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КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Аванпроект дальномагістрального літака
пасажиромісткістю 320 чоловік»

Виконав: _____ **Данило ГРОМОВ**

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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.

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" ____ " _____ 2023

BACHELOR DEGREE THESIS

Topic: "Preliminary Design of a High-Range Aircraft with 320 Passenger Capacity"

Fulfilled by:

Danylo HROMOV

Supervisor: senior teacher

Oleksandr Yakobchuk

Standards inspector

PhD, associate professor

Volodymyr

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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

ГРОМОВА ДАНИЛА ДМИТРОВИЧА

1. Тема роботи: «Аванпроект далекомагістрального літака пасажиромісткістю 320 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 320, дальність польоту з максимальним комерційним навантаженням 12000 км, крейсерська швидкість польоту 850 км/год, висота польоту 12.6 км.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проєктованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компоновання пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить проєктування персонального місця для ручної поклажі.
5. Перелік обов'язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (A1×1), компоновальне креслення фюзеляжу (A1×1), креслення персональних багажних полицок (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 _____ Олександр ЯКОБЧУК

Завдання прийняв до виконання _____ Данило ГРОМОВ

NATIONAL AVIATION UNIVERSITY

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

APROVED BY

Head of Department,
Professor Dr. of Sc.

_____ Sergiy IGNATOVYCH
" _ " _____ 2023

TASK

for the bachelor's degree thesis

Danylo HROMOV

1. Topic: "Preliminary design of a high-range aircraft with 320 passenger capacity", approved by the Rector's order № 624/CT from 1 May 2023.
2. Period of work: since 29 May 2023 till 25 June 2023.
3. Initial data: cruise speed $V_{cr}=850$ km/h, flight range $L=12000$ km, operating altitude $H_{op}=12.6$ km, 320 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 modified luggage racks (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 works 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: _____

Oleksandr YAKOBCHUK

Student: _____

Danylo HROMOV

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Аванпроект далекомагістрального літака пасажиромісткістю 320 чоловік»:

50 с., 3 рис., 4 табл., 21 літературне джерело

Ця кваліфікаційна робота присвячена проектуванню дальніх пасажирських літаків для перевезення 320 осіб. Основна увага у роботі приділяється розробці персональних місць для ручної поклажі, які будуть розташовані на полицках над головами пасажирів.

У роботі використовується метод порівняльного аналізу існуючих прототипів літаків для вибору оптимальних параметрів для проектування нового літака. Також використовуються інженерні розрахунки для визначення геометричних та компоновальних параметрів, а також для вирішення технічних питань проекту.

Основна мета роботи полягає у поліпшенні безпеки, комфорту та ефективності пасажирських перевезень. Інтегровані у багажні полицки сканери штрих-коду забезпечать достатній рівень приватності, задовільний об'єм для індивідуального багажу та підвищать рівень безпеки пасажирів у разі виникнення аварійної ситуації.

Дипломна робота має практичне значення, оскільки результати дослідження можуть бути застосовані в авіаційній галузі для поліпшення пасажирського комфорту та ефективності перевезень. Крім того, робота може бути корисною в навчанні студентів авіаційних спеціальностей.

Аванпроект літака, кваліфікаційна робота, аванпроект літака, сканери штрих-коду, інженерні розрахунки, багажні полицки

ABSTRACT

Bachelor's degree thesis "Preliminary design of a high-range aircraft with 320 passenger capacity"

50 pages, 3 figures, 5 tables, 21 references

This qualification work is dedicated to the design of long-haul passenger aircraft capable of carrying 320 passengers. The main focus of the work is on implementing barcode scanners into individual storage compartments for carry-on baggage, which will be located in the doors of the overhead baggage bins above the passengers' heads. The work utilizes a method of comparative analysis of existing aircraft prototypes to determine the optimal parameters for the design of the new aircraft. Engineering calculations are also employed to determine the geometric and layout parameters, as well as to address technical aspects of the project.

The primary objective of this work is to enhance the safety, comfort, and efficiency of passenger transportation. Integrated barcode scanners in the baggage shelves will ensure privacy, sufficient space for individual luggage, and enhance passenger safety in the event of an emergency.

The practical significance of this thesis lies in its potential application within the aviation industry to improve passenger comfort and transportation efficiency. Additionally, the research findings can be beneficial in the education of students pursuing aviation-related disciplines.

Preliminary design of an aircraft, qualification work, barcode scanners engineering calculations, luggage

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INTRODUCTION

The aviation industry is a critical component of global transportation and the economy, providing a safe and convenient mode of travel. With continuous advancements in aviation technology, each new aircraft design integrates cutting-edge technology, innovative engineering, and scientific research to enhance safety, reliability, and performance.

The primary goal of this thesis is to develop a modified aircraft that incorporates insights from three distinct aircraft models while identifying the key determinants that influence its efficiency and safety. This research will explore the latest trends and advancements in aviation technology, examining the various approaches and methodologies employed in aircraft design. Furthermore, this thesis will extensively investigate a range of factors that impact aircraft design, encompassing areas such as fuselage structure, wing configuration, and engine specifications.

