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 надважкого пасажирського далекомагістрального літака з багатокласнимкомпонуванням салону»

Виконав: __________ **Ростислав МАЦІБОРСЬКИЙ**

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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.
_________ Sergiy IGNATOVYCH
"___" ____________ 2023

BACHELOR DEGREE THESIS

Topic: "Preliminary design of super heavy long range passenger aircraft with multi-class layout of passenger cabin"

Fulfilled by: ____________ **Rostislav MATSIBORSKYI**

Supervisor:
PhD, associate professor ____________ **Volodymyr KRASNOPOLSKYI**

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

МАЦІБОРСЬКОГО РОСТИСЛАВА АНДРІЙОВИЧА

1. Тема роботи: «Аванпроект надважкого пасажирського далекомагістрального літака з багатокласним компонуванням салону», 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: маса комерційного навантаження 103420 кг, дальність польоту з максимальним комерційним навантаженням 9000 км, крейсерська швидкість польоту 880 км/год, висота польоту 11 км, габаритні розміри вантажної кабіни.

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 детальну інформацію про вимоги до пасажирських крісел та їх методи тестування, характеристики різних матеріалів які використовуются в обшивці крісел.

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

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	29.05.2023 – 31.05.2023	
2	Вибір та розрахунок параметрів проєктованого літака.	01.06.2023 – 03.06.2023	
3	Виконання компонування літака та розрахунок його центрування.	04.06.2023 – 05.06.2023	
4	Розробка креслень по основній частині дипломної роботи.	06.06.2023 – 07.06.2023	
5	Огляд літератури за проблематикою роботи. Аналіз варіантів завантаження ближньомагістральних літаків.	08.06.2023 – 09.06.2023	
6	Розробка механізму для завантаження негабаритних вантажів.	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 ____________ Володимир КРАСНОПОЛЬСЬКИЙ

Завдання прийняв до виконання ____________ Ростислав МАЦІБОРСЬКИЙ

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

Rostislav MATSIBORSKYI

1. Topic: "Preliminary design of super heavy long range passenger aircraft with multi class layout of passenger cabin", 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: payload 103 tons, flight range with maximum capacity 9000 km, cruise speed 880 km/h, flight altitude 11 km, cargo cabin dimensions.
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, special part: detailed information on the requirements for passenger seats and their testing methods, characteristics of various materials used in seat upholstery.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), design of the passanger chair (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	Cargo loading planning analysis for short range aircraft.	08.06.2023 – 09.06.2023	
6	Development of a mechanism for loading of oversized cargo.	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: ____________ Volodymyr KRASNOPOLSKYI

Student: ____________ Rostislav MATSIBORSKYI

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Аванпроект надважкого пасажирського далекомагістрального літака з багатокласним компонуванням салону»:

57 с., 3 рис., 5 табл., 9 джерел

Дана кваліфікаційна робота присвячена розробці аванпроєкту пасажирського літака для дальномагістральних авіаліній з можливістю транспортування багатьох пасажирів, що відповідає міжнародним стандартам польотів, нормам безпеки, економічності та надійності, а також проєктування матеріалу для обшивки пасажирських крісел в кабіну літака.

В роботі було використано методи аналітичного розрахунку, компьютерного проєктування за допомогою CAD систем, ескізного проєктування матеріалу для обшивки пасажирських крісел з використанням технічних даних подібних матеріалів.

Практичне значення результату кваліфікаційної роботи полягає в підвищенні надійності та ефективності пасажирських повітряних перевезень, підвищення рівня комфорту багатьох пасажирів під час перельоту.

Матеріали кваліфікаційної роботи можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проєктних установ.

Дипломна робота, аванпроєкт літака, компонування, центрування, матеріал обшивки, пасажирське крісло

ABSTRACT

Bachelor degree thesis "Preliminary design of super heavy long range passenger aircraft with multi-class layout of passenger cabin"

57 pages, 3 figures, 5 tables, 9 references

This qualification work is devoted to the development of an advanced design of a passenger aircraft for long-haul airlines with the ability to transport many passengers, which meets international flight standards, safety, efficiency and reliability standards, as well as the design of material for upholstery of passenger seats in the cockpit.

The work used methods of analytical calculation, computer-aided design using CAD systems, and preliminary design of the material for passenger seat upholstery using technical data from similar materials.

The practical significance of the qualification work is to improve the reliability and efficiency of passenger air transport, increase the comfort level of many passengers during the flight.

The materials of the qualification work can be used in the educational process and in the practical activities of designers of specialised design institutions.

Bachelor thesis, aircraft preliminary design, layout, alignment, passenger seat, upholstery material

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 23 07M 00 00 00 12 TW	Task for work	1	
	2	NAU 23 07M 00 00 00 12	Mid-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 23 07M 00 00 00 12 EN	Mid-range passenger aircraft	57	
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 23 07M 00 00 00 12	Design of pilot's seat	1	

	Sh.	№ doc.	Sign	Date	**NAU 23 07M 00 00 00 12 EN**
Done by	Matsiborskyi R.A.				Preliminary design of mid-range passenger aircraft with 150 passenger capacity (List of diploma work)
Supervisor	Krasnopolskyi V.S.				list: Q; sheet: 9; sheets: 57
St.control.	Krasnopolskyi V.S.				**402 ASF 134**
Head of dep.	Ignatovich S.R.				

CONTENT

INTRODUCTION

In modern air transport, aviation plays a key role in global connectivity and economic development. One of the most iconic and majestic symbols in the world of aviation is the Boeing 747, which has contributed significantly to the development of civil aviation and left an indelible mark on the history of the aviation industry.

The purpose of this thesis is to conceptualise and design a new aircraft based on the legendary Boeing 747. This project seeks to apply advanced technologies and innovations in aviation design to create a more efficient, environmentally sustainable and comfortable aircraft that meets modern air transport requirements.

Drawing on a rich aviation heritage, this concept seeks to inherit superior characteristics such as capacity, range and reliability, and complement them with modern technical and conceptual innovations. This work will focus on aerodynamic design, the use of new materials and engine efficiency, with the aim of achieving an optimal balance between performance, cost-effectiveness and environmental sustainability.

An important aspect of this work is also to take into account the growing needs of air transport and the changing requirements of passengers. This concept seeks to create an aircraft that not only meets high standards of safety and comfort, but also offers new opportunities for passengers in entertainment, communication and in-flight work.

In conclusion, this thesis is a unique opportunity to explore and develop a new aircraft concept based on the Boeing 747, which will combine advanced technology with the rich experience and heritage of air transport. The aim of this thesis is that the results will make a significant contribution to the development of aviation and meet the needs of future generations of air transport.

1. TECHNICAL DESCRIPTION OF THE AIRCRAFT

The designed aircraft is a passenger aircraft made according to the type of classical aerodynamic layout, low-wing scheme, and has an all-metal semi-monocoque structure. This aircraft is intended for operation on medium-haul routes with adequately equipped air navigation facilities and at the main type of airfields of class

Structurally, the aircraft is divided into the following elements:

- fuselage, including pressurized cabin for crew and passengers;
- horizontal and vertical tail unit;
- power plant with turbofan engines;
- landing gear;
- torsion box type wing.

1.1 Choise of the projected data

The layout of the aircraft is determined by the relative position of the units, their number and shape. Its aerodynamic and technical and operational properties depend on the scheme and aerodynamic layout of the aircraft. A well-chosen scheme makes it possible to increase the safety and regularity of flights, and the economic efficiency of the aircraft.

The concept aircraft is made according to the low-wing scheme, which is the least advantageous from the point of view of aerodynamics and layout, since in the wing-to-fuselage interface the smoothness of the flow is disturbed and additional resistance arises due to the interference of the wing-fuselage system. This disadvantage can be significantly reduced by setting fairings, providing diffuser effect. From the layout point of view, the low-wing aircraft has a higher location of the lower fuselage contour above the ground. This complicates the process of unloading and loading cargo, luggage, as well as boarding and landing passengers.

The need to maintain a higher position of the fuselage is associated with aircraft ensuring the condition of non-touching by the wing tip during landing with a roll of the runway surface, as well as ensuring the safe operation of the control system when placing engines on the wing.

The designed aircraft has a tricycle landing gear with a nose support. Such a scheme of the landing gear provides the aircraft with high stability during the take-off and landing run, good controllability when moving on the ground and effective braking of the wheels due to the lack of a cowling. Aircraft on which such an undercarriage scheme is implemented have a horizontal position of the longitudinal axis, both in the parking lot and when moving along the airfield, therefore, for pilots, visibility from the cockpit is improved and comfort for passengers is increased.

As a design basis, was taken prototype of the aircraft such as: Boeing 747-400. On the basis of these aircraft I will try to create a competitive aircraft. Statistic data of prototypes are presented in table1.1.

