431.93	1.48	641.08
Main landing gear (retrected)	1727.73	13.26	22918.79

Table 2.5

Airplanes C.G. position variants

№	Name	Mass, m_i kg	Mass moment	Centre of mass	Centring X_C %
1	Take off mass (L.G. extended)	43090	524781.98	12.178	30.001
2	Take off mass (L.G. retracted)	43090	524559.10	12.173	29.85
3	Landing weight (LG extended)	37350	452573.45	12.103	28.3
4	Ferry version (without payload, max fuel, LG retracted)	34061	408747.15	12.04	25.11
5	Parking version (without payload, without fuel foe flight, LG extended)	26480	316442.54	11.951	23.73

Conclusions to the part

Here was calculated a two class passenger plane for 88 passengers at the take off weight of 43700 kg during this project work. There are twin-circuit turbojet engines D-436-148 and a triplane landing gear with Goodyear tyres in this aircraft. Calculations have also been made of the parameters of the wing, fuselage, tail and landing gear. The number of kitchens, toilets, wardrobes and their size were determined. Moreover, calculations were carried out to determine the centre of gravity and blueprints have been made for the aircraft.

3. PROBLEMS OF DAMAGE AND WEAR OF PASSENGER SEATS

Nowadays human has possibility for solution different problems. Aviation on of the simplest way to traveling for people. One of the important point of that way of traveling is a comfort, especially when is a long-distance travel.

So one of the biggest case of the passenger comfort is passenger seats, where people spent all their time of flight.

Once of this problem in that case is a damage and wear of passenger seats. Some common issues include: tears or fraying of seat covers; loose or broken components; seat cushion deterioration; malfunctioning recline mechanisms; damaged seat frames; worn or damaged seat belts.

Timely maintenance, regular inspections, and swift repairs or replacements are necessary to address these problems with damage and wear of passenger seats in aircraft. It helps maintain passenger comfort, safety, and the overall aesthetic appeal of the cabin environment. Is a great way to stay stable level of comfort, but mostly that way possibly can be more expensive for developer companies.

One of the way of solution that problem is analysis of construction internal parts of passenger seats kind like frame, movable parts as regulator mechanism and types of material that used for manufacturing.

As result of researching this topic we can find solution for that case. Conducting of researching shows opportunities of modern world kind like change parts of constructions, using different types of materials or gain all of internal construction.

3.1. Analyses of frame construction of passenger seats

So this chapter about frame construction of passenger seat, on figure 1 illustrated scheme of frame with movable parts. A passenger seat frame assembly, including a seat bottom chassis including a plurality of leg modules and section assembly modules. The leg modules are attached to fixed, spaced-apart attachment points on a supporting surface, such as the deck of an aircraft fuselage. A plurality of beam elements are carried by the leg modules and section assembly modules. A plurality of clamp joints are provided for being positioned on the plurality of leg modules and for receiving the plurality of beam elements in spaced-apart relation to each other for defining a ladder frame assembly having a specified width and seat spacing.

Analysis of the frame construction of passenger seats in aircraft is crucial for ensuring their strength, durability, and overall safety. Various factors are considered during such analyses, including material selection, structural design, manufacturing processes, and compliance with regulatory standards. Here are some key aspects involved in the analysis of frame construction

Structural Design of seat frames involves considerations such as load distribution, stress concentrations, and crashworthiness. Finite Element Analysis (FEA) is often employed to simulate and analyze the structural behavior of seat frames under various loading conditions. This helps identify potential weak points, stress concentrations, and areas prone to failure.

The manufacturing processes used for seat frame construction play a vital role in ensuring the integrity and quality of the final product. Processes like extrusion, forging, stamping, and welding are commonly used. Quality control measures, such as non-destructive testing, are employed to detect any manufacturing defects that may compromise the strength and reliability of the seat frames.

Seat frame designs must comply with applicable aviation regulatory standards, such as those set by organizations like the Federal Aviation Administration (FAA) or the European Union Aviation Safety Agency (EASA). These standards specify requirements for structural integrity, crashworthiness, flammability, and other safety aspects related to seat construction.

Dynamic Testing - seat frames undergo rigorous dynamic testing to evaluate their performance under simulated crash or emergency landing scenarios. Dynamic tests, such as sled tests or drop tests, are conducted to assess the seat's ability to absorb impact energy, prevent deformation, and protect occupants during severe accelerations.