The main goal of this thesis is to create a better long-distance airplane that can carry 320 passengers. The main idea is to improve the technical quality of luggage compartments by introducing a barcode scanner into them, which will increase the overall safety of passengers and ensure better safety of their personal luggage.

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1.ANALYSIS OF PROTOTYPES AND SHORT DESCRIPTION OF DESIGNED AIRCRAFT

1.1 Choice of the projected data

To guarantee the aircraft's quality and safety, selecting the right design parameters is crucial. These parameters encompass weight attributes, geometric factors, aerodynamic characteristics, and economic considerations. During the initial stage of aircraft design, statistical transfer methods, approximate aerodynamics, and statistical relationships are employed to shape its appearance. Subsequently, in the second phase, a comprehensive aerodynamic calculation is conducted using specific formulas to determine the overall weight, incorporating experimental data.

We took the following prototypes of existing aircraft as the basis for the design: Airbus 350, Boeing 787-9 and Il-96. The Airbus A350 is generally larger than the Il-96 and the Boeing 787-9. The A350 has a longer fuselage and a larger wingspan, allowing it to carry more passengers and cargo compared to the other two aircraft.

Both the Airbus A350 and Boeing 787-9 incorporate advanced technologies to enhance fuel efficiency, reduce noise, and provide a more comfortable flying experience. These include lighter composite materials, more efficient engines, and improved aerodynamics. The Il-96, on the other hand, is an older design and does not incorporate the same level of modern technology found in the A350 and 787-9.

In terms of performance, the A350 and 787-9 excel in fuel efficiency, range, and operational capabilities. They are equipped with more fuel-efficient engines and offer longer range capabilities compared to the Il-96. Additionally, the A350 and 787-9 have better climb and descent performance, enabling them to operate from a wider range of airports.

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flight-related features of the aircraft are directly impacted by its design and aerodynamic layout. Opting for an ideal configuration not only enhances flight safety and consistency but also maximizes operational efficiency, ultimately leading to improved aircraft economy.

1.2 Brief description of the main parts of the aircraft

The Aircraft is designed as a wide-body, twin-aisle aircraft with a high-wing configuration. It is equipped with two turbofan engines mounted on pylons under the wings. The aircraft features a tricycle landing gear system, consisting of a two-wheel nose gear and two four-wheel main landing gears.

1.2.1 Fuselage

The fuselage of the aircraft has a sleek and aerodynamically optimized shape, providing a spacious cabin for passengers and cargo. The tail units follow the traditional configuration, consisting of a vertical stabilizer (rudder) and a horizontal stabilizer (stabilizer) with height controls.

1.2.2 Wing

The wing design incorporates a high aspect ratio and a subtle sweep for improved aerodynamic performance. The wing is a continuous structure from root to tip, without a centerplane or separate consoles. The wing is swept backward, meaning it angles rearward from the root (where it attaches to the fuselage) towards the wingtip. This sweep helps improve the aircraft's handling characteristics, reduces drag, and enhances stability during flight. Additionally, the wing incorporates modern aerodynamic devices, such as winglets or wingtip devices. These devices are located at the wingtip and help reduce drag by minimizing the formation of vortices, which are swirling air currents that can create additional resistance. Winglets improve fuel efficiency and increase the aircraft's range.

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1.2.3 Flight control system

The aircraft is equipped with a sophisticated flight control system that enhances its maneuverability, stability, and overall flight performance. The flight control system of the aircraft consists of several components and technologies working together to ensure safe and efficient flight operations.

One of the key components of the aircraft's flight control system is the fly-by-wire system. Fly-by-wire technology replaces conventional mechanical control systems with electronic systems, allowing for precise and responsive control inputs. In the aircraft, the fly-by-wire system is designed to provide pilot inputs through side-stick controllers, which send electronic signals to the flight control computers.

The flight control computers interpret the pilot's inputs and calculate the necessary control surface movements to achieve the desired aircraft response. These control surface movements include adjustments to the ailerons (wing control surfaces), elevators (horizontal tail control surfaces), and rudder (vertical tail control surface).

The aircraft's flight control system also incorporates various automated features to assist pilots and enhance safety. These features include envelope protection, which prevents the aircraft from exceeding its safe flight parameters, and flight envelope monitoring, which continuously monitors the aircraft's performance and alerts the crew to any deviations.

1.2.4 Landing gear

The landing gear of the aircraft is an important component that enables safe takeoff and landing operations. The aircraft is equipped with a tricycle landing gear configuration, which consists of three main landing gears: a two-wheel nose gear and two four-wheel main landing gears.

The nose gear is located under the aircraft's forward fuselage and is responsible for supporting the front portion of the aircraft during taxiing, takeoff, and landing. It allows for steering the aircraft on the ground and provides stability during ground operations.

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The main landing gears are positioned under the wings, closer to the center of the aircraft. Each main landing gear consists of four wheels, providing increased weight distribution and enhanced load-bearing capacity. These landing gears bear the majority of the aircraft's weight during landing and provide stability and shock absorption upon touchdown.