Table 1.1

Operational-technical data of prototypes

PARAMETERS	Boeing 747-400	Designed aircraft
The purpose of airplane	Passenger	Passenger
Crew/flight attend. persons	6/6	6/6
Maximum take-off weight, kg	397000 kg	396890 kg
Maximum payload, $m_{k.max}$, kg	103 000 kg	103 420 kg
Passenger seat	330	300
The height of the flight H_{cr}, m	11000 m	11000 m
Range L, km	9000 km	9000 km
Take-off distance L_{tr}, m	2600 m	2593 m
Number and type of engines	The Pratt & Whitney PW4000	The Pratt & Whitney PW4000
The form of the cross-section fuselage	circular	circular
Fineness ratio of the fuselage	7.6 m	7.6 m
Sweepback on 1/4 chord, °	33	33

1.2 Brief description of the main parts of the aircraft

The plane is a cantilever low-wing monoplane with turboprop engines placed on the wing and twin-cycle landing gear with a front single-strut landing gear and two main gears. Fuselage has circular cross section. Empennage has a conventional design. Rudder and elevators are equipped with aerodynamic balance.

1.2.1 Fuselage

The fuselage has semimonocoque design. It is pressurized between the first and the fourteenth formers.

The fuselage framework consists of formers, longitudinal beams and stringers manufactured from extruded profiles, and working skin.

The cockpit, passenger cabin and all auxiliary units are located in the fuselage. There is a cargo bay behind the cockpit on the lower part of the fuselage, in front of which located a large cargo hatch. In the non-pressurize nose compartment (up to the first frame) the units of radio equipment are located. The passenger cabin is separated of the rest compartments by the bulkhead. In the tail section there is an entrance hall, a sideboard with a flight attendant’s seat, a toilet and wardrobe. At the rear of the compartment is the trunk. On the left side is the passenger front door with a sidewalk.

1.2.2 Wing

The wing of the aircraft has high taper ratio and trapezoidal planform. There is a set of structural elements of different thickness in vertical planform of cross-section, providing good loaded drag during insignificant parasitic, good lateral stability and controllability during significant angles of attack.

The wing is torsion box type. It is divided into a center section, two middle and two detachable parts, joined along ribs with the help of fitting connections.

The wing consists of a central (made by spars, upper and lower panels and ribs), nose and tail parts, end fairings, ailerons and slotted flaps. The wing center section consists of solid-pressed large-sized panels and spars that reduces its weight and greatly simplifies the process of assembly, and also increases the reliability of the design. There are four soft fuel tanks in the torsion box of the center section of the wing. The middle parts of the wing are the sealed fuel tank.

1.2.3 Crew cabin

The cockpit of aircraft meets the highest requirements for comfort and functionality: excellent visibility, low noise level, excellent air conditioning, adjustable seat position. Basic information about flight, navigation and engine operation is displayed on six instrument panels. Color displays make it easier for pilots to understand incoming data about the general condition of the aircraft, the need for repair operations on it, the functioning of control and communication systems, and the operation of engines. The cockpit unified with the Boeing 747, it equipped with LCD displays and Fly-By-Wire controls, the aircraft's fuel efficiency should be 10% better than that of competitors (A330 and MD-11).

Aircraft is equipped with a Fly-by-Wire control system. However, for the convenience of the pilots, it was decided to leave the usual steering columns. Along with the traditional helm control system, the cockpit has a simplified layout that is similar to previous Boeing models. The wireless control system is also equipped with flight parameter protection, which ensures that pilots' movements on the control sticks do not go beyond the set flight configuration limits. Also, the system prevents dangerous maneuvers. True, in case of emergency, the system can be turned off at the command of the pilot.

Places for rest of the crew are presented. They are located above the main cockpit and are equipped with ladders. The seating area consists of two chairs and two beds at the front of the fuselage, as well as several seats at the rear of the fuselage. The aircraft is a long-haul liner capable of serving non-stop commercial flights up to 18 hours in duration. However, the rules of various aviation regulators, professional and trade union organizations limit the hours of continuous work of the crew and flight attendants. For the rest of the pilots, seats are usually reserved in business class or special containers are installed in the luggage compartment, equipped with berths and communication with the cockpit and the cabin of the aircraft. Unfortunately, such solutions reduce passenger capacity or the volume of transported cargo.

Therefore, for this purpose, the space between the luggage racks and the fuselage is used. In the front part of the aircraft above the first-class cabin there is a resting compartment for the pilots. It includes two comfortable armchairs, 2 or 3 beds separated by partitions, a wardrobe, a TV set and a washbasin. The entrance to this compartment is via the stairs located at door (front left door). This solution allows to free up from 4 to 7 seats in business class. Resting places for flight attendants are also equipped in the space between the passenger compartment and the fuselage, but in the rear of the aircraft. The entrance is via a staircase in the central part of the aircraft, and the compartment itself is designed for 6 or 7 flight attendants. The compartment is equipped with berths, lighting and communication with the cabin.

1.2.4 Passenger furnishing

The comfortable and cozy cabin of these aircraft is equipped with comfortable recliners, a modern lighting system Sky Interior, power supplies for mobile devices, as well as widescreen monitors so that can enjoy the onboard entertainment system. Each passenger is provided with high-quality service and full hot meals in accordance with the class of service.

Seats in economy class are placed according to the scheme 3 + 4 + 3

There are no sockets for recharging, however, USB-ports located under the monitors in each seat will help passengers to charge mobile devices. A standard audio jack is mounted on the screens, so can use headphones without an adapter.

Passengers are provided with a plaid, as well as full-fledged hot meals, panini, tea, coffee, juice.

The free Economy class service provides online check-in for a flight, a separate check-in desk at the airport, an increased baggage allowance and hand luggage.

1.2.5 Control system

When designing the first commercial airliner with a fly-by-wire control system, it was decided to leave the usual steering columns, in contrast to the control stick used in many fly-by-wire fighters and in most Airbus airliners.

Along with the traditional steering wheel control system, the cockpit has a simplified layout that remains similar to previous Boeing models.

The fly-by-wire control system is also equipped with a flight parameter protection system, which ensures that pilots' movements on the control levers do not go beyond the specified flight configuration limits and which prevents dangerous maneuvers. This system can be disabled at the command of the pilot if deemed necessary.

1.2.6 Landing gear

The landing gear consists of five struts. All undercarriage struts are retractable. The direction of retraction is counter the flight.

The nose landing gear strut is located under the cockpit compartment. The main landing gear struts are installed under the engine nacelles and retract in flight forward into special compartments under the engines. On a fixed axis of each main strut two wheels with disc brakes are installed. Wheels are equipped with inertial sensors.

In extended and retracted positions landing gear struts are locked with the mechanical locks actuated by the hydraulic cylinders.

Landing gear wheel well are closed by doors while landing gear struts are fully extended or retracted. The doors actuation is performed by mechanisms which kinematically joined with strut actuation system.

The nose landing gear is used for steering. The turn of the nose strut wheel is performed by the actuators powered by aircraft hydraulic system. Besides the extension and retraction, braking, locks opening, doors actuations are performed by hydraulic system too. In case of hydraulic system failure the retraction and extension of a landing gear can be performed with use of mechanical system. In this case the extension of nose or main landing gear is performed partially due to their own weight.

The struts location was chosen to reach the optimum balance between aircraft stability and controllability. That’s why during the calculation of wheel base and the wheel track the centre of gravity of an aircraft should be considered.

1.2.7 Power Plant

The Pratt & Whitney PW4000 engine is a turbofan engine that is widely used on various aircraft models, including the Boeing 747. Here is a brief description of the characteristics and features of the Pratt & Whitney PW4000 engine:

Thrust: The PW4000 engine offers different models with different thrust levels, depending on the specific version and modification. For example, the PW4056, PW4060 and PW4077 models have different thrust levels, allowing the engine to be adapted to the requirements of specific airlines and aircraft types.

Economy: The PW4000 is renowned for its good fuel economy. It is equipped with advanced control systems and advanced technologies to improve fuel efficiency and reduce fuel consumption during flight.

Reliability: the PW4000 engine has a solid construction and a good reputation for reliability. It has undergone numerous tests and certifications to ensure safe and reliable operation during flight.

Soundproofing: the PW4000 features state-of-the-art sound insulation systems which reduce noise levels, providing a more comfortable journey for passengers and lowering the environmental impact.

Compatibility with environmental standards: the PW4000 engine complies with international environmental standards and emission reduction requirements, including nitrogen oxide (NOx) emissions.

The Pratt & Whitney PW4000 engine is a reliable, economical and environmentally sustainable platform that has been used successfully on Boeing 747 aircraft and other models, providing the thrust and performance needed for successful flights.

Conclusions to analytical part

The study examined various aspects and characteristics of the Boeing 747, one of the most significant and recognisable aircraft in aviation history, examining its technical features, including size, seating capacity, cabin configuration, engines and range.

The Boeing 747 has had an enormous impact on the development of civil aviation, providing long-range mass transport of passengers, its capacity and range enabling airlines to fly between continents without refueling, significantly reducing travel time and extending geographic reach.

The aircraft attracts attention with its double-deck configuration to accommodate a large number of passengers and create a comfortable environment for them, this model offers different classes of service, from economy to first class, to meet the different needs of passengers.

An important aspect of the analysis was the Boeing 747's engines, such as the Pratt & Whitney PW4000. These engines provide the necessary thrust and economy, as well as meeting environmental requirements for reduced emissions.

The results of the analysis confirm that the Boeing 747 continues to be a significant achievement in aviation and makes a significant contribution to air transport.

