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

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, к.т.н., доцент.
_________ Святослав ЮЦКЕВИЧ
«___» ____________ 2024 р.

КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Система кондиціонування повітря далекомагістрального пасажирського літака»

Виконав:	__________	**Сергій СЕМЕНЧУК**
Керівник: старший викладач	__________	**Юрій ВЛАСЕНКО**
Нормоконтролер: к.т.н., доц.	__________	**Володимир КРАСНОПОЛЬСЬКИЙ**

Київ 2024

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

PERMISSION TO DEFEND
Head of the department,
Associate Professor, PhD.
______ Sviatoslav YUTSKEVYCH
"___" ____________ 2024

BACHELOR DEGREE THESIS
Topic: "The air conditioning system of a long-range passenger aircraft"

Fulfilled by: ____________ **Serhii SEMENCHUK**

Supervisor:
Senior teacher ____________ **Yuriy VLASENKO**

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

Kyiv 2024

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, к.т.н, доцент
________Святослав ЮЦКЕВИЧ
«___» ____________ 2024 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

СЕМЕНЧУКА СЕРГІЯ ДМИТРОВИЧА

1. Тема роботи: «Система кондиціонування повітря далекомагістрального пасажирського літака», затверджена наказом ректора від 15 травня 2024 року № 794/ст.

2. Термін виконання роботи: з 20 травня 2024 р. по 16 червня 2024 р.

3. Вихідні дані до роботи: маса комерційного навантаження – 15675 кг, дальність польоту з максимальним комерційним навантаженням 5000 км, крейсерська швидкість польоту 840 км/год, висота польоту 12 км.

4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, аналіз та робота системи кондиціонування повітря в літаку.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), розрахункові графіки і діаграми, рисунки.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	20.05.2024 – 21.05.2024	
2	Вибір та розрахунок параметрів проектованого літака.	22.05.2024 – 23.05.2024	
3	Виконання компонування літака та розрахунок його центрування.	24.05.2024 – 25.05.2024	
4	Розробка креслень по основній частині дипломної роботи.	26.05.2024 – 27.05.2024	
5	Огляд літератури за проблематикою роботи. Аналіз та пояснення роботи системи кондиціонування повітря на далекомагістральному пасажирському літаку	28.05.2024 – 29.05.2024	
6	Аналіз та експериментальні дослідження функціонування систем кондиціонування повітря.	30.05.2024 – 31.05.2024	
7	Оформлення пояснювальної записки та графічної частини роботи.	01.06.2024 – 02.06.2024	
8	Подача роботи для перевірки на плагіат.	03.06.2024 – 06.06.2024	
9	Попередній захист кваліфікаційної роботи.	07.06.2024	
10	Виправлення зауважень. Підготовка супровідних документів та презентації доповіді.	08.06.2024 – 10.06.2024	
11	Захист дипломної роботи.	11.06.2024 – 16.06.2024	

7. Дата видачі завдання: 20 травня 2024 року

Керівник кваліфікаційної роботи ___________ Юрій ВЛАСЕНКО

Завдання прийняв до виконання ___________ Сергій СЕМЕНЧУК

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 the department,
Associate Professor, PhD.
______ Sviatoslav YUTSKEVYCH
"___" ____________ 2024

TASK

for the bachelor degree thesis

Serhii SEMENCHUK

1. Topic: "The air conditioning system of a long-range passenger aircraft", approved by the Rector’s order № 794/ст from 15 May 2024.
2. Period of work: since 20 May 2024 till 16 June 2024.
3. Initial data: payload 157 tons, flight range with maximum capacity 5000 km, cruise speed 840 km/h, flight altitude 12 km.
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: analysis and explanation of the operation of the air conditioning system on a long-haul passenger plane.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), calculation charts and diagrams, figures.

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	20.05.2024 – 21.05.2024	
2	Selection and calculation of the aircraft designed parameters.	22.05.2024 – 23.05.2024	
3	Performing of aircraft layout and centering calculation.	24.05.2024 – 25.05.2024	
4	Development of drawings on the thesis main part.	26.05.2024 – 27.05.2024	
5	Review of the literature on the problems of the work. Analysis and explanation of the operation of the air conditioning system on a long-haul passenger plane	28.05.2024 – 29.05.2024	
6	Examination and experimental exploration of air conditioning system functionality	30.05.2024 – 31.05.2024	
7	Explanatory note checking, editing, preparation of the diploma work graphic part.	01.06.2024 – 02.06.2024	
8	Submission of the work to plagiarism check.	03.06.2024 – 06.06.2024	
9	Preliminary defense of the thesis.	07.06.2024	
10	Making corrections, preparation of documentation and presentation.	08.06.2024 – 10.06.2024	
11	Defense of the diploma work.	11.06.2024 – 16.06.2024	

7. Date of the task issue: 20 May 2024

Supervisor: ___________ Yuriy VLASENKO

Student: ___________ Serhii SEMENCHUK

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Система кондиціонування повітря далекомагістрального пасажирського літака»:

66 с., 9 рис., 12 табл., 9 джерел

Ця кваліфікаційна робота створена з метою розробки прототипу пасажирського літака, призначеного для використання на дальніх маршрутах міжнародних авіаліній, з дотриманням вимог міжнародних стандартів щодо польотів, безпеки, ефективності та надійності, з додатковою можливістю транспортування вантажів, із системою кондиціонування, яка пройшла аналіз та оцінку її ефективності та відповідності вимогам.

Для виконання роботи використовувалися методи аналітичних розрахунків, комп'ютерного проектування з використанням систем CAD/CAM/CAE та чисельного моделювання, теоретичний аналіз, експериментальні дослідження і моделювання і симуляція.

Практичне значення результатів дослідження полягає в поліпшенні ефективності та надійності системи кондиціонування, що сприяє зменшенню енергоспоживання та покращенню загального функціонування повітряного судна.

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

Дипломна робота, аванпроект літака, компонування, центрування, повітря, фільтр, кондиціонер

ABSTRACT

Bachelor degree thesis "The air conditioning system of a long-range passenger aircraft"

66 pages, 9 figures, 12 tables, 9 references

This qualification project focuses on crafting an initial blueprint for a passenger aircraft tailored for long-distance airline operations, aligning with international flight standards while ensuring safety, cost-effectiveness, and reliability, with the additional possibility of cargo transportation, with an air conditioning system that has undergone analysis and assessment of its efficiency and compliance with requirements.

The design approach relies on analyzing prototypes to identify cutting-edge technical solutions, conducting engineering calculations to acquire the technical specifications of the designed aircraft, and employing computer-aided design (CAD/CAM/CAE) systems. A particular emphasis is placed on numerical modeling in a specific section and theoretical analysis, experimental research and modeling and simulation.

The practical importance of the research findings lies in enhancing effectiveness and reliability of the air conditioning system, which contributes to reducing energy consumption and improving the overall functioning of the aircraft.

The materials of the qualification work can be used in the aviation industry and educational process of aviation specialties.

Bachelor thesis, preliminary design, cabin layout, center of gravity calculation, air, filter, conditioner

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 24 17S 00 00 00 31 EN	Task for work	1	
	2	NAU 24 17S 00 00 00 31	Long-range passenger aircraft	2	
A1		Sheet 1	General view	1	
A1		Sheet 2	Fuselage layout	1	
A4	3	NAU 24 17S 00 00 00 31 EN	Long-range passenger aircraft	66	
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 24 17S 00 00 00 31	Design of wing skin	1	

NAU 24 17S 00 00 00 31 EN

	Sh.	№ doc.	Sign	Date
Done by	Semenchuk S.D.			
Supervisor	Vlasenko Y.V.			
St.control.	Krasnopolskyi V.S.			
Head of dep.	Yutskevych S.S.			