The landing gears are equipped with shock absorbers or struts, which help absorb the impact forces during landing, reducing the stress exerted on the airframe and providing a smoother landing experience for passengers. Additionally, the landing gears of the aircraft are retractable, meaning they can be raised and stowed inside the aircraft during flight. This retraction mechanism helps reduce drag and improves the aircraft's overall aerodynamic efficiency during cruise.

1.2.5 Tail unit

The tail unit of this aircraft follows a traditional configuration, with a vertical stabilizer and a horizontal stabilizer incorporating elevators. This configuration provides stability, control, and maneuverability during flight, contributing to the overall safety and performance of the aircraft.

The vertical stabilizer is the upright fin located at the rear of the aircraft. It provides stability in the yaw axis and houses the rudder, which is a movable control surface attached to the trailing edge of the vertical stabilizer. The rudder is used by the pilot to control the aircraft's yaw movement, allowing for directional control.

The horizontal stabilizer, also known as the stabilizer, is a horizontal wing-like structure positioned at the tail of the aircraft. It provides stability in the pitch axis. The stabilizer can be adjusted horizontally, typically through a mechanism called an elevator, which is a movable control surface attached to the trailing edge of the stabilizer. The elevator allows the pilot to control the aircraft's pitch movement, enabling changes in altitude.

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Conclusion to the analytic part

Within this analytical section, we have examined several prototype aircraft models, namely the Airbus 350, Boeing 787-9, and Il-96, providing concise descriptions for each. Furthermore, I have presented a conceptual aircraft design, which involves a low-wing monoplane configuration and the inclusion of two turbojet engines. Additionally, I have outlined the significance and characteristics of essential components such as the wing, fuselage, flight control system, landing gear, and tail unit, shedding light on their respective functions and notable attributes.

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2. PRELIMINARY DESIGN OF A MID-RANGE PASSENGER AIRCRAFT

2.1. Geometry calculations for the main parts of the aircraft

2.1.1 Wing geometry calculation

The gross weight, expressed as m_0 , and the specific load applied to it, expressed as P_0 , are used to determine the geometric properties of the wing.

The calculated area of the plane wing is equal to:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{286945.86 \cdot 9.8}{6 \cdot 1000} = 468.68 \text{ m},$$

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

Relative wing extensions area is 0.1.

The wingspan of the aircraft design has been determined as:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{468.68 \cdot 8.22} = 62.06 \text{ m},$$

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

The calculated root chord is equal to:

$$C_{root} = \frac{2S_w \cdot \eta_w}{(1 + \eta_w) \cdot l} = \frac{2 \cdot 468.68 \cdot 3.5}{(1 + 3.5) \cdot 62.06} = 11.74 \text{ m},$$

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

The calculated tip chord is equal to:

$$C_{tip} = \frac{C_{root}}{\eta_w} = \frac{11.74}{3.5} = 3.35 \text{ m},$$

where C_{tip} – tip chord, m .

On board chord for trapezoidal shaped wing was calculated according to the formula:

$$b_{board} = C_{root} \cdot \left(1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}\right) = 11.74 \cdot \left(1 - \frac{(3.5 - 1) \cdot 5.64}{3.5 \cdot 62.06}\right) = 10.46 \text{ m},$$

where b_{board} – wing board chord, m ; D_f – fuselage diameter, m .

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Ailerons are control surfaces on aircraft wings, usually near the trailing edge. The main purpose of the ailerons is to control the roll of the aircraft. By deflecting the ailerons up or down, the pilot can create differential lift on the wings, causing the aircraft to roll left or right.

The following formulas are used to determine the geometry of the ailerons.

Ailerons span of the aircraft design has been determined as:

$$l_{ail} = (0.3...0.4) \cdot \frac{l}{2} = 0.35 \cdot \frac{62.06}{2} = 10.864 \text{ m},$$

where l_{ail} – ailerons span, m.

The calculated aileron area is equal to:

$$S_{ail} = (0.05...0.08) \cdot \frac{S_w}{2} = 0.065 \cdot \frac{468.68}{2} = 15.18 \text{ m},$$

where S_{ail} – ailerons area, m.

The aileron chord is determined using the following formula:

$$C_{ail} = 0.23 \cdot 3.63 = 0.83 \text{ m},$$

where C_{ail} – aileron chord, m.

Flaps and slats are aerodynamic devices on aircraft wings designed to increase lift and improve aircraft performance during takeoff, landing and low speeds.

The geometrical parameters of the slats are as follows:

Calculated chord of slat is equal to:

$$C_s = C_{root} \cdot 0.12 = 11.74 \cdot 0.12 = 1.41 \text{ m},$$

where C_s – chord of slat, m.

The geometrical parameters of the flaps are as follows:

Calculated length of flap is equal to:

$$l_f = (0.3...0.4) \cdot C_w = 0.35 \cdot 3.63 = 1.27 \text{ m},$$

where l_f – length of flap, m.

We will determine the geometric parameters of the ailerons using the formulas below:

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The estimated length of the aileron trim tabs for the project aircraft is equal to:

$$l_{tr} = (0.04...0.06) \cdot S_{ail} = 0.05 \cdot 15.18 = 0.759 \text{ m},$$

where l_{tr} – length of the aileron trim tab, m.

Area of ailerons trim tab.