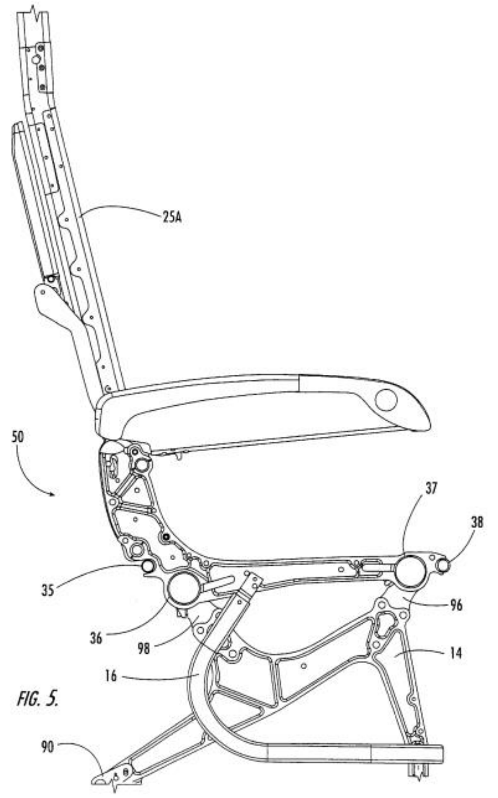

Fig.3.1 – Passenger seat construction: 14 – leg modules; 16 – baggage guard rail; 25A – pan; 35, 37,38 – beam elements; 50 – ladder frame assembly; 90 – counterclockwise direction; 96,98 – joint clamps.

3.2. Analyses of the regulator mechanism of passenger seats, problem with it and analyses of the material

The analysis of the regulator mechanism of passenger seats in aircraft is crucial to ensure proper functionality, ease of use, and passenger safety. The regulator mechanism refers to the system responsible for adjusting the position and orientation of the seat, including features like seatback recline, headrest adjustment, and armrest movement. Here are some key aspects involved in the analysis of the regulator mechanism and potential problems that can arise:

Design and Engineering: The design of the regulator mechanism should be ergonomic, intuitive to use, and durable. It involves considerations such as the range of motion, locking mechanisms, and ease of adjustment. Engineering analysis ensures that the mechanism can handle expected loads and forces without failure.

Material Selection: The materials used in the regulator mechanism should be robust, lightweight, and resistant to wear and corrosion. Common materials include various metals and high-strength polymers. Compatibility with the surrounding seat structure and the ability to withstand the forces and stresses encountered during normal operation are essential.

Performance Testing: The regulator mechanism undergoes extensive performance testing to assess its reliability and functionality. Tests include repetitive motion tests, load tests, endurance tests, and environmental tests to evaluate the mechanism's ability to withstand prolonged use, vibrations, temperature variations, and other environmental factors.

Safety Considerations: The regulator mechanism should comply with safety regulations and standards, such as those related to emergency evacuations, crashworthiness, and fire safety. It should not impede rapid egress from the aircraft in case of an emergency and should remain securely locked during flight to prevent unintended movement.

Common problems with the regulator mechanism can include:

Jamming or sticking: The mechanism may become jammed or difficult to adjust due to debris, improper maintenance, or wear and tear.

Loose or worn components: Over time, the mechanism may develop loose or worn parts, resulting in instability or reduced functionality.

Failure to lock: Inadequate locking or failure to engage the locking mechanism properly can lead to unexpected movement during turbulence or emergencies.

Malfunctioning controls: Issues with control handles, buttons, or levers can prevent smooth and accurate adjustment of the seat position.

Inconsistent performance: Variations in performance among different seats or within the same seat type can occur, leading to passenger discomfort or dissatisfaction.

To address these problems, regular maintenance, inspections, and proper lubrication are essential. Prompt repairs or replacements should be carried out when issues are identified to ensure the regulator mechanism operates reliably and maintains passenger comfort and safety

The bolts in the AN-158 seats, as in many other aircraft, are usually made of high-strength steels or stainless steels. The choice of the specific material for the bolts depends on the requirements for strength, corrosion resistance, weight and other factors.