2. Aircraft layout and center of gravity calculation

2.1 Calculations of geometry for the aircraft principles structural units

Aircraft layout calculation is based on the selection of the purpose of the designed aircraft, its main dimensions, and operational requirements.

Layout consists of geometry calculation of principles structural units as wing, fuselage, tail unit, and landing gear. Besides all above mentioned, this analytical part includes choice of power plant and interior scheme. The interior scheme estimation includes dimensional calculation based on aircraft capacity requirements.

This layout was implemented in line with both modern standards and well-established calculation methods.

2.1.1 Wing geometry calculation

Full wing area is:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{256121 \cdot 9.81}{6772} = 370.641\,\text{m}^2$$

where m_0 – take-off weight; g – gravity acceleration; P_0 – specific wing load.

Wing span is:

$$l_w = \sqrt{S_w \cdot \lambda_w} = \sqrt{370.641 \cdot 10.6} = 62.68\,\text{m}$$

where λ_w – wing aspect ratio.

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l_w} = 8.869\,\text{m}$$

where η_w – wing taper ratio.

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} = 2.956 \text{ m}$$

Maximum wing thickness is:

$$c_{\max} = c_w \cdot b_t = 0.11 \cdot 2.956 = 0.325 \text{ m}$$

where c_w – medium wing relative thickness.

On board chord is:

$$b_b = b_0 \cdot \left(1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}\right) = 8.869 \cdot \left(1 - \frac{(3-1) \cdot 7}{3 \cdot 62.68}\right) = 8.208 \text{ m}$$

where D_f – fuselage diameter.

For mean aerodynamic chord determination the geometrical method was used (fig. 1.1). The geometrical method implies the measuring of parallel to the chords line which lies on the intersection of the section connecting the middles of tip and root chords with another section connecting the upper end of tip chord extension (which is equal to the length of root chord) with lower end of root chord extension (which is equal to the length of the tip chord). This method was chosen due to accuracy and simplicity in performance.

Thus, the mean aerodynamic chord is equal 6.4 m.

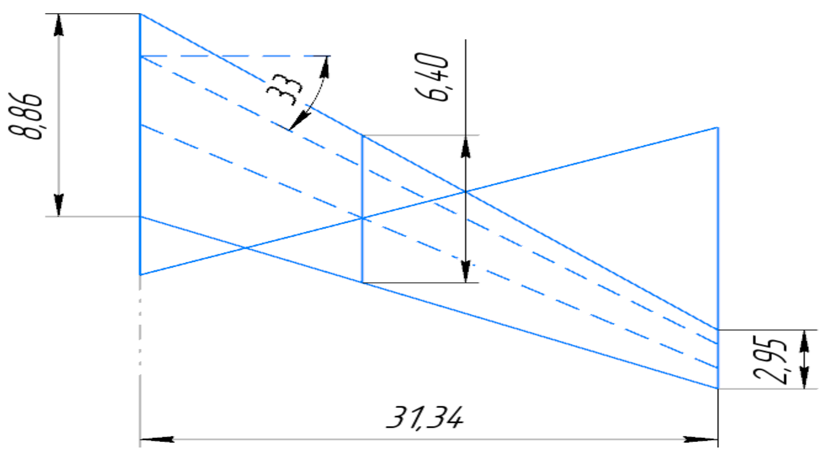

Fig. 1.1. Geometrical method of determination of mean aerodynamic chord.

To choose the force scheme of the wing it is necessary to determine the type of its internal design. The box-spar type with three spars was chosen to meet the requirements of strength and at the same time to make the structure comparatively light.

For wing geometry estimation it is necessary to determine and calculate the main parameters of control surfaces.

Ailerons geometrical parameters are determined in the next order:

Ailerons span is:

$$l_{ail} = (0.3...0.4) \cdot \frac{l_w}{2} = 0.35 \cdot \frac{31.34}{2} = 10.96 \text{ m}$$

Aileron chord is:

$$b_{ail} = (0.2...0.26) \cdot b_t = 0.24 \cdot 0.3982 = 0.095 \text{ m}$$

Aileron area is:

$$S_{ail} = (0.05...0.08) \cdot \frac{S_w}{2} = 0.07 \cdot \frac{370.641}{2} = 12.97 \text{ m}^2$$

The calculated above values are recommended. Increasing of aileron span and chord more than these values are not convenient because with the increase of aileron span the increase of the aileron's coefficient falls, and the high-lift devices span decreases. In the case of aileron chord, its value increase lead to the decreasing of wing box width.

Aerodynamic compensation of the aileron:

Axial $S_{ax.ail} \leq (0.25...0.28) \cdot S_{ail}$

$$S_{ax.ail} = 0.27 \cdot 12.97 = 3.5 \text{ m}^2$$

Area of ailerons trim tab. For four engine airplane:

$$S_{tt} = (0.07...0.08) \cdot S_{ail} = 0.07 \cdot 12.97 = 0.9 \text{ m}^2$$

Range of aileron deflection for upward is 25 degrees, downward is 15 degrees.

2.1.2 Fuselage layout

Generally, the fuselage layout estimation consists of main geometrical dimensions calculation and interior scheme creation.

In case of geometrical calculation, it is necessary to take into account the expected aerodynamic characteristics of designed airplane, typical resistances during normal and extreme flight conditions in accordance with estimated purpose. Airplane's fuselage geometry should allow to avoid high values of parasitic, skin friction and wave drags, withstand the aerodynamic loads and have as greater as possible safety factor value. To decrease form and wave drug and to provide necessary strength characteristics avoiding the stress concentrators in fuselage cross-section the round shape was chosen.

Another part of fuselage calculation as interior scheme creation is based on the required capacity of designed aircraft. Besides that, the requirements of ergonomics and sanitary standards must be considered for passenger aircrafts.

The next steps are necessary to calculate the main geometrical characteristics of the fuselage and consequently to obtain its outline.

Nose part length is:

$$l_{np} = (1.8...3) \cdot D_f = 1.8 \cdot 7 = 12.6 \text{ m}$$

Fuselage length is:

$$l_f = \lambda_f \cdot D_f = 7.6 \cdot 7 = 53.2 \text{ m}$$

where λ_f – fuselage fineness ratio.

Fuselage nose part fineness ratio is:

$$\lambda_{np} = \frac{l_{np}}{D_f} = \frac{12.6}{7} = 1.8$$

Length of the fuselage rear part is:

$$l_{rp} = \lambda_{rp} \cdot D_f = 2.2 \cdot 7 = 15.4 \text{ m}$$

where λ_{rp} – fuselage rear part fineness ratio.

Cabin height is:

$$H_{cab} = 1.48 + 0.17 B_{cab} = 1.48 + 0.17 \cdot 3.76 = 2.12 \text{ m}$$

where B_{cab} – width of the cabin.

For economic class passenger cabin the location of seats in one row (2 + 2) determine the next parameter:

$$B_{cab} = n_{2chblock} \cdot b_{2chblock} + b_{aisle} + 2 \cdot \delta = 2 \cdot 1450 + 550 + 2 \cdot 55 = 3.76 \text{ m}$$

where $n_{2chblock}$ – width of 2 chairs; $b_{2chblock}$ – number of 2 chair block; b_{aisle} – width of aisle.

The length of passenger cabin is:

$$L_{cab} = L_1 + (n_{raws} - 1) \cdot L_{seatpitch} + L_2 = 1200 + (30 - 1) \cdot 900 + 250 = 27.55 \text{ m}$$

where L_1 – distance between the wall and the back of first seat; n_{rows} – number of rows; $L_{seatpitch}$ – seat pitch; L_1 – distance between the back of last seat and the wall.

2.1.3 Luggage compartment

Cargo compartment volume is:

$$V_{cargo} = \nu \cdot n_{pass} = 0.2 \cdot 300 = 60 \text{ m}^3$$

where ν – relative mass of baggage (0.2…0.4 for $D_f \le 4 \text{ m}$ and 0.36…0.38 for $D_f > 4 \text{ m}$); n_{pass} – number of passengers.

Luggage compartment design is similar to the prototype.

2.1.4 Galleys and buffets

Volume of buffets (galleys) is:

$$V_{galley} = (0.1...0.12) \cdot n_{pass} = 0.1 \cdot 300 = 30 \text{ m}^3$$

where V – volume of buffets; n_{pass} – number of passengers.

Area of buffets (galleys) is:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{30}{2.12} = 14.15 \text{ m}^2$$

Number of meals per passenger breakfast, lunch and dinner – 0.7 kg, tea and water – 0.4 kg. Buffet design is similar to prototype.

2.1.6 Layout and calculation of basic parameters of tail unit

The chosen tail unit scheme is conventional. This choice is based on prototype empennage scheme.

To estimate the general tail unit outlines it is necessary to calculate the geometrical dimensions of vertical and horizontal stabilizers and dimensions of control surfaces. In general tail unit must to meet the requirements of aircraft stability and controllability.

Area of vertical tail unit is:

$$S_{VTU} = \frac{l_{wx} \cdot S_w}{L_{VTU}} \cdot A_{VTU} = 48.18 \text{ m}^2$$

where L_{VTU} – length of vertical tail unit; A_{VTU} – coefficient of static momentum of vertical tail unit (see the table in methodical guide).