Since the plane has two engines, we will use the following formula:

$$S_{tail} = (0.04...0.06) \cdot S_{ail} = 0.055 \cdot 15.18 = 0.8349 \text{ m}^2,$$

where S_{tail} – area of ailerons trim tab, m².

Range of aileron deflection upward $\delta_{ail} \geq 20^\circ$; downward $\delta_{ail} \geq 10^\circ$.

The determination of the wing's geometric parameters serves the purpose of achieving the desired lift coefficients for takeoff and landing. By calculating these values based on a specified lift speed and the chosen wing type, optimal performance and efficiency can be achieved during these critical phases of flight.

2.1.2 Fuselage layout calculation

In the development and construction of aircraft, a crucial aspect is the calculation and design of the fuselage shape. The fuselage serves as the primary structural component of the aircraft, ensuring passenger safety and comfort while influencing key characteristics such as weight, aerodynamics, and interior space. The calculation of the fuselage shape considers various factors, including internal and external loads, aerodynamic requirements, and ergonomic functionality. By analyzing the specific requirements and objectives of the aircraft, such as passenger capacity and flight range, an optimal fuselage design can be determined to meet these demands.

When calculating the airframe, static and dynamic resistance, aerodynamic stability and controllability, noise and vibrations must be taken into account.

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

Substituting our values into the formula for obtaining the length of the fuselage, we obtained:

$$l_f = \lambda_f \cdot D_f = 10.24 \cdot 5.64 = 57.75 \text{ m},$$

where D_f – fuselage diameter, m; l_f – length of fuselage, m; λ_f – 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:

$$\lambda_{frp} = (2...5).$$

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

$$l_{fnp} = \lambda_{fnp} \cdot D_f = 1.5 \cdot 10.24 = 15.36 \text{ m},$$

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

Calculated length of the fuselage rear part is equal to:

$$l_{frp} = \lambda_{frp} \cdot D_f = 2.5 \cdot 5.64 = 14.1 \text{ m},$$

where l_{frp} – length of fuselage rear part, m; λ_{frp} – fuselage rear part fineness ratio.

In the case of passenger and cargo aircraft, the size of the passenger lounge or cargo cabin initially determines the center section of the fuselage. One of the main parameters that determines the middle part of the airliner is the height of the passenger cabin.

The width of the cabin where seats are located in two rows (3+3+3) is:

economy class seat width $b_{3ec} = 1455...1650$ (mm).

The distance from the outside of the seat handle to the inside of the fuselage wall $\delta_1 = 40...50$ mm. The distance between the inner and outer wall of the fuselage $\delta_{wall} = 80...120$ mm.

For three seats on one block distribution, we can take the width as:

economy class seat width $b_{3ec} = 1430...1530$ (mm).

For the width of the aisle we can take as: $b_{ais-ec} = 400...510$ (mm).

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For the economy class with the scheme of allocation of seats in a row (3+3+3) determines the appropriate width of the cabin, I choose the following parameters:

The estimated width of the economy class according to the formula is equal:

$$B_{ec} = n_{bl3} \cdot b_{3ec} + n_{aisle} \cdot b_{aisle} + 2 \cdot \delta_1 + 2 \cdot \delta_{wall} = 3 \cdot 1450 + 2 \cdot 450 + 2 \cdot 50 + 2 \cdot 100 = 5370 \text{ mm},$$

where n_{bl3} – number of three-seat blocks; b_{3ec} – width of three-seat blocks for economy class, mm; n_{aisle} – number of aisles; b_{aisle} – width of aisle, mm; δ_1 – distance from the outside of the seat handle to the inside of the wall, mm; δ_{wall} – distance between the inner and outer wall, mm.

The estimated length of the economy class cabin for the aircraft is equal to:

$$L_{ec} = l_1 + L_{sp} (n - 1) + l_2 = 1300 + (35 - 1) \cdot 870 + 260 = 31980 \text{ mm},$$

where L_{ec} – length of economy class cabin, m; l_1 – distance from the wall to the back of the seat in first row, mm; l_2 – distance from the back of the seat in last row to the wall, mm; n – number of rows; L_{sp} – seat pitch, mm.

2.1.3 Luggage compartment

The luggage compartment of an aircraft is an enclosed space where checked baggage, cargo and other thingth of passengers are stored during the flight. It is usually located under the main passenger compartment on commercial aircraft, although some aircraft may have overhead bins or other storage areas.

The standard unit of floor load is equal to $K = 400 \dots 600 \text{ kg/m}^2$

Then, the calculated area of cargo hold is equal to:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo}}{0.6K} = \frac{20 \cdot 320}{0.4 \cdot 500} + \frac{15 \cdot 320}{0.6 \cdot 500} = 48 \text{ m}^2,$$

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

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

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$$V_{cargo} = v \cdot n_{pass} = 0.2 \cdot 320 = 64 \text{ m}^3,$$

where V_{cargo} – cargo compartment volume, m^3 ; v – cargo volume coefficient, m^3 ;

n_{pass} – number of passengers.