High-strength steels, such as 10.9 or 12.9 series steels, are often used for bolts in aircraft seats. They have high strength, which allows them to withstand heavy loads. These steels are often heat treated to achieve the required mechanical properties.

Stainless steels, in particular 300 series stainless steels such as AISI 304 or AISI 316, can also be used for aircraft seat bolts. They are characterised by high corrosion resistance, which is an important factor in the humid or aggressive environment of an aircraft.

The final choice of material for bolts depends on the specifications and requirements set by the aircraft manufacturer or relevant aviation industry standards.

If high strength and fatigue resistance are required, which steels are better than AISI 304 and AISI 316?

Some of them are special steels: Some special steels, such as AISI 630 (17-4PH) or AISI 718, are designed specifically for high strength and fatigue resistance. These steels may have high levels of chromium, nickel, molybdenum and other alloy elements that improve their mechanical properties.

3.3. Solution

On the figure 3.2 shown internal part that will be an improvement of the durability and strength by way to change the material of that detail.

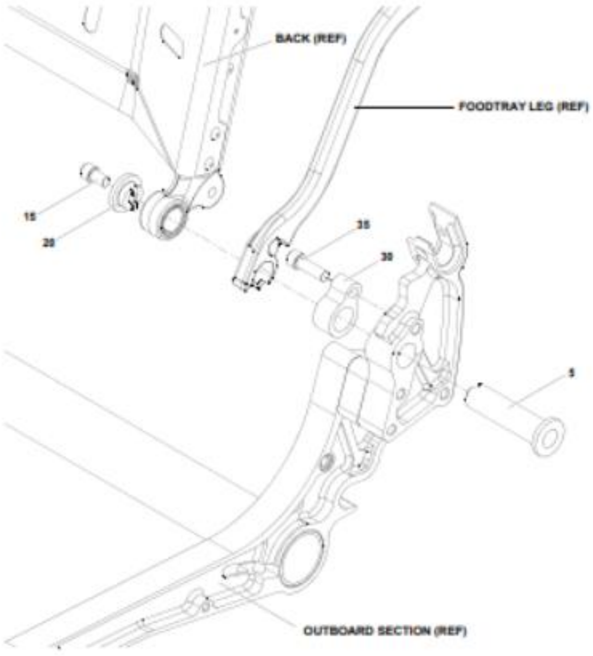

Fig.3.2. Internal part of the passenger seat

So in result of the analysis we have answer Solution: change the steel of the fasteners from AISI 316 (10X17H13M2) to AISI 630 (03X17H4M3)

Here is an initial table of tensile strength, yield strength and hardness characteristics for AISI 314 and AISI 630 (17-4PH):

Characteristics of AISI 314

Tensile strength Approximately 515 MPa

Tensile strength Approx. 205 MPa

Hardness Approx. 20HRC

AISI 630 (17-4PH).

Tensile strength Approx. 1100 MPa

Tensile strength Approx. 930 MPa

Hardness Approx. 35 HRC

Therefore, we choose the second second option - AISI 630 steel

Moreover, it will contain less scarce nickel, so this is an additional benefit

A layer of chromium or titanium can be applied to compensate for the relatively low corrosion resistance

Conclusion to the part

Here we alanalysed the problem of life cycle of the internal part of passanger seat part detail in back pivot tube. This problem has a significant impact on passenger comfort and costs the company money to maintain passenger seats. The solution to this problem is to replace the materials in the internal parts of the passenger seat. In this part of the analysis, we have selected the materials that will determine the life cycle of these parts

GENERAL CONCLUSION

During the writing of the thesis, a large-scale analysis and research of the complete aircraft structure was carried out, including its design, functionality and safety systems. The following aircraft prototypes were chosen to create a conceptual monoplane passenger aircraft with two engines: the AN 158, AN 72 and A1. A full analysis of the structures and loads on the prototype aircraft was carried out, as well as a number of calculations. A passenger aircraft with a seating capacity of up to 88 passengers for short- and medium-haul flights was created

The project also included analysing and solving the problem with the internal seat cradles. Namely, the analysis of the problem and the materials used at the moment. A selection of materials that will help to increase the life cycle of the passenger seat without loss of comfort for the passenger and additional costs for passenger seat maintenance.