Area o horizontal tail unit is:

$$S_{HTU} = \frac{b_{MAC} \cdot S_w}{L_{HTU}} \cdot A_{HTU} = 74.12 \text{ m}^2$$

where L_{HTU} – length of horizontal tail unit; A_{HTU} – coefficient of static momentum of horizontal tail unit (see the table in methodical guide).

Determination of the elevator area and direction:

Altitude elevator area is:

$$S_{el} = k_{el} \cdot S_{HTU} = 0.3 \cdot 74.12 = 22.23 \text{ m}^2$$

where k_{el} – relative elevator area coefficient (k_{el} = 0.3…0.4).

Rudder area is:

$$S_{rud} = k_r \cdot S_{VTU} = 0.2 \cdot 48.18 = 9.63\,\text{m}^2$$

where k_r – relative rudder area coefficient (k_r = 0.35…0.45).

Choose the area of aerodynamic balance:

$$0.3 \le M \le 0.6$$

$$S_{eb} = (0.22...0.25) \cdot S_{el} = 0.23 \cdot 22.23 = 5.11\,\text{m}^2$$

$$S_{rb} = (0.2...0.22) \cdot S_{rud} = 0.2 \cdot 9.63 = 1.926\,\text{m}^2$$

where k_{eb} – relative elevator balance area coefficient; k_{rb} – relative rudder balance area coefficient.

The area of altitude elevator trim tab is:

$$S_{te} = k_{te} \cdot S_{el} = 0.08 \cdot 22.23 = 1.778\,\text{m}^2$$

where k_{te} – relative elevator trim tab area coefficient (k_{te} = 0.08…0.12).

Area of rudder trim tab is:

$$S_{tr} = k_{tr} \cdot S_{rud} = 0.8 \cdot 9.63 = 7.7\,\text{m}^2$$

where k_{tr} – relative trim tab area coefficient (k_{tr} = 0.04…0.06 for airplanes with 2 engines and k_{tr} = 0.06…0.1 for airplanes with 4 engines).

Root chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2 \cdot S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot L_{HTU}} = \frac{2 \cdot 74.12 \cdot 2.85}{(1+2.85) \cdot 7.76} = 14.14\,\text{m}$$

where η_{HTU} – horizontal tail unit taper ratio; L_{HTU} – horizontal tail unit span.

Tip chord of horizontal stabilizer is:

$$b_{tHTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{4.71}{2.63} = 1.79\,\text{m}$$

Root chord of vertical stabilizer is:

$$b_{0VTU} = \frac{2 \cdot S_{VTU} \cdot \eta_{VTU}}{(1+\eta_{VTU}) \cdot L_{VTU}} = \frac{2 \cdot 48.18 \cdot 2.63}{(1+2.63) \cdot 14.8} = 4.71\,\text{m}$$

where η_{VTU} – vertical tail unit taper ratio; L_{VTU} – vertical tail unit span.

Tip chord of vertical stabilizer is:

$$b_{tVTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{4.71}{2.63} = 1.79\ \text{m}.$$

2.1.6 Landing gear design

To estimate the landing gear outline in this project it is necessary to calculate the location of every strut relatively to each other, to determine the loads on landing gear system, and its location considering centre of gravity of an airplane. In this layout the principal scheme of landing gear is fully based on the prototype data.

As in the case with the tail unit it is necessary to provide the aircraft with the stable and controllable base during operation on the ground including landing and take-off.

Main wheel axes offset is:

$$e = k_e \cdot b_{MAC} = 0.3 \cdot 6.4 = 1.92\ \text{m}$$

where k_e – coefficient of axes offset (k_e = 0.15…0.3); b_{MAC} – mean aerodynamic chord.

Landing gear wheel base is:

$$B = k_b \cdot L_f = 0.4 \cdot 53.2 = 21.28\ \text{m}$$

where k_b – wheel base calculation coefficient (k_b = 0.3…0.4).

That means that the nose strut holds 5...11% of airplane weight.

Front wheel axial offset is:

$$d_n = B - e = 21.28 - 1.92 = 19.36\ \text{m}$$

Wheel track is:

$$T = k_T \cdot B = 0.7 \cdot 21.28 = 14.896\ \text{m}$$

where k_T – wheel track calculation coefficient (k_T = 0.7…1.2).

Nose wheel load is:

$$P_n = \frac{9.81 \cdot e \cdot k_d \cdot m_0}{B \cdot i} = \frac{9.81 \cdot 1.92 \cdot 1.5 \cdot 396890}{21.28 \cdot 2} = 175646 \text{ N} = 39500 \text{ lbs}$$

where k_d – dynamics coefficient (k_d = 1.5…2.0); i – number of wheels.

Main wheel load is equal to:

$$P_m = \frac{9.81 \cdot (B-e) \cdot m_0}{B \cdot n \cdot i} = \frac{9.81 \cdot (15.96 - 1.92) \cdot 396890}{15.96 \cdot 5 \cdot 4} = 171255 \text{ N} = 38500 \text{ lbs}$$

where n – number of main landing gear struts.

According the calculated values of wheel loading and take-off speed we can choose the tires for landing gear. From the catalog we got:

for nose landing gear

Flight Leader 431K62-1 with parameters $P_{rated} = 40600 \text{ lbf}$; $V_{rated} = 225 \text{ MPH}$; size H43.5×16.0-21.

for main landing gear

Flight Leader 405K89-2 with parameters $P_{rated} = 39500 \text{ lbf}$; $V_{rated} = 235 \text{ MPH}$; size 40×15.5-16.

The rate of wheel loading is:

for nose wheel $\frac{40600 - 39500}{40600} \cdot 100\% = 2.71\%$

for main wheel $\frac{39500 - 38500}{39500} \cdot 100\% = 2.53\%$

The values are less than 10% so choosed tires can be used for this airplane.

2.2 Determination of the aircraft center of gravity position

2.2.1 Determination of centering of the equipped wing

The distance from the main aerodynamic chord to the centre of gravity of the airplane is called the centering. Due to changing of the aircraft loading variants or changing of the weight during flight the position of aircraft centre of gravity is changing. The moving of the cargo inside the aircraft leads to changing of centre of mass position too.

The centering is important aircraft characteristic as it affects on the balancing, stability and controllability of the aircraft. That's why it is necessary to keep it inside strict limits.

To calculate the centering, it is necessary to determine the mass of main structural units and devices. The list of the units masses for the aircraft given in the table 2.1. The mass of aircraft is 257050 kg.

The longitudinal static stability of the aircraft is determined by the location of its centre of mass relatively to the focuses. The closer the centre of mass is to the nose part of the aircraft, the more longitudinal stability the aircraft have.

Coordinates of the center of gravity for the equipped wing are:

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

Table 2.1

Trim-sheet of equipped wing masses

#	Object name	Mass		C.G coordinates, m	Mass moment, kgm
		Units	Total mass, kg		
1	2	3	4	5	6
1	Wing (structure)	0.12579	32217.46	2.752	88662.45
2	Fuel system	0.0142	3636.91	2.72	9892.42
3	Flight control system, 30%	0.0011	281.73	3.84	1081.86
4	Electrical equipment, 10%	0.00241	617.25	0.64	395.04
5	Anti-ice system, 40%	0.00688	1762.11	0.64	1127.75
6	Hydraulic systems, 70%	0.00812	2079.70	3.84	7986.06
7	Power plant	0.09006	23066.25	1.7	39212.64
9	Equipped wing without landing gear and fuel	0.24856	63661.43	2.33	148358.21
10	Nose landing gear	0.00404	1034.72	-17.2	-17797.34
11	Main landing gear	0.03238	8293.19	1.2	9951.84
12	Fuel	0.42616	109148.52	1.92	209565.17
13	**Total**	**0.71114**	**182137.88**	**1.92**	**350077.88**

2.2.2 Determination of the centering of the equipped fuselage

The list of the units for the aircraft is given in table 1.4.

The center gravity coordinates of the equipped fuselage are:

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

Table 2.2

Trim-sheet of equipped fuselage masses

#	Objects names	Mass		C.G coordinates, m	Mass moment, kgm
		Units	Total mass		
1	2	3	4	5	6
1	Fuselage	0.0614	15725.83	26.6	418307.06
2	Horizontal tail	0.00775	1984.94	0.852	1691.17
3	Vertical tail	0.00787	2015.67	1.18	2378.49
4	Radar	0.0021	537.85	1	537.85
5	Radio equipment	0.0016	409.79	1	409.79
6	Instrument panel	0.0037	947.65	2	1895.30
7	Aero navigation equipment	0.0031	793.98	2	1587.95
10	Flight control system 70%	0.00259	663.35	29.26	19409.72
11	Hydraulic system 30%	0.00348	891.30	1.92	1711.30
12	Electrical equipment 90%	0.02169	5555.26	26.6	147770.04
13	Not typical equipment	0.0047	1203.77	3	3611.31
14	lining and insulation	0.0065	1664.79	16.93	28176.51
15	Anti ice system, 20%	0.00344	881.06	0.21	187.66
16	Airconditioning system, 40%	0.006880	1762.11	16.93	29823.75
17	Passenger seats (bussiness)	0	0	10	0
18	Passenger seats (economic class)	0.0094	2407.54	19	45743.21
19	Seats of flight attendence	0	0	19	0
20	Seats of pilot	0	0	1.7	0
21	Emergency equipment	0.0037	947.65	8.1	7675.95
22	Lavatory1, galley 1	0.0036	922.04	5	4610.18
23	Lavatory2, galley 2	0.0036	922.04	30	27661.07
24	Operational items	0.0035	906.20	26	23561.21

Ending of table 2.2

1	2	3	4	5	6
25	Additional eguipment	0.0025	640.30	5	3201.51
26	Equipped fuselage without payload	0.163138	41783.1121	18.427326	769951.0341
27	Passengers(economy)	0.081992496	21000	19	399000
28	Passengers(bussiness)	0.005856607	1500	10	15000
29	On board meal	0.001366542	350	30	10500
30	Baggage	0.032211338	8250	20	165000
31	Cargo, mail	0.002537863	650	20	13000
32	Flight attend	0.001171321	300	19	5700
33	Crew	0.000585661	150	2.5	375
34	**Total**	**0.28886**	**73983.1121**	**18.63298251**	**1378526.034**

2.2.3 Calculation of center of gravity positioning variants

The list of mass objects for center of gravity variants calculation given in Table 1.5 and Center of gravity calculation options given in table 1.6 completes on the base of both previous tables.