Preliminary design of long-range cargo aircraft
(List of qualification paper)

list	sheet	sheets
Q	9	66

404 ASF 134

CONTENT

INTRODUCTION

While scientific progress has undoubtedly simplified many aspects of life, air travel, while indisputably safe, could use some enhancements. The primary obstacle remains cost. Trains outshine airplanes in terms of affordability, compelling budget-conscious travelers to opt for the slower mode of transportation. Concerns also linger about accidents, even minor incidents with the potential to escalate into major issues. Additionally, the discomfort of prolonged periods in airplane seats, even in the most luxurious ones, cannot be ignored.

However, airplanes boast their own advantages. Aircraft like the Airbus 320 swiftly transport passengers to their destinations, significantly reducing travel time. Onboard amenities such as refreshments, meals, and entertainment options like movies and magazines ensure passengers remain engaged. Moreover, the breathtaking window views offer glimpses of expansive landscapes and captivating cloud formations. Furthermore, airplanes provide access to a wider array of destinations compared to trains or cars.

Inspired by the Airbus 320, my aim is to create a long-range aircraft capable of accommodating 150 passengers. The objective is to maintain the positive aspects of air travel, including speed, comfort, and stunning views, while alleviating drawbacks such as cost and discomfort.

	Sh.	№ doc.	Sign	Date	NAU 24 17S 00 00 00 31 EN		
Done by	Semenchuk S.D.				Introduction	list	sheet	sheets
Supervisor	Vlasenko Y.V.					Q	12	66
St.control.	Krasnopolskyi V.S.				404 ASF 134		
Head of dep.	Yutskevych S.S.						

1. PRELIMINARY DESIGN OF LONG-RANGE AIRCRAFT

1.1. Analysis of prototypes and short description of designed aircraft

To develop an aircraft that aligns with stringent quality and safety standards, it is crucial to carefully choose the most suitable design parameters. These include flight technical, weight, geometric, aerodynamic, and economic characteristics. In establishing the initial "Appearance of the plane," I will employ statistical methods, approximate aerodynamic assessments, and statistical dependencies in the first stage. The subsequent phase will involve a comprehensive aerodynamic calculation, utilizing specified formulas for aggregate weight calculations and incorporating experimental data.

Using prototypes such as the Airbus A320-200, Boeing B737-200, and Airbus A321 as design references, I aim to develop a competitive aircraft [1]. The statistical data for these prototypes is outlined in table 1.1. With this information as a foundation, I'll strive to integrate the best features from each model while also innovating to create an aircraft that stands out in terms of performance, efficiency, and safety.

Table 1.1

Performances of prototypes

PARAMETERS	AIRCRAFTS		
	A320-200	B737-200	A321-100
1	2	3	4
The purpose of airplane	Passenger	Passenger	Passenger
Crew/ attend. persons/flight attend. persons	2/2	2/2	2/2
Maximum take-off weight, kg	77000 kg	52390 kg	93500 kg

Ending of the table 1.1

1	2	3	4
Most pay-load, kg	16600 kg	13600 kg	25300 kg
Passenger's seat	136	149	185
The height of the flight, m	11900 m	11887 m	13 100 m
Range mk.max, km	6150 km	2720 km	5926 km
Take off distance, m	2090 m	2580 m	2180 m
Number and type of engines	2× CFM56-5	2 x Pratt & Whitney JT8D-17	2 x IAE V2500-A5
The form of the cross-section fuselage	round	round	round
Length of the fuselage	37.57 m	30.53 m	44.5 m
Sweepback angle at quarter of the chord, ^{0}	25	25	25

The arrangement of the aircraft parts, their number, and shape determine the overall layout.

For example, the classic layout with a single main wing and tail assembly differs from the "tailless" design, where the traditional tail assembly is absent. The aerodynamic and operational properties of the aircraft depend on its layout and aerodynamic structure. Aircraft with swept wings are generally better suited for high-speed flights, whereas aircraft with straight wings are usually used for low-speed flights and have better takeoff and landing characteristics. A well-chosen layout enhances the safety and regularity of flights. For example, aircraft with two engines mounted under the wings can continue flying even if one engine fails, which increases safety. Economic efficiency also depends on the layout: an optimized arrangement of aircraft parts can reduce aerodynamic drag and, consequently, fuel consumption. This is especially important for commercial airlines, where even a slight reduction in fuel consumption can lead to significant cost savings.

1.2. Brief description of the main parts of the aircraft.

The airplane is configured as a low-wing monoplane with cantilever design, incorporating rear-mounted bypass turbojet engines and a tricycle landing gear arrangement. The landing gear arrangement includes a singular front strut gear, which supports the aircraft's weight, along with two main gears positioned beneath the wings. This design optimizes stability during takeoff, landing, and taxiing maneuvers, ensuring enhanced control and safety throughout the flight. The swept wing boasts a high aspect ratio and is constructed using a new supercritical profile. The fuselage is characterized by a circular cross-section.

In terms of its empennage, the aircraft adopts a T-type construction, with an adjustable vertical stabilizer mounted on the fin. The rudder and elevators are outfitted with aerodynamic balancing features, augmenting their effectiveness in controlling the aircraft's direction and pitch. This design refinement contributes to smoother handling and improved maneuverability, bolstering the overall performance and responsiveness of the aircraft. Additionally, by optimizing aerodynamic balance, the aircraft achieves greater stability and precision during various flight phases, from ascent to descent, ensuring a safer and more comfortable journey for passengers and crew alike.

1.2.1. Fuselage

One of its standout features compared to other modern aircraft is its clever use of a variety of lightweight yet incredibly strong materials. These materials include advanced alloys and composite materials, which are carefully integrated into key parts of the plane's structure. For instance, composite materials are used in critical components like the floor beams in the passenger cabin and the aerodynamic fairings. In fact, these composites make up about nine percent of the total weight of the aircraft's structure. This strategic use of lightweight materials significantly reduces the plane's overall weight, resulting in both lower production costs and a lighter overall load.

As for its design, the main part of the fuselage has a circular shape, transitioning into a sleek tail cone towards the back, where you'll find the auxiliary power unit located.

1.2.2. Wing

The aircraft's wing features a supercritical airfoil profile, initially designed to maximize efficiency at a cruise speed of Mach 0.83. However, following rigorous testing and optimization efforts, the design was further refined to perform optimally at Mach 0.84. This adjustment demonstrates a commitment to enhancing the aircraft's performance, ensuring it remains competitive in the dynamic aviation industry. By fine-tuning the aerodynamic characteristics of the wing, the aircraft achieves improved fuel efficiency, reduced drag, and enhanced stability, ultimately delivering a superior flying experience for passengers and operators alike. In emergency situations, an aircraft turbine is positioned in the wing fairing under the fuselage, featuring a small propeller that extends to provide a minimum power supply.

Significantly, the wings are engineered with heightened thickness and an extended span compared to preceding airliners. This strategic design decision yields several benefits, including increased payload capacity, extended range capabilities, enhanced takeoff performance, and the ability to achieve higher cruising altitudes. Moreover, the wings double as fuel reservoirs, with extended-range variants capable of accommodating up to 47,890 US gallons (181,300 L) of fuel. This substantial fuel capacity empowers the aircraft to undertake ultra-long-distance, trans-polar routes, exemplified by flights from Toronto to Hong Kong. Constructed using cutting-edge composite materials, the wings boast an expanded span and integrate design elements inspired by the innovative features of the 787's wings, further elevating the aircraft's efficiency and performance standards.

The aircraft is equipped with large folding wingtips, measuring 21 feet (6.40 m) long. Originally intended to appeal to airlines with gates designed for smaller aircraft, this option did not attract any purchasers. However, the concept of folding wingtips has been reintroduced with smaller versions measuring 11 feet (3.35 m). The incorporation of smaller folding wingtips enables the aircraft to utilize existing airport infrastructure, including gates and taxiways, without requiring modifications. Importantly, these compact folding wingtips boast simpler design elements compared to those previously proposed for similar aircraft models. Their implementation primarily affects internal wiring for wingtip lights, resulting in reduced complexity during manufacturing and maintenance processes. This innovation streamlines operations and enhances compatibility with established airport facilities, contributing to seamless operations and cost-effective utilization of resources.