2.1.4 Galleys and wardrobes

Galleys and wardrobes are essential components of an aircraft. Galleys serve as the onboard kitchens, providing a range of facilities and equipment for food and beverage preparation and service to passengers and crew. These compact kitchens are equipped with ovens, ranges, and other appliances for heating and cooking. Trolleys, carts, and trays are used for serving meals, drinks, and other necessities during the flight.

The total volume V_G in m^3 and its area S_G in m^2 can be defined as

$$V_G = (0.1 \dots 0.12) \cdot n_{pass} = 0.12 \cdot 320 = 38.4 \text{ m}^3;$$

$$S_G = \frac{V_G}{h_G} = 16.7 \text{ m}^2,$$

where $h_G=2,3$ - the height of the galley.

2.1.5 Lavatories

Lavatories are integral components of an aircraft's interior design, catering to the passengers' sanitary requirements during the flight. The quantity and positioning of the lavatories depend on the aircraft's size and configuration. These compact facilities are thoughtfully designed to maximize space efficiency, ensuring passenger comfort and convenience. Typically equipped with toilets, sinks, and mirrors, aircraft lavatories provide essential amenities for maintaining personal hygiene while adhering to aviation regulations and standards.

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2.1.6 Layout and calculation of basic parameters of tail unit

Determining the optimal placement of the tail is a crucial consideration in aerodynamic design. The longitudinal stability index is calculated by assessing the distance between the center of gravity and the aircraft's focal point, relative to the average value of the wing's aerodynamic chord. Statistical data on the static moment coefficient for the horizontal tail (A_{HTU}) and the vertical tail (A_{VTU}), along with arm correlations (H_{TU} and V_{TU}), are used to estimate the geometric parameters. By referring to a table, we can effectively analyze and make an initial estimation of these parameters. This process ensures that the tail is positioned appropriately to achieve longitudinal stability and optimize aerodynamic performance during flight.

The values of L_{HTU} and L_{VTU} are dependent on various factors. Firstly, they are influenced by the length of the nose and tail sections of the fuselage, as well as the wing's sweptback configuration and its location.

Length of the vertical tail unit is equal to:

$$L_{HTU} = 2.6 \cdot b_{MAC} = 2.6 \cdot 3.2 = 8.32 \text{ m},$$

where L_{HTU} – length of horizontal tail unit, m;

The area of horizontal tail unit is calculated according to the following formulas:

$$A_{HTU} = (0.65 \dots 0.8);$$

$$S_{HTU1} = \frac{b_{MAC} \cdot S_w \cdot A_{HTU}}{L_{HTU}} = \frac{2.74 \cdot 468.68 \cdot 0.7}{8.32} = 34.52 \text{ m}^2,$$

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

$$S_{HTU2} = (0.18 \dots 0.25) \cdot S_w = 0.2 \cdot 468.68 = 93.736 \text{ m}^2.$$

Finally, $S_{HTU} = 93.736 \text{ m}^2$.

The length of the vertical tail unit is approximately equal to the length of the horizontal tail unit:

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Calculation of the rudder trim tab area:

$$S_{tr} = 0.06 \cdot S_{rud} = 0.06 \cdot 20.6 = 1.23 \text{ m}^2,$$

where S_{tr} – rudder trim tab area, m^2 .

Tail unit span determination:

$$L_{ro} = (0.32 \dots 0.5) \cdot l_w = 0.4 \cdot 62.06 = 24.8 \text{ m},$$

where L_{ro} – tail unit span, m.

2.1.7 Landing gear design

The distance from the center of gravity to the main landing gear is determined by the following formula:

$$B_m = (0.15 \dots 0.2) \cdot b_{MAC} = 0.185 \cdot 3.2 = 0.576 \text{ m},$$

where B_m – main wheel axes offset, m.

The estimated wheel base is equal to:

$$B = (0.3 \dots 0.4) \cdot l_f = 0.35 \cdot 57.75 = 20.212 \text{ m},$$

where B – wheel base, m.

Distance between the center of gravity and nose landing gear:

$$B_n = B - B_m = 20.212 - 0.576 = 19.636 \text{ m},$$

where B_n – nose wheel axes offset, m.

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

$$T = (0.7 \dots 1.2) \cdot B = 0.9 \cdot 20.212 = 18.19 \text{ m},$$

where T – wheel track, m.

Nose wheel loading is calculated according to the following formula:

$$F_{nose} = \frac{B_m \cdot m_0 \cdot K_g \cdot 9.81}{B \cdot z} = \frac{0.576 \cdot 286945 \cdot 1.8 \cdot 9.81}{20.212 \cdot 2} = 72198 \text{ N},$$

Where F_{nose} – nose wheel load, N; K_g – dynamics coefficient; z – number of wheels.

Main wheel loading is calculated according to the following formula:

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8.	Engine equipment, fastening units	0.022074	6360.18	0.02	135.85
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Ending table 2.1

1	2	3	4	5	6
9.	Fire protection system	0.014433	4158.58	0.02	88,83
Equipped wing (without fuel and landing gear)			57217.37	1.84	105441.50
10.	The main supports of the landing gear	0.029496	8498.68	3.05	25920.98
11.	Fuel (including aero-navigation stock):	0.40534	116790.61	4.25	495974.54
In total			182506.67	3.44	627337.02

To determine the coordinates of the center of gravity of the equipped wing, the following formulas are used:

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

where X'_w – center of mass for equipped wing, m; 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

The presented table 2.2 provides a list of aircraft objects with engines located beneath the wing where the origin of coordinates is determined by the projection of the nose part of the fuselage onto the horizontal axis. The X axis represents the structural part of the hull.