The position of mean aerodynamic chord from the nose of the fuselage is:

$$X_{MAC} = \frac{m_f \cdot X_f + m_w \cdot X_w - m_0 \cdot c_n}{m_0 - m_w}$$

where m_0 – aircraft take-off mass, kg

m_f – mass of equipped fuselage, kg

m_w– mass of equipped wing, kg

Table 2.3

Calculation of the C.G. positioning variants

Name	mass in kg	coordinate	mass moment
1	2	3	4
Object	m_i	X_i, м	kgm
Equipped wing (without fuel and landing gear)	63661.44	20.16	1283176.09
Nose landing gear (extended)	1034.73	0.63	647.56
Main landing gear (extended)	8293.20	19.03	157784.97

Ending of table 2.3

1	2	3	4
Fuel reserve	10052.75	19.75	198499.87
Fuel for flight	99095.78	19.75	1956728.27
Equipped fuselage (without payload)	41783.11	18.43	769951.03
Passengers(economy)	21000	19.00	399000.00
Passengers(bussiness)	1500	10.00	15000.00
On board meal	350	30.00	10500.00
Baggage	8250	20.00	165000.00
Cargo, mail	650	20.00	13000.00
Flight attend	300	19.00	5700.00
Crew	150	2.50	375.00
Nose landing gear (retrected)	1034.73	2.13	2199.66
Main landing gear (retrected)	8293.19798	19.03	157784.97

Table 2.4

Airplanes C.G. position variants

Name	Mass kg	mass moment, kgm	centering, %
Take-off mass (L.G. extended)	256121.00	4975362.79	19.42582916
Take-off mass (L.G. retracted)	256121.00	4976914.88	19.43188916
Landing weight (LG extended)	157025.22	3018634,53	19.22388295
Ferry version (without payload, max fuel, LG retracted)	224071.00	4368714.88	19.49701159
Parking version (without payload, without fuel foe flight, LG extended)	124825.22	2410059.53	19.30747207

Conclusions to project part

During this designing work I’ve got the next results:

- preliminary design of the middle range aircraft with 300 passengers;
- the cabin layout of the middle range aircraft with 300 passengers;
- the center of gravity of the airplane calculations;
- the calculation of the main geometrical parameters of the landing gear;
- the chose of the wheels, which satisfy the requirements;
- the design of nose landing gear.

The selected design of the lowplane with four engines located on the wing, increasing the aerodynamic characteristics of the wing, to balance the centre of mass of the aircraft that will positively affect fuel consumption and aerodynamics.

The maximum level of passenger comfort provides:

- rational layout and convenient service facilities;
- ergonomic optimization of common and individual space;
- modern interior design;
- low noise;

Installation of turbofan engines type, Pratt & Whitney PW4000 provides high cruise speed and good thrust-to weight ratio.

PART 3. IMPROVEMENT OF PASSENGER SEAT SKIN

3.1 Aircraft seat requirements

A chair (or a bed for a person who cannot move) must be provided for each person over two years of age. In order to assure the comfort, safety, and general happiness of passengers during flight, airplane seats are a crucial part of the aircraft cabin. A passenger airplane must be designed to carry a specific number of passengers (referred to as a "commercial load") at the least amount of weight for an empty aircraft. This mostly entails deciding on the ideal measurements for the fuselage, passenger cabin, and accessory areas. The major components in the design and production of aircraft seats are outlined in the following precise specifications:

3.1.1 Safety requirements:

Every seat, berth, lap belt, and adjacent components of the aircraft in every seat designed to accommodate occupants during take-off and landing must be constructed so that a person using these features properly won't sustain serious injuries as a result of inertial forces during an emergency landing. Every person in a seat that is angled more than 18 degrees from a vertical plane that runs through the longitudinal axis of the aircraft must wear a lap belt, an energy-absorbing support for their arms, shoulders, head, and spine, or shoulder and lap straps to prevent hitting their heads on anything harmful. Everyone occupying any other seat must be secured with a lap belt and, depending on the style, positioning, and angle of each seat, one or more of the following to prevent head injuries: shoulder restraints that prevent the head from coming into touch with any dangerous objects; removing any injury-causing objects that are outside the head's travel radius; an energy-absorbing support for the spine, head, shoulders, and arms; the maximum overloads, inertia forces, and interactions between the person, seat, lap belt, and harness system for each specific in-flight and on-ground loading condition (including emergency landing conditions) must all be taken into account when designing a seat or berth for a person weighing 77 kg. The sleeping harness does not require a forward-facing overload. Each cockpit seat at work should have a single-point release actuator and a combined lap and shoulder harness system that allows the crew member seated in that cockpit to execute all flight-related tasks while the harness system is fastened. Each combination tether system must include a way to be locked into place when not in use in order to prevent tangles during flight control and quick exits in an emergency.

Standards for flammability shouldn't be ignored either. To reduce the possibility of a fire spreading, airline seats must adhere to high flammability regulations. They are extensively tested to meet regulatory criteria and built using flame-resistant materials. The section on high-quality aircraft materials used in the aircraft cabin will provide more details.

3.1.2 Design reliability:

- Stability and toughness. The pressures and strains experienced during flight, including as turbulence and emergency landings, must be accounted for in the design and construction of the seats. For the passengers' safety, they must be robust and structurally sound. The inertial forces must be multiplied by a safety factor of 1.33 to determine the strength of each seat to structure and each tie-down strap or tether system to the seat or structure. For inertial forces acting laterally, factor 1.33 is taken into consideration in the value of 4g.

- Resistance to impact. To prevent passengers from harm, seats must be able to endure impact, such as during an emergency landing or sudden braking. To make sure the impact resistance standards are met, extensive testing is done. Critical loads in the forward, lateral, downward, upward, and reverse directions (as determined by prescribed in-flight, ground, and emergency landing loading conditions) may be assumed to operate separately in the strength design and testing of seats, berths, and their support structures, or selected load combinations may be used if the necessary strength in each of the prescribed directions is demonstrated.

3.1.3 Location:

Each seat in the passenger cabin designated by the operating regulations for use by a flight attendant during takeoff and landing shall be:

- At floor level, close to the required emergency exit, albeit another position is permitted if it facilitates passenger emergency evacuation.

- There must be a flight attendant chair next to each Type A or Type B emergency exit. If at all possible, additional steward seats ought to be dispersed equitably among the necessary floor-level emergency exits.

- Direct view of the cabin area that the flight attendant is in charge of, as far away from the mandatory emergency exit at floor level as practicable without endangering the position.

- Positioned so that, when unoccupied, the seat does not obstruct access to the passenger aisle or the exit.

- Positioned to reduce the chance that people will be hurt by objects that are knocked loose from storage spaces, servicing equipment, or service areas.

- With an energy-absorbing support that is intended to support the arms, shoulders, head, and spine, and is positioned in either the direction of flight or the opposite direction.

3.1.4 Comfort for passengers:

- Seat width. In order to ensure that passengers are comfortable and do not feel crammed, airplane seats should be wide enough. Economy class chairs typically vary from 17 to 20 inches, while bigger seats may be available in premium class for more comfort.

- Seat pitch: The distance between a position on one seat and the same point on the front or back seat is referred to as seat pitch. It establishes the amount of passenger legroom. In economy class, there are typically 28 to 34 inches between seats, although there is more legroom in first class.

- Ability to recline the seatback. Most airplane cabin seats may recline to some extent, giving passengers the option to change the seat's position for added comfort during lengthy flights. Depending on the carrier and kind of aircraft, the degree of recline may change.

- Armrests: Seats often include two armrests, one on each side, to support and separate occupants, allowing for comfort and personal space.

- Sleepers: Each berth must be built with an upholstered endboard, a bulkhead made of tarpaulin, or an equivalent that can withstand the static reaction force generated by a person experiencing a forward inertial force. The berths must be free of protrusions and corners that could harm the person using them in an emergency.

3.1.5 Functionality and ergonomics:

- Seat Shape and Contour: to give passengers the best support possible, seats are created with ergonomics in mind. They are shaped to support healthy spinal alignment, lessen fatigue, and improve comfort all around.