1.2.3. Crew cabin

Crafted to adhere to the pinnacle of comfort and functionality, the aircraft's cockpit surpasses industry standards. It provides exceptional visibility, ensuring optimal situational awareness for the crew. Furthermore, meticulous attention has been dedicated to minimizing noise levels within the cockpit, fostering a conducive working environment for pilots. Additionally, the cockpit features efficient air conditioning systems, maintaining a comfortable temperature throughout flights. Moreover, the seats are fully adjustable, accommodating the ergonomic preferences of each pilot and further enhancing comfort during long-haul journeys. This dedication to cockpit design underscores a commitment to prioritizing both pilot well-being and operational efficiency. Key flight, navigation, and engine operation information is displayed on six instrument panels, utilizing color displays for better comprehension of data related to the aircraft's condition, maintenance needs, control and communication systems, and engine operations.

Aligned with the design principles of the Boeing 747, the cockpit is equipped with modern LCD displays and Fly-By-Wire controls, resulting in a remarkable 10%

enhancement in fuel efficiency when juxtaposed with competitors such as the A330 and MD-11 [2]. Despite the adoption of Fly-by-Wire technology, the aircraft preserves traditional steering columns, ensuring familiarity and ease of use for pilots. This integration of advanced avionics and ergonomic design elements underscores a commitment to not only fuel efficiency but also pilot comfort and confidence during flight operations. The cockpit layout resembles previous Boeing models, and the wireless control system includes flight parameter protection to ensure pilots operate within predetermined limits. The system prevents dangerous maneuvers, though it can be disabled in emergencies at the pilot's command.

Rest areas for the crew are situated above the main cockpit and accessible via ladders. The accommodations within the fuselage comprise two chairs and two beds located at the forward section, providing comfort and rest options for crew members during long-haul flights. Additionally, supplementary seating arrangements are available towards the rear of the aircraft, catering to the needs of passengers and crew alike. This thoughtful layout ensures that occupants can relax and recharge throughout the duration of the journey, fostering a comfortable and rejuvenating travel experience. The aircraft, designed for long-haul flights of up to 18 hours, complies with regulations limiting continuous working hours for the crew. Crew rest areas may include business class seats or special containers in the luggage compartment with berths and communication links to the cockpit and cabin. However, such solutions may impact passenger capacity or cargo volume. The space between luggage racks and the fuselage is utilized for this purpose. A dedicated resting compartment for pilots is positioned above the first-class cabin, equipped with comfortable armchairs, beds, a wardrobe, TV, and a washbasin. This arrangement allows the freeing up of business class seats. Additionally, flight attendants have their rest area towards the rear of the aircraft, accessible via a staircase in the central part, accommodating berths, lighting, and communication facilities with the cabin.

1.2.4. Passenger furnishing

The aircraft boasts a comfortable and inviting cabin featuring plush recliners, a state-of-the-art Sky Interior lighting system, power outlets for mobile devices, and widescreen monitors for an enhanced onboard entertainment experience. Every passenger is treated to high-quality service, including full hot meals tailored to the respective service category.

In economy class, seating arrangements follow a 3 + 3 configuration, maximizing space efficiency while ensuring comfort for passengers. This layout allows for optimal utilization of available space within the cabin, providing ample room for passengers to relax during their journey.

While there are no power outlets available for charging purposes, passengers have the convenience of charging their mobile devices via USB ports conveniently situated under the monitors in every seat. This feature ensures that travelers can keep their devices powered throughout the flight, enabling them to stay connected and entertained during their journey. Additionally, the strategic placement of USB ports enhances accessibility, allowing passengers to charge their devices without inconvenience. The screens also feature a standard audio jack, eliminating the need for an adapter when using headphones.

Passengers in Economy class enjoy complimentary amenities, including blankets and a selection of full-fledged hot meals, panini, tea, coffee, and juice. The free service in Economy class extends to online check-in, a dedicated check-in desk at the airport, an expanded baggage allowance, and allowances for hand luggage.

1.2.5. Control system

In pioneering the integration of a fly-by-wire control system in the first commercial airliner, the choice was made to preserve conventional steering columns, departing from the Roller-Controller Unit System (RUS) commonly found in fly-by-wire fighters and numerous Airbus airliners. Alongside the traditional steering wheel control system, the cockpit retains a simplified layout reminiscent of earlier Boeing models, prioritizing familiarity and ease of operation for pilots transitioning to this advanced technology. This deliberate approach underscores a commitment to seamless pilot adaptation and safety in the transition to innovative flight control systems.

The fly-by-wire control system is augmented with a flight parameter protection system, which serves to safeguard against hazardous maneuvers by ensuring that pilots' inputs on the control levers remain within predetermined flight configuration limits. However, pilots retain the discretion to deactivate this system should the circumstances necessitate, allowing for flexibility and adaptability in response to dynamic flight conditions. This dual-layered approach to flight safety underscores a commitment to empowering pilots with the tools and authority needed to effectively manage and mitigate risks during flight operations.

1.2.6. Landing gear

The landing gear of the Airbus A320 comprises a tricycle configuration, including a single nose gear and two main landing gears. This tricycle layout contributes to stability during landing and facilitates effective maneuvering during takeoff and landing.

The main landing gears are known for their high reliability and strength, ensuring safety during landings on various types of runways. Additionally, the landing gear is equipped with shock absorbers to dampen the impact during landings, providing comfort for both passengers and the crew.

A crucial element of the landing gear design is its emphasis on lightweight construction and efficiency, playing a pivotal role in enhancing both the overall performance and fuel efficiency of the Airbus A320. This focus on optimizing the landing gear system underscores Airbus's commitment to maximizing operational efficiency and minimizing fuel consumption, ultimately leading to enhanced cost-effectiveness and environmental sustainability in aviation. Additionally, the lightweight design of the landing gear contributes to improved agility during takeoff and landing maneuvers, further enhancing the aircraft's operational capabilities and safety standards.

The aircraft boasts the largest landing gear and tires ever employed in a commercial jetliner. Specifically engineered six-wheel bogies effectively disperse the aircraft's weight across a broad surface area, obviating the necessity for an additional centerline gear. This pioneering design not only minimizes overall weight but also streamlines the aircraft's braking and hydraulic systems, enhancing operational efficiency and reliability. Furthermore, the robust construction of the landing gear ensures optimal performance and durability, enabling smooth and secure landings even on challenging runways.

Each tire on the six-wheel main landing gear has an impressive load-carrying capacity of 59,490 lb. (26,980 kg), surpassing the capabilities of other wide-body aircraft like the 747-400. This robust landing gear system enhances the overall performance and load-bearing capacity of the Airbus A320.

Conclusions to the analytical part

In conclusion, the design and development of the aircraft have been meticulously planned and executed to meet stringent quality and safety standards while also optimizing for efficiency and passenger comfort. By drawing inspiration from successful prototypes such as the Airbus A320-200, Boeing B737-200, and Airbus A321-100, the aircraft has been crafted to be competitive in the modern aviation market.

Key considerations such as flight technical parameters, weight distribution, aerodynamic characteristics, and economic feasibility have been carefully analyzed and integrated into the aircraft's design. The use of lightweight yet robust alloys and composite materials, especially in critical components like the fuselage and wings, has significantly contributed to reducing the overall weight of the aircraft, thereby improving fuel efficiency and operational costs.

The aircraft's design features a cantilever low-wing monoplane configuration, with rear-placed bypass turbojet engines and a tricycle landing gear setup. The wings, equipped with a supercritical profile and incorporating advanced design features, enable enhanced performance, increased payload capacity, and extended range capabilities.

Overall, the aircraft represents a harmonious balance between innovation, safety, and passenger satisfaction, positioning it as a competitive and reliable option in the commercial aviation industry.