The CG coordinates of the FEF are determined by 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 2.2

Trim sheet of equipped fuselage

No n/p	Name object	Mass M_i		Coordinate of the center of mass, m	Static mass moment $m_i x_i$, kgm
		relative	absolute kg		
1	2	3	4	5	6
AIRFRAME					
1.	Fuselage (construction)	0.08496	24479.52	30.54	747536.54
2.	Horizontal tail unit	0.00942	2714.18	56.96	154603.55
3.	Vertical tail unit	0.01106	3186.72	56.96	181519.67
EQUIPMENT AND CONTROLS					
4.	Height equipment	0.00546	1573.19	29,26	46039.14
5.	Anti-icing system (30%)	0.003822	1101.23	30.54	33628.59
6.	Passenger equipment	0.0106	3054.18	31,17	95209.14
7.	Decorative paneling and TZS	0.005	1440.65	31,17	44909.97
8.	Household goods:	0.0145	4177.89	31.81	132896.85
9.	Hydraulic system (30%)	0.0036	1037.27	31.81	32995.08
10.	Electrical equipment (90%)	0.02034	5860.56	25.45	149137.76
11.	Location equipment	0.0019	547.45	0.64	348.28
12.	Navigation equipment	0.0029	835.58	3.18	2657.94
13.	Equipment for radio communication	0.0015	432.20	3.18	1374.80

14.	Instrument equipment	0.0034	979.64	2.54	2492.96
15.	Aircraft control systems (70%)	0.00266	766.43	31.81	24379.70
16.	Auxiliary power plant	0.005943	1712.36	62.35	106759.98

Ending table 2.2

1	2	3	4	5	6
Empty fuselage			53899.04	32.59	1756489.93
EQUIPMENT					
17.	Crew		190.00	3.18	604.38
18.	Flight attendants		750.00	31.81	23857.20
19.	Documentation and tools	0.003	432.20	4.45	1924.71
20.	Water (chemical species)		784.00	30.54	23941.18
21.	Additional equipment	0.0053	1527.09	25.45	38860.87
Empty equipped fuselage			57582.32	32.05	1845678.27
22.	Front landing gear support	0.007374	2124.67	8.20	17422.30
In total			59706.99	31.20	1863100.57
COMMERCIAL CARGO					
23.	Passengers		28500.00	32.45	924705.07
24.	Baggage		14820.00	29.90	443133.18
25.	Products (food)		1412.20	33.08	46718.21
In total			104439.19	31,38	3277657.03

After we determined the C.G. of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively to the fuselage nose:

$$T_f \cdot X_f + T_w \cdot (X_{MAC} + X'_w) = T_0 \cdot (X_{MAC} + C),$$

$$T_f \cdot X'_f + T_w \cdot (X_{MAC} + X'_w) = T_0 \cdot (X_{MAC} + C).$$

From here we can determine the wing MAC leading edge position relative to fuselage, means X_{MAC} value by formula:

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

Conclusions to the project part

During this project work, were calculated a two-class passenger plane for 320 passengers with a take-off weight of 28645 kg. This aircraft has 2 GE9X turbofan engines and a tri-cycle landing gear with Goodyear tires. The parameters of the wing, fuselage, tail and landing gear were also calculated. The number of galleys, toilets, wardrobes and their size were determined. In addition, the center of gravity was calculated and drawings of the aircraft were made.

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3. NEW DESIGN OF THE PASSENGER PERSONAL STOWAGE BINS

3.1 Introduction

Aviation has become an integral part of modern society, revolutionizing long-distance travel for passengers. However, as passenger demands for comfort and convenience continue to grow, airlines face new challenges.

Ensuring the safety and preservation of personal belongings and luggage during flights is crucial to enhancing passenger comfort. The conventional overhead luggage compartments, although widely used, have proven to be limited and inconvenient over time. Their restricted capacity and complex usage necessitate a fresh approach to their design.

To address these limitations, a new design for passenger personal luggage compartments is being developed, taking into account passenger experiences and feedback. The aim is to provide ample space for personal belongings and luggage, enhance safety during retrieval, and offer protection against theft.

Incorporating innovative materials and technologies, the new design strives to optimize weight and space utilization. The primary objective of this research is to enhance passenger satisfaction by improving the functional characteristics of personal luggage compartments.

This work will assess the current state of passenger personal luggage compartments, analyze the shortcomings of existing solutions, and propose novel concepts and design strategies to enhance their functionality.

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<i>Head of dep.</i>	<i>Ignatovich S.R.</i>							

3.2 General requirements to the passenger equipment

Safety and passenger comfort are of utmost importance in the aviation industry. To ensure these aspects, there exist strict regulations and standards that govern the design, construction, and operation of passenger equipment. Advisory Circulars (AC), CS 25 (Certification Specifications), and FAR 25 (Federal Aviation Regulations) provide comprehensive guidelines for passenger equipment, driving its development and certification.