- Headrests: seats frequently include movable headrests to offer neck support and more comfort, especially on lengthy trips. Different passenger heights can be accommodated by padding the headrests.

- Tray Tables: passengers can usually use the folding tray tables that come with their seats to dine, work, or store personal goods. These tables should have a strong locking mechanism to avoid unintentional folding, be durable, and be simple to operate.

- Seatback Pockets: The front seatback of many sefats has a pocket that allows occupants to conveniently store personal goods like magazines, books, or technological devices.

- Seat Control and Customization: in premium class seats, there are frequently built-in controls that let passengers change the seat's position, lumbar support, and massage settings. These controls provide comfort for passengers and enable customisation.

3.1.6 Salon design and aesthetics:

- Fabrics and upholstery. In addition to meeting safety requirements, seat materials and upholstery must also be aesthetically pleasing, long-lasting, and simple to maintain. Seat cushions, with the exception of flight crew seats, must meet the applicable test criteria specified in Part **7** material test criteria, of this standard or other approved equivalent methods, regardless of the aircraft passenger capacity.

- Color palette and style. The design of the seats reflects the corporate brand and visual character of the airline and coordinates with the general décor of the cabin. A cohesive and aesthetically pleasing ambiance is created in the cabin by the selection of colors, patterns, and design components.

3.1.7 Material test criteria:

- Sample shape. Materials must be tested as either a section cut from the finished part as it is fitted to the aircraft, or as a specimen that simulates the cut-out section, such as a specimen cut from a flat sheet of material or a model of the finished part, with the exception of small parts and insulation of electrical wires and cables. Any location on the completed part may be used to cut the sample. The sample's thickness must not be greater than the minimal thickness required for use on the aircraft. The minimum thickness for samples of thick foam elements, such as seat cushions, is 12.7 mm. Tests on both the warp and weft directions of the yarn weave must be done for fabrics in order to identify the most dangerous flammability state. The top and two long edges of the specimens must be securely secured in the metal frame during vertical testing, and the flame-retarded top and two long edges must be securely clamped in the metal frame during horizontal tests. Unless the actual measurements of the part on the aircraft are smaller, the specimen's open surface must have a width of at least 51 mm and a length of at least 305 mm. The edge of the specimen to which the burner flame is carried must not be its shielded or terminated edge and must instead represent the usual actual cross-section of the material or part used to construct the aircraft. The specimen must be fixed in a metal frame for testing at an angle of 45° so that all four edges are firmly fastened therein and the open surface of the specimen is at least 203x203mm in size.

- Vertical and horizontal testing. The test findings must be averaged over at least 3 specimens. When testing fabrics, the weaving direction corresponding to the most severe flammability conditions must run parallel to the size of the largest specimen. Each specimen needs to be held vertically. A Bunsen or Tirril burner flame with a nozzle having a nominal internal diameter of 9.5 mm and set to a flame height of 38 mm must be used to expose the specimen to the flame. A thermoelectric pyrometer that has been calibrated must measure the flame's minimum temperature at its center at 843 °C. The sample's bottom edge must be 19 mm above the burner's top edge. Along the axis of the sample's lower edge, the flame must be applied. In order to test materials, the flame must be present for 60 seconds before being extinguished. It is necessary to keep track of the time spent burning, the size of the burned area, and, if any, the time spent burning any droplets. To the nearest 1 mm, measure the length of the charring to be calculated.

Testing in the horizontal position has distinct criteria for the sample's placement in space and time while being exposed to the fire than testing in the vertical position. The specimen must be set up so that the tested edge is in the middle of the burner, 19 mm above its upper edge. The flame must be used for 15 seconds before being removed. A minimum of 254 mm of the sample must be consumed before the combustion front reaches the timing zone, and 38 mm of that sample must be used for timing. Recordings of the average combustion rate are required.

- Seat cushions flammability. The following requirements must be met by each seat cushion:

(1) Seat and backrest cushion samples from at least 3 pairs must be evaluated.

(2) The foam core of the cushion must be entirely covered by the fire-retardant material if the cushion was made with that material.

(3) The standard parts (such as foam filler, buoyant material, fire retardant, if utilized, and cover) and assembly techniques (typical seams and joints) anticipated for the production of serial goods must be employed to create each test specimen.

Both material combinations must be tested as full specimen sets, each set consisting of a back cushion specimen and a seat cushion specimen, if a separate combination of materials is utilized for the back cushion and the seat cushion. The charring length from the burner flame must not extend to the cushion's other side for at least 2/3 of the total number of specimen sets tested. The maximum charring length is 432 mm.

The term "charring length" refers to the distance, measured perpendicularly, between the inner edge of the seat frame closest to the burner and the test piece's farthest visible flame damage. This distance includes any areas of the test piece that have been completely or partially destroyed, charred, or brittle, but excludes any areas where the material has been smoked, discolored, warped, or stained, as well as any areas where it has been wrinkled or melted by the heat source.

Additionally, a mass loss of no more than 10% must be present in at least 2/3 of the total number of specimen sets evaluated. The average vertical air velocity at the top of the backrest cushion must be 0.127±0.05 m/s. Directly above the seat cushion, the horizontal air velocity must be less than 0.05 m/s. It is necessary to measure the air velocity with the ventilation on and the burner turned off.

- Equipment and samples.

(1) A seat cushion and a backrest cushion from the same sample set shall be used in each experiment.

(2) The seat cushion sample must meet the following specifications, omitting fabric closures and seam overlaps: width (457±3) mm, depth (508±3) mm, and thickness (102±3) mm.

(3) The back cushion pattern must meet the following specifications, excluding the fabric closure and overlap seams: width (457±3) mm, height (635±3) mm, and thickness (51±3) mm.

(4) The specimens need to be matured for a minimum of 24 hours at (21±2) °C and (55±10)% relative humidity.

Mounting pole for specimens. Steel angles are used to construct the mounting pole for the test specimens. The mounting pole supports are (305±3) mm tall. The test specimens for the chair's seat and backrest cushions must be mounted on the mounting pole. A suitable drip tray lined with aluminum foil that has the brushed side up must be included with the mounting post as well.

The sample of mounting pole for specimens is shown in (picture 1.)

Test burner. The burner used in the testing must be one that is adapted to resemble a handgun;

(1) be a modified pistol type burner;

(2) have an atomization angle of 80 degrees in their nozzle, with a nominal fuel flow rate of 8.5 l/h at a pressure of 7.0 kg/cm^2;

(3) have a 305 mm tall cone positioned on the feed tube's end with a 152 mm high by 280 mm wide hole;

(4) The burner must have a fuel pressure regulator that is set to the test's nominal flow rate of 7,6 l/h of GOST 305-82 diesel or an equivalent fuel.

The sample of test burner is shown in (picture 2.)

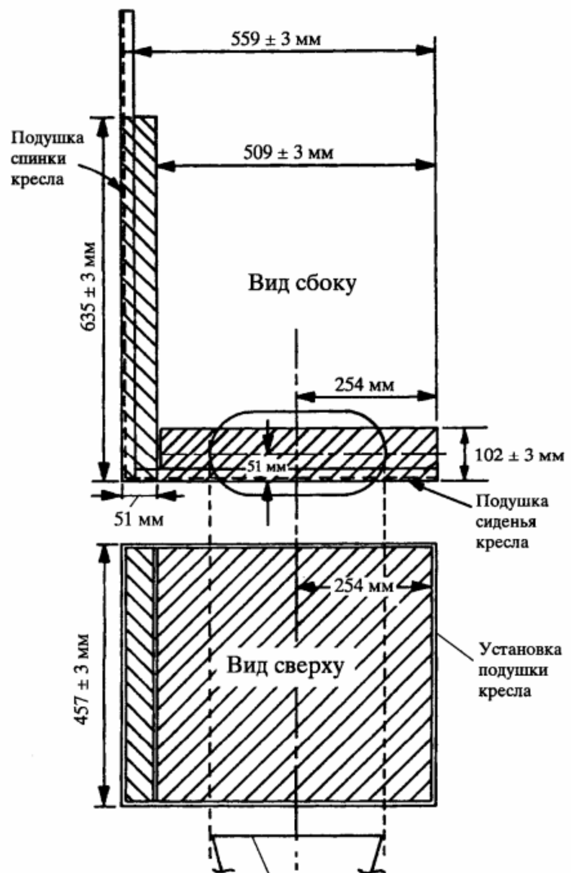

Fig. 3.1. Material mounting frame.