2. AIRCRAFT MAIN PARTS CALCULATIONS

2.1. Geometry calculations for the main parts of the aircraft

The aircraft layout entails organizing the spatial arrangement of its diverse components and structures, accommodating a wide array of loads such as passengers, luggage, cargo, and fuel, among others. This comprehensive design approach ensures optimal utilization of available space within the aircraft, prioritizing efficiency, safety, and comfort for passengers and crew. Additionally, meticulous attention is given to balancing weight distribution and optimizing storage capacity to meet operational requirements and regulatory standards. By meticulously orchestrating the arrangement of various elements, the aircraft layout aims to enhance overall performance, functionality, and versatility across diverse flight missions. It encompasses the strategic organization of the aircraft's internal and external elements to optimize efficiency, balance, and overall performance.

The selection of the composition scheme and aircraft parameters is guided by the paramount consideration of aligning with operational requirements. This meticulous process involves analyzing and evaluating various factors such as performance metrics, regulatory standards, and operational needs to ensure that the chosen configuration optimally meets the demands of diverse flight missions. By prioritizing conformity to operational requirements, aircraft designers aim to achieve optimal efficiency, safety, and reliability throughout the aircraft's lifecycle. Additionally, this approach facilitates the customization of aircraft designs to suit specific operational contexts, enhancing adaptability and versatility across different aviation scenarios.

2.1.1 Wing geometry calculation

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

Full wing area with extensions is:

$$S_{wfull} = \frac{m_o \cdot g}{P_o} = 151.2\ m^2$$

Relative wing extensions area is 0.12.

Wing area is:

$$S_{wing} = 151.2 \cdot 0.8 = 120.97\ \mathrm{m}^2$$

Wing span is:

$$l = \sqrt{s_{wing} \cdot \lambda_w} = \sqrt{120.97 \cdot 9.5} = 33.9\ \mathrm{m}$$

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l_w} = 5.76\ m$$

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} = 1.37\ m$$

Maximum wing width is determined in the forehead i-section and by its span it is equal: $c_i = c_w \cdot b_t = 0.165\ m$

When selecting the power scheme for the wing, we assess factors such as the number and positioning of longerons, as well as the allocation of wing sections. In contemporary aircraft design, the xenon double- or triple-longeron wing configuration is prevalent, particularly in light sport, medical, and personal aircraft. Our aircraft is equipped with three longerons to enhance structural integrity and load-bearing capacity.

To determine the mean aerodynamic chord, I employ a geometrical method as depicted in Figure 2.1. This method allows for accurate calculation of the mean aerodynamic chord, a critical parameter in assessing aerodynamic performance and stability of the aircraft.

Mean aerodynamic chord is equal: $b_{MAC} = 4.02$ m

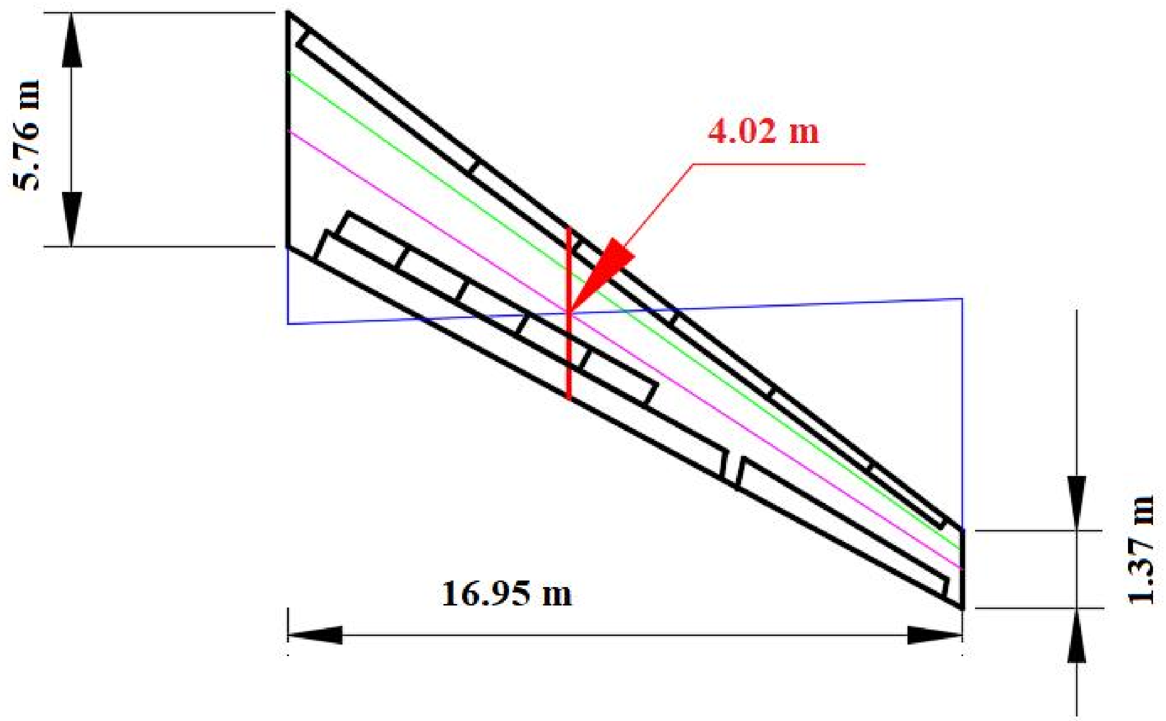

Fig. 2.1. Calculation of average aerodynamic chord.

Once the geometrical characteristics of the wing have been established, we proceed to assess the design and effectiveness of the ailerons, as well as any additional high-lift devices. This phase involves evaluating the dimensions, positioning, and functionality of the ailerons to ensure optimal control and maneuverability of the aircraft. Additionally, we consider the incorporation of high-lift devices such as flaps or slats to enhance lift during takeoff and landing, further refining the aerodynamic performance of the wing system.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{aileron} = 0.375 \cdot \frac{l_w}{2} = 6.36\ m$$

Aileron area:

$$S_{aileron} = 0.065 \cdot \frac{S_w}{2} = 3.93\ m^2$$

Exceeding the recommended values for l_{ail} and bail is neither necessary nor advantageous. An increase in l_{ail} beyond the specified threshold results in a decline in the ailerons coefficient and a reduction in the span of high-lift devices. Similarly, an increase in b_{ail} leads to a decrease in the width of the xenon.

In third-generation aircraft, there is a trend towards reducing the relative wing span and ailerons area, with l_{ail} typically set at 0.122. To maintain effective lateral control, spoilers are utilized in conjunction with ailerons. This combination allows for the potential augmentation of high-lift device span and area, thereby enhancing the aircraft's performance during takeoff and landing maneuvers.

Aerodynamic compensation of the aileron.

Axial:

$$S_{axinail} \leq (0.25\ldots0.28) \cdot S_{ail} = 0.98\ m^2$$

Inner axial compensation:

$$S_{inaxinail} = (0.3..0.31)\ S_{ail} = 1.18\ m^2;$$

Area of ailerons trim tab.

For two engine airplane:

$$S_{tail} = (0.04\ldots0.06) S_{ai} = 0.197\ m^2$$

Range of aileron deflection

Upward $\delta'_{ail} \geq 20^\circ$;

Downward $\delta''_{ail} \geq 10^\circ$.

The objective of establishing the geometrical parameters of wing high-lift devices is to ensure that the calculated coefficients of wing lifting force during takeoff and landing align with the predetermined values. This process considers the selected configuration of high-lift devices and the specific characteristics of the airfoil profile chosen for the wing. By accurately determining these parameters, we aim to optimize the aerodynamic performance of the wing during critical phases of flight, enhancing the aircraft's ability to generate lift and maintain stability during takeoff and landing operations.

Before proceeding with the subsequent calculations, it is essential to select the appropriate airfoil type from the available airfoil catalog, specify the value of lift coefficient $C_{y\max bw}$ and determine necessary increase for this coefficient $C_{y\max}$ for the high-lift devices outlet by the formula:

$$\Delta C_{y\max} = (\frac{C_{y\max l}}{C_{y\max bw}}).$$

Where $C_{y\max l}$ represents the required coefficient of lift force in the landing configuration of the wing, ensuring safe aircraft landing, a parameter determined during the selection of aircraft parameters. In my aircraft exist such types of high-lift devises: slotted flap, spoiler, winglets, slat.