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Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	88
Flight Crew Number	2
Flight Attendant or Load Master Number	2
Mass of Operational Items	688.17 kg
Payload Mass	8618.00 kg

Cruising Speed	820 km/h
Cruising Mach Number	0.7685
Design Altitude	11.50 km
Flight Range with Maximum Payload	3500 km
Runway Length for the Base Aerodrome	2.5 km

Engine Number	2
Thrust-to-weight Ratio in N/kg	3.2000
Pressure Ratio	24.00
Assumed Bypass Ratio	5.50
Optimal Bypass Ratio	5.50
Fuel-to-weight Ratio	0.20000

Aspect Ratio	9.6
Taper Ratio	3.8
Mean Thickness Ratio	0.11
Wing Sweepback at Quarter Chord	25 deg
High-lift Device Coefficient	0.93
Relative Area of Wing Extensions	0.000

Wing Airfoil Type supercritical
Winglets not installed
Spoilers installed

Fuselage Diameter	3.4 m
Finess Ratio	9.4
Horizontal Tail Sweep Angle	32.0
Vertical Tail Sweep Angle	40.0

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point 0.43318

Induce Drag Coefficient 0.00916

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

Cruising Mach Number	0.76849
Wave Drag Mach Number	0.77408
Calculated Parameter D_m	0.00560

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	4.481
At Middle of Cruising Flight	4.170
At the Beginning of Cruising Flight	4.316

Drag Coefficient of the Fuselage and Nacelles	0.01134
Drag Coefficient of the Wing and Tail Unit	0.00917

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.03127
At Middle of Cruising Flight	0.03072

Mean Lift Coefficient for the Ceiling Flight 0.43318

Mean Lift-to-drag Ratio	14.09883

Landing Lift Coefficient	1.624
Landing Lift Coefficient (at Stall Speed)	2.435
Takeoff Lift Coefficient (at Stall Speed)	2.029
Lift-off Lift Coefficient	1.481
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.682
Start Thrust-to-weight Ratio for Cruising Flight	2.867
Start Thrust-to-weight Ratio for Safe Takeoff	2.915

Design Thrust-to-weight Ratio = 3.136

Ratio $D_r = R_{cruise} / R_{takeoff=}$ 0.913

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

Takeoff	37.1755
Cruising Flight	58.7160
Mean cruising for Given Range	59.6480

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03551
Block Fuel	0.13252

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12624
Horizontal Tail	0.01577
Vertical Tail	0.01832
Landing Gear	0.04317
Power Plant	0.09405
Fuselage	0.17108
Equipment and Flight Control	0.14581
Additional Equipment	0.01310
Operational Items	0.01753
Fuel	0.16804
Payload	0.20886

Airplane Takeoff Weight	43700 kg
Takeoff Thrust Required of the Engine	59.5 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0183
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0007
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0108
Furnishing Equipment Weight Fraction	0.0089
Flight Control Weight Fraction	0.0084
Hydraulic System Weight Fraction	0.0214
Electrical Equipment Weight Fraction	0.0338
Radar Weight Fraction	0.0059
Navigation Equipment Weight Fraction	0.0089
Radio Communication Equipment Weight Fraction	0.0044
Instrument Equipment Weight Fraction	0.0104
Fuel System Weight Fraction	0.0048

Additional Equipment:

Equipment for Container Loading
No typical Equipment Weight Fraction
(Build-in Test Equipment for Fault Diagnosis, 0.0025
Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	250.36 km/h
Acceleration during Takeoff Run	2.39 m/s*s
Airplane Takeoff Run Distance	1008 m

Airborne Takeoff Distance	578 m
Takeoff Distance	1586 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	237.84 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.34 m/s*s
Takeoff Run Distance for Continued Takeoff on Wet Runway	1587.63 m
Continued Takeoff Distance	2166.01 m
Runway Length Required for Rejected Takeoff	2243.86 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	35560 kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	21.8 min
Descent Distance	49.56 km
Approach Speed	244.75 km/h
Mean Vertical Speed	1.98 m/s
Airborne Landing Distance	515 m
Landing Speed	232.0 km/h
Landing run distance	718 m
Landing Distance	1233 m
Runway Length Required for Regular Aerodrome	2059 m
Runway Length Required for Alternate Aerodrome	1751 m