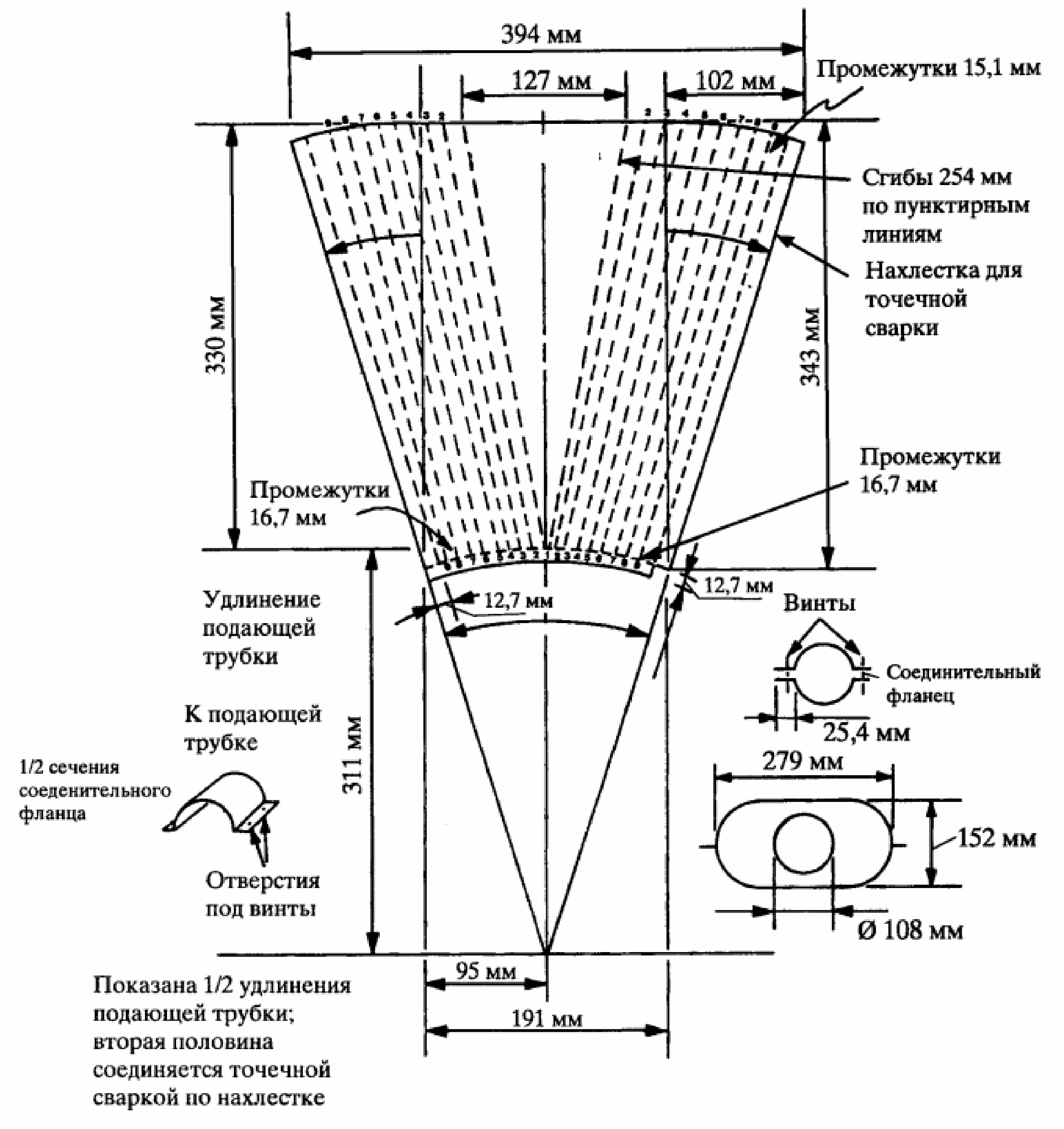

Fig. 3.2. Test burner.

3.2 Familiar materials

Over the decades aviation has used countless materials, including seat upholstery. Today, a variety of materials can be used in aircraft seat upholstery, depending on the specific aircraft model and customer or airline requirements. Some of the most common materials and their basic properties will be presented below:

Natural aero leather is a premium material that combines aesthetic appeal, durability and comfort, making it the ideal choice for aircraft seats. Natural aero leather used to upholster aircraft seats also has a number of special qualities that make it an attractive choice for this purpose:

- Strength and durability: natural aircraft leather is made from high-quality animal skins such as bull, calf or sheep. It has a strong structure which makes it durable and resistant to damage and abrasion. In addition, the leather is impregnated with special solutions that increase its durability and enable it to withstand enormous temperatures. This allows the leather to remain aesthetically pleasing and functional for long periods of time. It is worth noting that leather chairs are replaced about every 5 years, which is an excellent indicator of longevity.

- Natural appearance: natural leather has a unique and natural appearance that lends aviation seats an elegant and luxurious appearance, which is why it is often used in first and business classes. Its texture and hue can vary according to the type of leather and processing, adding personality and style to the aircraft interior.

- Breathability: natural leather is naturally breathable, allowing air to circulate and maintaining a comfortable temperature for the passenger. This is especially important on long flights, where the comfort and satisfaction of the passenger is important.

- Pleasant to the touch: natural leather is soft and smooth, giving a feeling of comfort and luxury when seated in an aircraft seat. It can also warm up in response to body temperature, giving an added sense of comfort.

- Resistant to dust and dirt: natural leather tends to be resistant to dust and dirt, making it easy to clean and maintain. It can be polished and treated to maintain its beauty and lustre. But we shouldn't forget the human element and the untidy people who find it difficult to wipe their hands on the leather seat.

Although leather has an impressive list of advantages, it is not devoid of shortcomings, as well as any existing material. These include its high cost compared to most other alternatives in the lining of the chairs. Natural leather still needs to be properly cared for with special, expensive cleaning products. And also do not forget about the most obvious, for the manufacture of this upholstery killed a huge number of animals. And as modern trends discourage it, leather is being used less and less every year in the aviation industry, giving way to other alternatives.

- Aviation leatherette (also known as aviation synthetic leather) has evolved considerably over recent decades and now has an impressive range of properties that make it a popular material for aircraft seat upholstery:

- Wear resistance: aviation leatherette has a high abrasion resistance which enables it to withstand the repetitive friction and stresses that occur during active use in an aviation environment. This contributes to the aesthetic appearance and durability of the material. Over the last 30 years, the average service life of seats with this liner has extended from 3 to 5 years.

- Resistance to fire: one of the important properties of an aircraft leatherette is its ability to be self-extinguishing. This is a property which it possesses through special impregnations. This means that it will not support combustion and will not spread fire, which is important for safety in an aviation environment.

- Easy-care and stain-resistant: aviation leather is generally easier to clean and maintain than natural leather. It usually requires no special care and can simply be wiped down with a damp cloth to remove dust or stains. The material also has the ability to repel liquids and be stain resistant. This makes it quick and easy to clean up stains or spills, which is important in aviation environments where accidental spills of drinks or food can occur. Add to that the fact that it is cheaper than leather, and all the facts make it an excellent choice.

- Design versatility: aviation leatherette offers a wide range of colours, textures and finishes to create different styles and designs for seat upholstery. This makes it possible to choose a material that matches the airline's interior and brand.

However, it should be noted that the properties and quality of an aircraft leatherette may vary from manufacturer to manufacturer and product to product. When choosing the material for the upholstery of aircraft seats, it is important to consider safety, comfort, durability and aesthetic preferences. Other disadvantages of this material include its lack of breathability and the ease with which it can be scratched with sharp objects compared to leather.

Aircraft fabric used in the upholstery of aircraft seats has a number of properties that make it a popular material in the aviation industry:

- Air permeability: aircraft fabric generally has good air permeability, even better than leather and even better than leatherette. This allows passengers to sit comfortably for long periods of time. This is particularly important in aviation where comfort and air circulation play an important role.

- Ease of care: fabric is generally easier and more economical to clean and care for than leather. It can easily be cleaned of dust or stains with a hoover or soft brush. Some fabrics are also detachable and washable.

- Design versatility: aviation fabric offers a wide range of colours, patterns and textures, enabling a variety of styles and designs to be created for the aircraft interior. This makes it possible to select a material to suit the requirements, brand and design of the airline.

- Wearability: high quality aircraft fabrics have good abrasion resistance, enabling them to withstand repetitive friction and stresses that occur during active use. They can retain their aesthetic appeal and functionality for long periods of time.

- Lightfastness and flame retardancy: good aircraft fabrics are resistant to fading due to exposure to sunlight. This is important for maintaining the fabric's brightness and colour saturation over long periods of use. Most aviation fabrics are specially treated to make them resistant to combustion. This is important for passenger safety and to prevent the spread of fire should it occur.

It is also worth noting its low cost compared to leather and leatherette. But despite all this, this material has a number of disadvantages, this material is not as premium as its alternatives, so it is used mainly in economy classes. Though this material and not fastidious in cleaning but it is polluted much easier than the above-mentioned counterparts (including human factor contributes to it and unclean people that, in combination with the structure of the material quickly pollutes it). The durability of these chairs is proportionally lower and averages 3 years.

However, it is worth noting that the properties and quality of an aircraft fabric may vary depending on its composition, manufacturer and specific product. It is important to consider safety, comfort and aesthetic preferences when selecting the material for the upholstery of aircraft seats.

3.3 Foam polymers

Foam polymers are materials that have a porous structure and are composed of polymeric polymers. They are multifunctional materials with a number of unique properties and advantages. Here is a detailed description of the properties and advantages of foamed polymers:

- Lightweight: foam polymers have a very low density which makes them lightweight materials. They have high strength at low weight, which is particularly important in the aerospace, automotive and aerospace industries where even a slight reduction in weight is critical to improve efficiency and fuel economy.