In the modern design the rate of the relative chords of wing high-lift devices is:

b_f = 0.28..0.3 – one slotted and two slotted flaps;

b_s = 0.1..0.15 – slats.

2.1.2. Fuselage layout

When selecting the shape and dimensions of the fuselage cross-section, it is imperative to consider aerodynamic requirements, particularly concerning streamlining and cross-sectional area. This ensures that the fuselage design optimally minimizes drag and enhances overall aerodynamic efficiency, contributing to improved performance and fuel economy of the aircraft. Additionally, careful consideration of aerodynamic demands ensures that the fuselage design maintains stability and control characteristics throughout various flight conditions.

For subsonic passenger and cargo aircraft (with velocities below 800 km/h), wave resistance is negligible and does not significantly impact aerodynamic performance. Therefore, when selecting aerodynamic characteristics, such as friction resistance (C_{xf}) and profile resistance (C_{xp}), we prioritize factors outlined in the specified list of conditions. This ensures that the chosen values effectively account for friction and profile resistance, optimizing aerodynamic efficiency and minimizing drag effects during flight.

During the transonic and subsonic flights, shape of fuselage nose part affects the value of wave resistance C_{xw}. Application of circular shape of fuselage nose part significantly diminishing its wave resistance.

For transonic aircraft, it is essential that the nose section of the fuselage meets specific requirements:

$$l_{nfp} = 2.1 \cdot D_f = 8.82\ m$$

Moreover, addressing aerodynamic requirements when selecting the cross-section shape, it is crucial to take into account strength and layout considerations.

To achieve minimal weight, the most advantageous fuselage cross-section shape is typically circular. This choice minimizes the width of the fuselage skin, contributing to overall weight reduction. As an alternative option, designers may opt for a combination of two or more vertical or horizontal series of circles as a partial case, providing versatility in design while retaining the advantages of circular cross sections. This approach offers greater flexibility in tailoring the fuselage shape to meet specific aerodynamic and structural requirements, allowing for enhanced customization and optimization of aircraft performance. Additionally, the use of multiple circular series enables engineers to achieve a balance between aerodynamic efficiency, structural integrity, and interior space utilization, resulting in a well-rounded design solution.

To geometrical parameters we concern: fuselage diameter D_f; fuselage length l_f ; fuselage aspect ratio λ_f ; fuselage nose part aspect ratio λ_{np} ; tail unit aspect ratio λ_{TU} . The length of the fuselage is established based on various factors including the aircraft's configuration, layout, and the unique characteristics of the airplane's center-of-gravity position. Additionally, careful consideration is given to the conditions required to ensure the appropriate landing angle of attack (α_{land}). This comprehensive approach ensures that the fuselage length is optimized to accommodate the necessary components, maintain proper balance and stability, and facilitate safe landing operations.

Fuselage length is equal:

$$l_f = \lambda_f \cdot D_f = 40.32\ m$$

Length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{frp} \cdot D_f = 9.66\ m$$

When determining the length of the fuselage, our goal is to balance two key considerations: approaching the minimum mid-section (S_{ms}) from one perspective and accommodating layout demands from the other.

For passenger and cargo airplanes, the dimensions of the fuselage mid-section are primarily dictated by the size of the passenger cabin or cargo hold. In the case of passenger aircraft, a critical factor in determining the mid-section is the height of the passenger cabin. This parameter plays a significant role in defining the overall dimensions of the fuselage and ensuring adequate space and comfort for passengers during flight.

For long range airplanes correspondingly: the height as: h_1=1.9m; passage width b_p=0.6m; the distance from the window to the flour h_2=1m; luggage space h_3=0.9...1.3m.

I choose the next parameters:

Cabin height is equal:

$$H_{cab} = 1.48 + 0.17B_{cab} = 1.48 + 0.17 \cdot 3.9 = 2.14\ m$$

While a round cross-section is favored from a design standpoint due to its strength and lightweight characteristics, it may not always be the most practical choice for accommodating passengers and cargo. In many cases, a combination of intersecting circles or an oval fuselage shape proves to be more suitable, allowing for efficient seating and cargo arrangements.

In an economy cabin layout with a seating arrangement of 3 + 3 in each row, it is crucial to ascertain the appropriate width of the cabin to ensure passenger comfort and efficient space utilization.

$$B_{cab} = n_{3block} \cdot b_{3block} + 2 \cdot b_{aisle} + 2\delta = 2 \cdot 1650 + 2 \cdot 50 + 470 = 3.9\ m$$

The length of passenger cabin is equal:

$$L_{econ} = L_1 + (n_{raws} - 1)L_{seatpitch} + L2 = 21\ m$$

2.1.3. Luggage compartment

Given the fact that the unit of load on floor K = 400… 600 kg/m^2

The area of cargo compartment is defined:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo}}{0.6K} = 22.5\ m^2$$

Cargo compartment volume is equal:

$$V_{cargo} = \upsilon \cdot n_{pass} = 0.2 \cdot 150 = 30\ m^3$$

The design of the luggage compartment is modeled after the prototype.

2.1.4. Galleys and buffets

According to international standards, in cases where the aircraft adopts a mixed layout, it is mandatory to provide two galleys. For flights lasting less than 3 hours, the provision of food to passengers is not required, but cupboards for water and tea should be available. However, for flights with a duration of less than one hour, buffets and toilets are not necessary. The location of kitchen cupboards is preferably between the cockpit and passenger or cargo areas, with separate entrances. It is essential to ensure that refreshment and food areas are not situated near toilet facilities or connected to wardrobes, maintaining hygiene and passenger comfort standards.

Volume of buffets(galleys) is equal:

$$V_{galley} = \upsilon \cdot n_{pass} = 0.2 \cdot 150 = 30\ m^2$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = 7\ m^2$$

Number of meals per passenger breakfast, lunch and dinner – 0,8 kg; tea and water – 0,4 kg;

If food organized once it is given a set number 1 weighing 0,62 kg. Food passengers appears every 3.5…4 hour flight.

Buffet design similar to prototype.

2.1.5. Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t> 4:00 one toilet for 40 passengers, at t = 2 ... 4 hours and 50 passengers t <2 hours to 60 passengers.

$$n_{lav} = 4$$

Area of lavatory:

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

Width of lavatory:1m. Toilets design similar to the prototype.

2.1.6. Layout and calculation of basic parameters of tail unit

One of the key objectives of aerodynamic layout is determining the placement of the tail unit. To ensure longitudinal stability, it is crucial to position the center of gravity ahead of the aircraft's center of lift. The distance between these points, relative to the average value of the wing's aerodynamic chord, dictates the degree of longitudinal stability. Additionally, proper tail unit placement contributes significantly to overall flight performance and maneuverability, enhancing the aircraft's handling characteristics during various flight conditions.

$$m_x^{Cy} = \bar{x}_T - \bar{x}_F < 0$$

Where $m^{Cy}{}_x$ –is the moment coefficient; x_T. x_F- center of gravity and focus coordinates. If $m^{Cy}{}_x=0$, than the plane has the neutral longitudinal static stability, if $m^{Cy}{}_x>0$, than the plane is statically instable. In the conventional aircraft configuration where the tail unit is positioned behind the wing, the combined focus of the wing and fuselage shifts rearward during the installation of the tail unit. This adjustment is essential to maintain proper aerodynamic balance and stability, ensuring optimal flight performance and control.

Static range of static moment coefficient: horizontal A_{htu}, vertical A_{vtu} given in the table with typical arm Htu and Vtu correlations. Using table we may find the first approach of geometrical parameters determination.