Passenger equipment encompasses various components and systems found onboard an aircraft, including seats, restraints, cabin lighting, and emergency equipment. The primary objective of these regulations is to guarantee that the equipment meets essential standards in terms of structural integrity, functionality, performance, and safety.

In addition to the core regulations, Advisory Circulars (ACs) play a significant role by offering supplementary guidance and interpretations of certification standards and regulations. These valuable documents provide further insights into specific procedures, test methods, and acceptable practices related to passenger equipment. By carefully analyzing these advisory circulars, experts gain a deeper understanding of the intent and practical application of the requirements, thereby facilitating the design, testing, and certification processes.

CS 25 (Certification Specifications) and FAR 25 (Federal Aviation Regulations) represent internationally recognized standards that establish minimum safety requirements for transport category aircraft. These extensive standards encompass diverse aspects of aircraft design and operation, including the certification of passenger equipment. Adhering to the stipulations outlined in CS 25 and FAR 25 ensures that passenger equipment meets stringent safety criteria and undergoes thorough testing and evaluation to ascertain its suitability for deployment in commercial aviation.

This analysis specifically focuses on examining the general requirements delineated in the advisory circulars, CS 25, and FAR 25.

By conducting a comprehensive study of these regulatory documents, a comprehensive overview of the requirements governing passenger equipment within the aviation industry is presented.

Key areas covered in these requirements include:

- Seats: Specifications pertaining to structural integrity, occupant protection, emergency evacuation conditions, impact resistance, and seat belt design.
- Emergency Equipment: Guidelines for emergency equipment such as exits, escape slides, life rafts, life jackets, and emergency lighting systems, all geared towards ensuring passenger safety during emergency situations.
- Cabin Interior: Design principles encompassing cabin layout, materials, and other considerations to optimize passenger comfort, accessibility, and safety.
- Toilets: Standards governing toilet design, including size, handicap accessibility, sanitation facilities, and waste disposal systems.
- Safety Briefing Materials: Requirements dictating the provision of safety briefing cards, placards, and displays, aimed at effectively conveying vital safety information to passengers prior to flight.
- Cabin Crew Equipment: Instructions pertaining to cabin crew equipment, encompassing intercom systems, crew seats, crew rest areas, and other equipment essential for facilitating the duties and responsibilities of flight attendants.

As the regulatory landscape continuously evolves, it is imperative for aircraft manufacturers, operators, and designers to remain abreast of the latest regulations and guidance issued by relevant authorities. This ensures ongoing compliance with standards and regulations, ultimately prioritizing the safety and well-being of passengers.

Passenger cabin luggage racks according to EATA and ICAO requires:

1. Size and Capacity: The luggage racks should be designed to accommodate various sizes of carry-on luggage commonly used by passengers. They should have

sufficient capacity to store the required number of bags per passenger. Width: Luggage racks typically have a width ranging from approximately 45 centimeters (18 inches) to 60 centimeters (24 inches). This width allows for standard-sized carry-on bags to fit comfortably. Height: The height of luggage racks varies, but it is typically around 30 centimeters (12 inches) to 40 centimeters (16 inches). This height provides sufficient space for bags to be placed vertically. Depth: Luggage racks have a depth ranging from approximately 40 centimeters (16 inches) to 50 centimeters (20 inches). This depth allows for bags to be stored securely and accommodates various bag sizes.

2. Structural Integrity: The luggage racks must be structurally sound and capable of withstanding turbulence and other dynamic forces experienced during flight. They should be designed to prevent sagging or deformation under load.

3. Weight Limit: There should be a specified weight limit for each luggage rack to ensure passenger safety and prevent overloading.

4. Accessibility: The luggage racks should be easily accessible to passengers and allow for convenient stowage and retrieval of their belongings. The height and position of the luggage racks should be ergonomically designed for passenger convenience

5. Secure Fastening: Luggage racks should have a reliable and secure fastening mechanism to prevent bags from shifting or falling during turbulence or in case of an emergency

6. Material and Finish: The luggage racks should be made of lightweight, durable materials such as aluminum or composite materials to minimize weight while maintaining strength. The surface finish should be resistant to scratches and stains

7. Lighting: The luggage racks should be equipped with adequate lighting to facilitate visibility and easy identification of stored bags

8. Integration with Cabin Design: The luggage racks should seamlessly integrate with the overall cabin design and interior aesthetics of the aircraft.

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9. **Impact on the electrical and electronic systems of the aircraft:** Materials and electronics used in the construction must not create electromagnetic and radiation emitting

3.3 Types of stowage bins currently in use, procedure of the luggage transportation

In the realm of luggage transportation, there exist various types of stowage bins that are presently employed. These bins are designed to accommodate the storage of passenger belongings and are strategically placed within the aircraft cabin. They come in different shapes and sizes to optimize space utilization and provide convenient access for passengers during their journey.

As for the procedure of luggage transportation, it involves a series of well-coordinated steps to ensure a smooth and secure process. Upon arrival at the airport, passengers are advised to check in their luggage at the designated counters. At this stage, the bags are tagged with unique identifiers to facilitate tracking throughout the journey.