- Insulation and breathability: foam polymers have low thermal conductivity and excellent ventilation due to their porous structure. This makes them excellent materials for long flights, and will allow a comfortable temperature to be maintained under all conditions.

- Damping properties: due to their porous structure, foamed polymers have excellent cushioning properties. They are able to absorb and dissipate energy on impact and vibration, making them ideal for use in safety elements, shock absorbers and airbags. Seat linings made of this material will not only increase safety but also comfort in turbulence zones and other aircraft jolts.

- Chemical and Contamination Resistance: some foams are highly resistant to chemicals. They are resistant to a variety of chemicals including solvents, acids and alkalis. This makes them durable and virtually eliminates the possibility of soiling or altering the structure of the material.

- Soundproofing: foam polymers have good soundproofing properties due to their porous structure. They can absorb and separate sound waves, which helps to reduce noise and create a more comfortable acoustic environment. This will have a positive impact on people who wish to relax during the flight and on passenger comfort in general.

- Fatigue Resistance: foamed polymers are highly resistant to fatigue and deformation. They can be subjected to repeated stresses and return to their original shape without loss of mechanical properties. Due to its porous structure, even if a cut occurs, the appearance is not spoiled. This makes foam a stable material that can withstand long term stresses and retain its shape even after prolonged use.

- Recyclability and Disposability: apart from the obvious fact that no animals need to be killed to make foams as in the case of leather, they can also be recycled and reused. They can be recycled to create new products or used as aggregate to improve energy efficiency. This makes foams more environmentally friendly and recyclable.

- Variation of properties: foam polymers can be produced with different properties by changing the composition, structure and production process. This makes it possible to create foams with specific characteristics such as elasticity, stiffness, thermal and acoustic insulation, depending on the application required. This material can thus be used with softer properties in the seating area and stiffer ones in the armrests.

- Easy processing and moulding: foam polymers can be easily processed and moulded into a variety of shapes and sizes. They can be easily cut, shaped and bonded, allowing complex structures and products to be created with minimum labour. This will allow the use of one material instead of several others (e.g. threads in stitches and different layers of gaskets).

In general, foams are versatile materials that combine a number of outstanding properties such as lightness, thermal and acoustic insulation, cushioning, chemical resistance and recyclability. These properties make them indispensable in many industries, including aviation.

Conclusions to special part

The study looked at various older materials that have been used in aircraft seat linings and compared them with the one new material proposed in the paper. Various factors such as durability, weight, fire resistance, comfort, environmental sustainability and cost were considered.

The study found that older materials, such as aviation leather and traditional textile materials, had their own advantages and disadvantages. Aviation leather is well-worn, durable and has an aesthetic appearance, but it can be heavy and less environmentally sustainable. Traditional textile materials can be lightweight and more breathable, but may have low resistance to fire.

On the other hand, the new proposed material described in the paper has the potential to overcome some of the disadvantages of older materials. It has high strength, lightness, fire resistance and improved environmental performance. In addition, it can provide improved passenger comfort by providing optimum support and ergonomics.

However, it must be noted that the introduction of this new material requires additional research, testing and evaluation of its compliance with aviation standards and safety requirements. The cost of production and the availability of the new material to airlines should also be considered.

Overall, the results confirm that the choice of seat liner is an important consideration in terms of safety, comfort and aesthetics. The new proposed material represents a potential solution to improve seat upholstery materials, but further research and testing is required to fully evaluate and implement it in the aviation industry.

GENERAL CONCLUSIONS

The study looked in detail at the technical characteristics of the aircraft, including its size, capacity, engines and flight range. Existing materials used in aircraft seat linings were also analysed and new materials were investigated to improve their quality, safety and comfort.

The study found that the technical characteristics of an aircraft play an important role in its performance and flight safety. The size and configuration of an aircraft determines its capacity, which affects the number of passengers it can carry, as well as comfort and cabin space.

Particular attention has been paid to seat shell materials, as they play an important role in creating a comfortable environment for passengers and ensuring flight safety. Our research into new materials has shown that modern technology and innovation is allowing the development of materials with improved properties such as high strength, fire resistance, lightness and durability.

It is important to note that the choice of materials for seat upholstery must consider not only their technical characteristics, but also their compliance with safety standards, regulatory requirements and the requirements of airline operators. Research into new materials may lead to the development of innovative solutions that enhance passenger safety and comfort in the aviation industry.

Overall, the research findings confirm the importance of aircraft performance and the selection of suitable seat shell materials to ensure safety, comfort and enhance the passenger experience. The recommendations proposed in the paper and the development of new materials can form the basis for further research and innovation in aviation technology.

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Appendix

Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger NumberFlight 300
Crew Number 2
Flight Attendant or Load Master Number 6
Mass of Operational Items
3676.55 kg
Payload Mass 33000.00kg

Cruising Speed 880
km/h
Cruising Mach Number
0.8247
Design Altitude 11 km
Flight Range with Maximum Payload 9000
km
Runway Length for the Base Aerodrome 3.30
km

Engine Number 4
Thrust-to-weight Ratio in N/kg
2.8000
Pressure Ratio
24.00
Assumed Bypass Ratio 3.50
Optimal Bypass Ratio 3.50
Fuel-to-weight Ratio
0.4200

Aspect Ratio 10.6
Taper Ratio 3
Mean Thickness Ratio
0.110
Wing Sweepback at Quarter Chord 33.0
degree
High-lift Device Coefficient
1.160
Relative Area of Wing Extensions
0.000

Wing Airfoil Type - supercritical
Winglets - yes
Spoilers - yes

Fuselage Diameter 7.00
m
Finess Ratio 7.60
m
Horizontal Tail Sweep Angle 37.5
degree
Vertical Tail Sweep Angle 45.0

degree

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point
0.50028

Induce Drag Coefficient
0.00892

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

Cruising Mach Number
0.82472

Wave Drag Mach Number
0.83840
Calculated Parameter D_m
0.01368

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	7.032
At Middle of Cruising Flight	5.420
At the Beginning of Cruising Flight	6.772

Drag Coefficient of the Fuselage and Nacelles
0.01380
Drag Coefficient of the Wing and Tail Unit
0.00893

Drag Coefficient of the Airplane:
At the Beginning of Cruising Flight
0.03461
At Middle of Cruising Flight
0.03238
Mean Lift Coefficient for the Ceiling Flight
0.50028

Mean Lift-to-drag Ratio
15.44863

Landing Lift Coefficient
1.571
Landing Lift Coefficient (at Stall Speed)
2.357
Takeoff Lift Coefficient (at Stall Speed)
1.920
Lift-off Lift Coefficient
1.402
Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.554
Start Thrust-to-weight Ratio for Cruising Flight
2.278

Start Thrust-to-weight Ratio for Safe Takeoff
2.469

Design Thrust-to-weight Ratio
2.568

Ratio $D_r = R_{cruise} / R_{takeoff}$
0.923

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

Takeoff	42.2277
Cruising Flight	63.8099
Mean cruising for Given Range	67.3807

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03925
Block Fuel	0.38691

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12579
Horizontal Tail	0.00775
Vertical Tail	0.00787
Landing Gear	0.03643
Power Plant	0.09006
Fuselage	0.06140
Equipment and Flight Control	0.09419
Additional Equipment	0.00719
Operational Items	0.01435
Fuel	0.42616
Payload	0.12885

Airplane Takeoff Weight	256121 kg
Takeoff Thrust Required of the Engine	164.43 kN

Air Conditioning and Anti-icing Equipment Weight Fraction
0.0172
Passenger Equipment Weight Fraction
0.0094
(or Cargo Cabin Equipment)
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction
0.0058
Furnishing Equipment Weight Fraction
0.0109
Flight Control Weight Fraction
0.0037
Hydraulic System Weight Fraction
0.0116
Electrical Equipment Weight Fraction
0.0241
Radar Weight Fraction
0.0021

Navigation Equipment Weight Fraction
0.0031
Radio Communication Equipment Weight Fraction
0.0016
Instrument Equipment Weight Fraction
0.0037
Fuel System Weight Fraction
0.0142

Additional Equipment:

Equipment for Container Loading
0.0047
No typical Equipment Weight Fraction
0.0025
(Build-in Test Equipment for Fault Diagnosis,
Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed
290.39 km/h
Acceleration during Takeoff Run 1.88 m/s^2
Airplane Takeoff Run Distance 2121 m
Airborne Takeoff Distance 472 m
Takeoff Distance 2593 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed
290.15 km/h
Mean Acceleration for Continued Takeoff on Wet Runway 0.77 m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway
2653.91 m
Continued Takeoff Distance
3126.15 m
Runway Length Required for Rejected Takeoff
3242.46 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight
165003 kg
Time for Descent from Flight Level till Aerodrome
Traffic Circuit Flight 21.8 min.
Descent Distance

53.19 km
Approach Speed
262.82 km/h
Mean Vertical Speed 2.10
m/s
Airborne Landing Distance 522 m
Landing Speed
247.82 km/h
Landing run distance 824 m
Landing Distance 1346
m
Runway Length Required for Regular Aerodrome 2247
m
Runway Length Required for Alternate Aerodrome 1911
m

ECONOMICAL EFFICIENCY

THESE PARAMETERS ARE NOT USED IN THE PROJECT