Determination of the tail unit geometrical parameters

Area of vertical tail unit is equal:

$$S_{VTU}=(0.12..0.20)S = 18.15\ m^2$$

Area o horizontal tail unit is equal:

$$S_{HTU}=(0.18..0.25)S = 24.2\ m^2$$

The values of L_{htu} and L_{vtu} are influenced by various factors, primarily the length of the nose and tail sections of the fuselage, the degree of wing sweepback, and the positioning of the wings. Additionally, these values are dependent on the stability and control characteristics of the aircraft, which play a crucial role in determining the optimal dimensions of the horizontal and vertical tail units. By considering these factors comprehensively, aircraft designers can ensure that L_{htu} and L_{vtu} are appropriately sized to achieve desired levels of stability and maneuverability.
Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = 0.3 \cdot 24.2 = 7.25\ m^2$$

Rudder area:

$$S_{rud} = 0.2 \cdot 18.15 = 3.63\ m^2$$

Choose the area of aerodynamic balance.

$$M \geq 0.75,\ S_{abea} \approx S_{abed} = (0.18\ldots0.2)\ S_e$$

To prevent over balance of the control surface we need to consider:

$$\frac{S_{akea}}{S_{el}} = \frac{S_{aded}}{S_{rud}} \leq 0.3$$

Elevator balance area is equal:

$$S_{eb} = 0.2765 \cdot S_{HTU} = 6.69 \text{ m}^2$$

Rudder balance area is equal:

$$S_{rb} = 0.2337 \cdot S_{VTU} = 4.24 \text{ m}^2$$

The area of altitude elevator trim tab:

$$S_{tb} = 0.08 \cdot S_{el} = 0.58 \text{ m}^2$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.06 \cdot S_{rud} = 0.21 \text{ m}^2$$

The height of the vertical tail h_{VTU} is:

for low-flying aircraft with wing-mounted engines at

$$M<1 \; h_{VTU} = (0{,}14\ldots0{,}2)\; l_{wing}$$

$$h_{VTU} = 6.78 \text{ m}$$

Root chord of horizontal stabilizer is:

$$l_{HTU} = (0.32\ldots0.5)\; l_{wing} = 14.75 \text{ m}$$

$$b_{oHTU} = \frac{2 \cdot S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}} = 2.34\, m$$

Tip chord of horizontal stabilizer is:

$$b_{tHTU} = \frac{b_{oHTU}}{\eta_{HTU}} = 0.94\, m$$

Root chord of vertical stabilizer is:

$$b_{oVTU} = \frac{2 \cdot S_{VTU} \cdot \eta_{VTU}}{(1+\eta_{HTU}) \cdot l_{VTU}} = 2.04\, m$$

Tip chord of vertical stabilizer is:

$$b_{tVTU} = \frac{b_{oVTU}}{\eta_{VTU}} = 1.53\, m$$

2.1.7. Landing gear design

During the initial phase of design, when the position of the aircraft's center of gravity is established and detailed drawings of the aircraft's overall configuration are not yet available, only a portion of the landing gear parameters can be determined.

This preliminary assessment helps lay the foundation for further development and refinement of the landing gear system as the design progresses.

Main wheel axel offset is:

$$e = 0.18 \cdot b_{MAC} = 0.18 \cdot 4.02 = 0.72\ m$$

With a significant axial offset of the main wheels, the lifting of the front gear during takeoff becomes more challenging. Conversely, with a smaller offset, there is a risk of the aircraft's tail dropping during takeoff, especially if the rear of the aircraft is loaded first. The calculation of the landing gear wheelbase is derived from the following expression. This calculation is crucial for determining the optimal positioning and dimensions of the landing gear system to ensure safe and stable operations during both takeoff and landing phases:

$$B = 0.4 \cdot L_f = 0.4 \cdot 40.32 = 16.128\ m$$

The final equation indicates that the nose landing gear supports approximately 6 to 10% of the total aircraft weight. This distribution of weight between the main and nose landing gear is crucial for maintaining proper balance and stability during ground operations, including taxiing, takeoff, and landing.

The front wheel axial offset will be equivalent :

$$d_{ng} = B - e = 16.128 - 0.723 = 15.4\ m$$

Wheel track is:

$$T = 0.396 \cdot B = 0.396 \cdot 16.128 = 6.39\ m$$

On a condition of the prevention of the side nose-over the value K should be > 2H, where H – is the distance from runway to the center of gravity.

The selection of landing gear wheels is based on the size and the applied load during takeoff from the aircraft's total weight. For the front landing gear, dynamic loading is also taken into account. The choice of pneumatic tire type (such as balloon, half balloon, or arched) and the pressure within it is dictated by the characteristics of the runway surface intended for use. Additionally, brakes are typically installed on the main wheels, and occasionally on the front wheel as well, to ensure safe and efficient ground operations. These considerations are essential for optimizing aircraft performance and safety during takeoff, landing, and taxiing maneuvers.

The load on the wheel is determined:

$K_g = 1.5...2.0$ – dynamics coefficient.

Nose wheel load is equal:

$$F_n = \frac{g \cdot e \cdot K_g \cdot m_0}{B \cdot z} = 33172.6\ N$$

Main wheel load is equal:

$$F_m = \frac{g \cdot (B - e) \cdot K_g \cdot m_0}{B \cdot z \cdot n} = 353202\ N$$

Table 2.1

Nose gear

Size	Construction			Service Rating		
	Ply Rating	TT or TL	Rated Speed (mph)	Rated Inflation (Psi)	Max. Breaking Load (Lbs)	Max. Bottoming Load (Lbs)
M 33	10	TL	222	210	8000	21600

Table 2.2

Inflated Tire Dimensions and Wheel Specifications

Inflated Dimensions (in)				Static Loaded Radius (in)	Aspect Ratio	Wheel (in)		
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height
Max	Min	Max	Min					
33.06	32.06	11.3	10.84	13.8	0.73	10.78	16.5	0.813

Table 2.3

Aircraft Landing Gear Tire Specifications

Size	Construction			Service Rating			Tread Design/ Trademark	Weight(L_{bs})
	Ply Rating	TT or TL	Rated Speed (mph)	Rated load (L_{bs})	Rated Inflation (Psi)	Max. Bottoming Load (L_{bs})		
56x20.0-20	38	TL	225	76000	315	228000	Flight Leader	281

Table 2.4

Aircraft Landing Gear Tire Dimensions

Inflated Dimensions (in)				Static Loaded Radius (in)	Aspect Ratio	Wheel (in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
55.9	54.8	16.2	15.5	50.85	0.88	12.75	28	2.25	4.6

2.1.8 Choice and description of power plant

Table 2.5

Characteristics of engines

Name	CFM 56-5B	Pratt & Whitney JT8D-17	IAE V2500-A5
Type	High bypass ratio turbofan	Three-shaft high bypass turbofan engine	High bypass ratio turbofan
Compressor	1 fan, 4 LP, 9 HP	Axial 13 HP	1 fan, 3-stage LP, 10-stage HP
Weight	1950 kg	1,454 kg	2359 kg
Thrust	98 – 147 kN 31275 -33975 lbs	76,580-92,940 lbf 340.6-413.4 kN	97.860 kN 21889 lbs
Length	176 in (450 cm)	123.56 in (313.8 cm)	126 in (320 cm)
Bypass ratio	5.5	0.96-1.06	4.9
Diameter	102 in (261 cm)	40.0 in (102.0 cm)	63.5 in (161.3 cm)
Overall pressure ratio	35.4:1	29.8:1	32.8:1

2.2. Determination of the aircraft center of gravity position

2.2.1. Trim-sheet of the equipped wing

The total mass of the equipped wing comprises the combined weight of its structural components, equipment, and fuel. This includes the main and front landing gear, irrespective of where they are mounted on the aircraft. The coordinates for the mass centers are referenced from the nose point of the mean aerodynamic chord (MAC) on the XOY surface. Positive coordinates indicate positions towards the aircraft's end, facilitating accurate weight distribution calculations and ensuring optimal balance and stability during flight [4].