Once checked in, the luggage is transported via conveyor belts to undergo security screening. This entails the use of advanced scanning technologies to detect any prohibited items or potential threats. Baggage handlers then carefully load the approved bags onto the aircraft, adhering to strict protocols to maintain proper weight distribution and ensure the safety of all passengers.

Upon arrival at the destination airport, the bags are unloaded from the aircraft and transferred to the baggage claim area. Passengers can retrieve their belongings by presenting their baggage claim tags for verification. Baggage handling personnel monitor this process to ensure accurate matching between passengers and their respective luggage.

In recent years, advancements in technology have played a significant role in improving the efficiency and security of luggage transportation. Automated systems

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for bag drop-off, baggage tracking, and retrieval have streamlined the process, minimizing human errors and enhancing overall passenger experience.

Overall, the types of stowage bins used and the procedure of luggage transportation are crucial components of the aviation industry's commitment to providing safe and reliable travel. Airlines, airports, and baggage handling authorities continuously work together to optimize these processes, ensuring the smooth flow of passenger belongings and maintaining high standards of security and convenience.

3.4 Stowage bin design

The design of stowage bins in aircraft cabins is a critical aspect of maximizing storage space and ensuring passenger convenience. Several key considerations come into play when designing these bins to accommodate various types of passenger belongings effectively.

Firstly, the size and shape of stowage bins are carefully determined to optimize space utilization within the aircraft cabin. The bins are designed to fit seamlessly into the overhead compartments or other designated areas, ensuring efficient use of available space without obstructing the cabin environment.

The accessibility of stowage bins is another important factor. They are designed to allow passengers to easily stow and retrieve their belongings during the flight. This typically involves the incorporation of user-friendly features such as doors or lids that open and close smoothly, along with mechanisms to secure items in place during takeoff, landing, and turbulence.

Durability and strength are critical considerations in stowage bin design. These bins must be capable of withstanding the forces experienced during flight, including vibration and turbulence. They are constructed using robust materials such as lightweight composites or reinforced plastics, ensuring they can withstand the rigors of regular use.

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3.5 Development of own design of luggage racks

The technical problem to be solved is to provide a multi-functional aircraft luggage rack that overcomes the shortcomings of existing technology. By incorporating a barcode reader and improving the structure of the luggage rack, the present invention addresses the problems in the prior art. The technical solution of the present invention is as follows: a multi-functional aircraft luggage rack, comprising a luggage rack, partition plates, and luggage rack doors. The luggage rack is divided into multiple independent luggage rack compartments by multiple partition plates, and the luggage rack doors correspond to the luggage rack compartments. It further includes a barcode reader, intermediate partition plates, limit blocks, and luggage rack locks. The inner wall of the luggage rack compartments is equipped with guide rails, and the limit blocks installed on the intermediate partition plates cooperate with the guide rails to vertically fix the intermediate partition plates within the luggage rack compartments, separating the internal space of the luggage rack compartments into different-sized independent spaces as needed. The luggage rack locks are installed at the interface between the luggage rack compartments and the luggage rack doors. The barcode reader is positioned on the outside of the luggage rack doors, and the opening of the luggage rack locks is controlled by the barcode reader's recognition of the barcodes. The scanner is fixed in the luggage compartment door using self-tapping screws with a Security T slot, which are covered with a plastic panel from the inside of the door. Further technical solutions of the present invention include: the guide rails are two parallel wedge-shaped guide rails. The presented invention is shown at Figure 3.1.

Another further technical solution of the present invention is that there is a magnetic connection between the limit blocks and the guide rails, allowing the intermediate partition plates to change their position relative to the tracks as needed, further adjusting the internal spatial structure of the luggage rack compartments. Another further technical solution of the present invention is that the intermediate partition plates are perforated plates.

Conclusion to the special part

In conclusion, we can say that the proposed improvement of luggage racks for long-haul aircraft does not contradict the basic requirements for luggage racks and has a number of advantages compared to the current luggage racks. Some of the benefits are listed below:

1. **Enhanced Security:** By implementing barcode recognition for opening the luggage rack locks, the invention ensures that only authorized passengers have access to their designated compartments. This prevents unauthorized individuals from tampering with or mistakenly taking others' belongings during the flight.

2. **Efficient Space Utilization:** The use of partition plates and adjustable intermediate partition plates with guide rails allows for flexible division of the internal space within the luggage rack compartments. Passengers can customize the compartments to accommodate different-sized luggage items, optimizing the utilization of available space.

3. **Time and Cost Efficiency:** The multi-functional aircraft luggage rack contributes to a reduction in the aircraft's turnaround time. Passengers can efficiently locate their seats and access their luggage, leading to smoother boarding and disembarking processes. This time-saving feature increases operational efficiency for airlines and potentially generates additional revenue.

4. **Improved Passenger Experience:** The incorporation of a barcode reader allows passengers to quickly locate their designated luggage rack compartments and open them using their boarding passes. This streamlined process reduces the time spent searching for seats and enhances the overall passenger experience.

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