The provided list of mass objects for aircraft, whether the engines are situated under the wing or within it, corresponds to the names outlined in table 3.1. The aircraft's total mass is recorded as 91295 kg. The coordinates of the center of pressure for the equipped wing are determined using the following formulas:

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

Table 2.6

Trim sheet of equipped wing

N	Name	Mass		C.G. coordinates x_i (m)	Moment $m_i x_i$ (kgm)
		Units	total mass m_i (kg)		
-	1	2	3	4	5
1	Wing (structure)	0.10952	8265.14584	1.7286	14287.1311
2	Fuel system, 40%	0.0084	633.9228	1.7085	1083.057104
3	Control system, 30%	0.00189	142.63263	2.412	344.0299036
4	Electrical equip. 10%	0.00325	245.26775	0.402	98.5976355

Ending of the table 2.6

-	1	2	3	4	5
5	Anti-icing system 70%	0.00896	676.18432	0.402	271.8260966
6	Hydraulic system, 70%	0.01197	903.33999	2.412	2178.856056
7	Power units	0.09403	7096.16201	-1.6	-11353.85922
8	Equipped wing without fuel and LG	**0.23802**	**17962.65534**	**0.384666885**	**6909.638678**
9	Nose landing gear	0.007778	586.982326	-12.86	-7548.59271
10	Main landing gear	0.031112	2347.929304	0.82	43958,89087
11	Fuel	0.28568	21559.41256	2	43118.82512
	Equipped wing	**0.56259**	**42456.97953**	**1.045886297**	**44405.17312**

2.2.2. Trim-sheet of the equipped fuselage

The coordinate origin is established at the projection of the fuselage nose onto the horizontal axis. The fuselage construction serves as the reference for the X-axis. Table 3.2 provides an illustrative list of objects for the aircraft, specifically tailored for configurations where engines are mounted under the wing. This comprehensive list aids in accurately assessing the distribution of mass and center of pressure, critical factors for ensuring optimal flight dynamics and stability [5].

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}};$$

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

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

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

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

where m_0 – aircraft takeoff mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; C – distance from MAC leading edge to the C.G. point, determined by the designer.

C = (0,22...0,25) B_{MAC} –low wing ;

C = (0,25...0,27) B_{MAC} – center wing;

C = (0,23...0,32) B_{MAC} – high wing;

For swept wings; at X = 30°...40° C = (0,28...0,32) B_{MAC}

at X= 45° C = (0,32...0,36) B_{MAC}

Table 2.7

Trim sheet of equipped fuselage

№	Objects	Mass		Coordinates of C.G.	Moment (kgm)
		Units	Total (kg)		
-	1	2	3	4	5
1	Fuselage	0.09059	6836.55553	15	133312.8328
2	Horizontal TU	0.00991	821.21197	30	26278.78304
3	Vertical tail unit	0.00984	815.41128	29.5	25685.45532
4	Anti ice system, 20%	0.00448	371.24416	16.8	10053.29185
5	Air conditioning system, 40%	0.00896	742.48832	16.925	12566.61482
6	Flight control system 70%	0.00441	365.44347	16.925	6185.13073
7	Hydraulic system 30%	0.00513	425.10771	23.695	10072.92719

Ending of the table 2.7

-	1	2	3	4	5
8	Electrical equipment 90%	0.02925	2423.85975	13.925	33752.24702
9	Radar	0.0032	265.1744	1	265.1744
10	Aero navigation equipment	0.0047	389.4749	2	778.9498
11	Radio equipment	0.0024	198.8808	1	198.8808
12	Instrument panel	0.0055	455.7685	2	911.537
Passenger aircraft					
Passenger eq+ Non typical eq+ Additional equipment+ Service equipment					
13	Seats of pass. economical class	0.0161	1334.1587	20	5.925
14	seats of pilot	0.000662	50	1.48	74
15	seats of flight attendance	0.000289	24.0000234	1.82	43.6800426
Furnishing (Lavatory, Galley/buffet)					
16	lavatory1, galley1, lavatory2, galley 2 20%	0.01	828.67	2.96	7049,917652
17	not typical equipment	0.0037	306.6079	3	919.8237
18	additional equipment	0.00367	304.12189	5	1520.60945
	Equipped fuselage without payload	0,19719	57049,3499	34,05927	1943059,776
Payload					
19	Cargo, mail	0.001060	80	18	1440
20	Crew/flight attend	0.003180	240	17	4080
21	Baggage	0.024431	1843.773	18	33187.914
22	Passengers	0.159009	12000	20	240000
	TOTAL	0.43741	34130.8695	18.68243	3522249,279

2.2.3. Calculation of center of gravity positioning variants

The list of mass objects for centyre of gravity variant calculation given in Table 3.3 and Center of gravity calculation options given in table 3.4, completes on the base of both previous tables [6].

Table 2.8

Mass Distribution and Coordinates of Objects for Aircraft Configuration

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G. M	kgm
Equipped wing without fuel and L.G.	17962.66	17.63	335160.49
Nose landing gear (retracted)	586.98	5.00	2934.91
Main landing gear (retracted)	2347.93	17.86	41934.02
Fuel	24826.95	20.27	503343.43
Equipped fuselage (without payload)	19438.10	17.87	347320.08
Passengers of economical class	11088	15	166320.00
Baggage of passenger	3120	18.00	56160.00
Cargo	650	18.00	11700.00
Crew/attendant	154	2.40	369.60
Nose landing gear (opened)	586.982326	4	2347.93
Main landing gear (opened)	2347.929304	17.86	41934.02

Table 2.9

Variants of Loading: Mass Distribution and Centering Parameters

№	Variants of the loading	Weight, kg	Moment of the mass, кg*m	Centre of the mass, m	Centering
1	Take-off mass (L.G. opened)	83522.44	1452428.87	17.38968353	0.035123394
2	Take-off mass (L.G. retracted)	83522.44	1452135.38	17.38616961	0.034282341
3	Landing variant (L.G. opened)	58695.49	974685.35	16.60579603	-0.158493025
4	Transportation variant (without payload)	68190.44	1207323.38	17.70516962	0.114982993
5	Parking variant (without fuel and payload)	43209.49	729503.75	16.88295174	-0.089548818

The provided data outlines various loading variants for the aircraft, each tailored to specific operational scenarios. These variants include take-off masses with the landing gear opened and retracted, a landing variant with the landing gear opened, a transportation variant without payload, and a parking variant without fuel and payload. For each variant, key parameters such as weight, moment of the mass, center of mass, and centering are provided, offering insights into the distribution and balance of the aircraft's load under different conditions.

Conclusions to the project part

The examination of aircraft geometry and weight distribution underscores the importance of optimizing space utilization while ensuring stability. By aligning with operational requirements, the design becomes adaptable to a variety of missions, enhancing versatility. Aerodynamic considerations not only improve fuel efficiency but also contribute to overall economic performance. Strategic placement of internal components prioritizes passenger comfort, further enhancing the aircraft's appeal. Precise positioning of the center of gravity is pivotal for maximizing stability and control, essential for safe flight operations. The flexibility inherent in the design allows for seamless adaptation to diverse operating conditions, ensuring optimal performance across different scenarios.

3. THE AIR CONDITIONING SYSTEM OF A LONG-RANGE PASSENGER AIRCRAFT.

3.1. Introduction

The aircraft's Air Cycle System is meticulously engineered to establish and regulate essential living conditions throughout the cabin. This advanced system operates efficiently, ensuring optimal comfort for passengers and crew alike. Its innovative design enables precise control over temperature and humidity levels, creating a pleasant environment conducive to long-haul flights. Additionally, the Air Cycle System enhances overall air quality, providing passengers with a refreshing and rejuvenating travel experience. This system works by extracting hot air from the engine compressor and then adjusting the pressure, temperature, and humidity of the air to the desired levels.

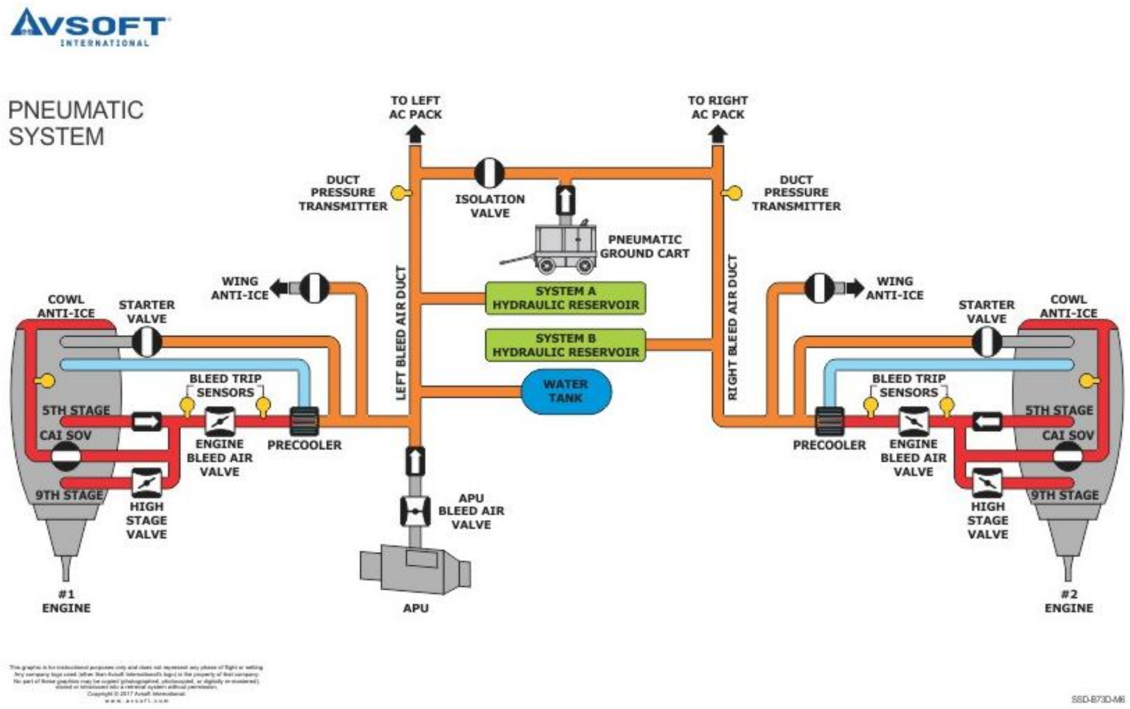

Fig. 3.1. Conditioning system of The Boeing 787 Dreamliner.

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Done by	Semenchuk S.D.			Project part	list Q	sheet 45	sheets 66
Supervisor	Vlasenko Y.V.						
					404 ASF 134		
St.control.	Krasnopolskyi V.S.						
Head of dep.	Yutskevych S.S.						

Each aircraft has its own air conditioning system. The image depicts the air conditioning system of the Boeing 787 Dreamliner, showcasing its advanced engineering and sophisticated design. This system plays a critical role in maintaining optimal cabin conditions, ensuring passenger comfort and well-being throughout the flight. With its innovative features and cutting-edge technology, the air conditioning system exemplifies the Dreamliner's commitment to providing a superior travel experience for passengers around the world (fig 3.1.).

3.2. The air conditioning system of my plane

The Airbus A320's air conditioning system is indeed a marvel of engineering, designed to provide optimal comfort for passengers and crew alike. Its intricate network of ducts and vents ensures that air is distributed evenly throughout the cabin, maintaining a consistently pleasant temperature. This system not only cools the air but also filters out impurities, ensuring that everyone on board breathes fresh, clean air throughout the flight. Whether you're flying short-haul or long-haul, the A320's air conditioning system remains efficient and reliable, creating a comfortable environment for passengers to relax and enjoy their journey. From takeoff to touchdown, the A320's aircon system works tirelessly behind the scenes to ensure a pleasant and enjoyable flying experience for all on board. It regulates the air so well, making sure everyone's breathing fresh and chill air throughout the flight the individual materials alone (fig. 3.2).

Furthermore, the Airbus A320's air conditioning system is designed with passenger comfort in mind. It operates quietly, minimizing disruptions during the flight, allowing passengers to rest or work without distraction. The system's ability to regulate humidity also contributes to the overall comfort level, preventing the air from feeling too dry or too humid. This attention to detail enhances the flying experience, making it more enjoyable for passengers regardless of the duration of the journey. Additionally, the A320's air conditioning system is equipped with advanced technology to adapt to changing external conditions, ensuring that the cabin remains comfortable even during extreme temperatures or fluctuations in altitude.

This reliability and adaptability instill confidence in both passengers and crew, making the Airbus A320 a preferred choice for airlines around the world.

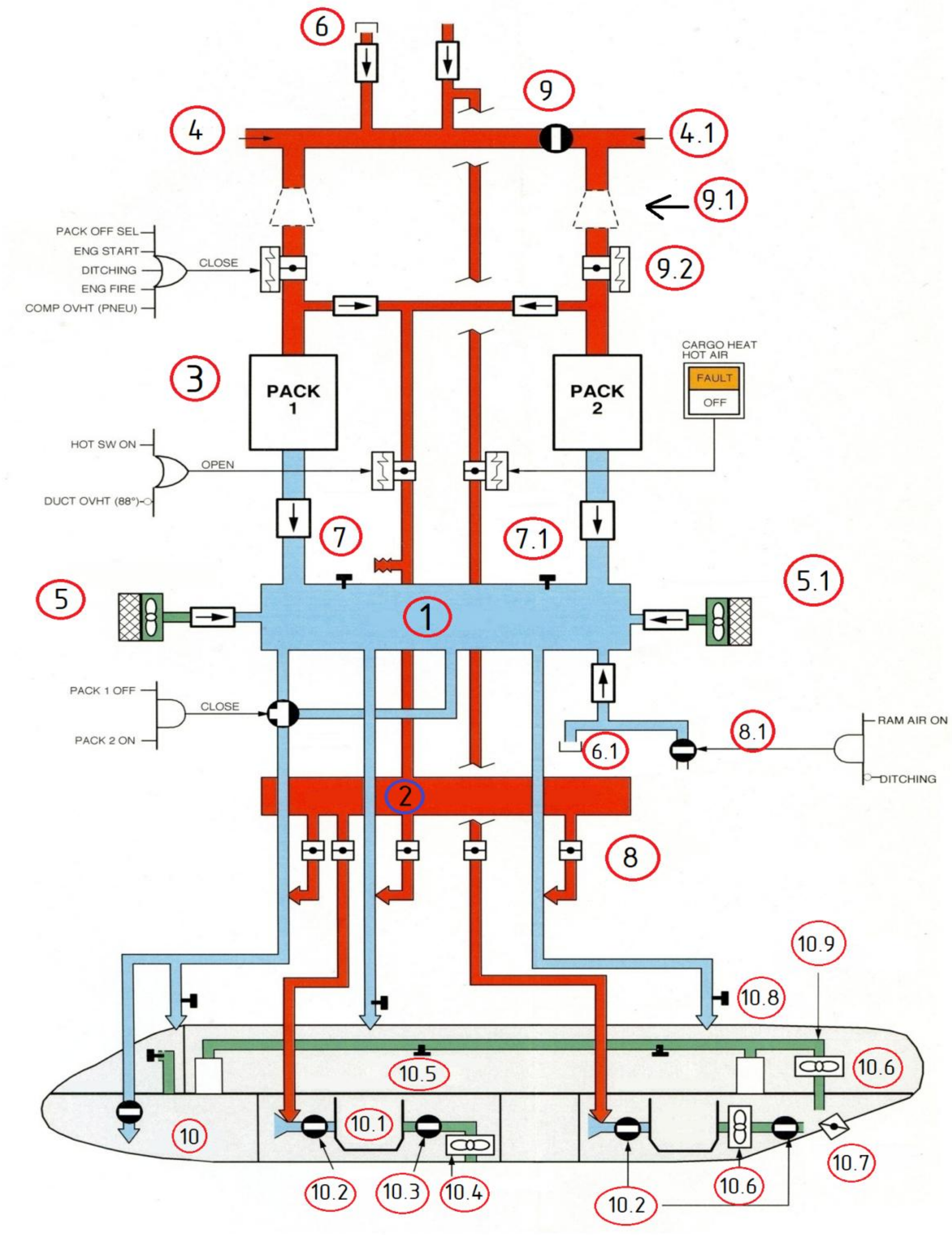

Fig. 3.2. The air conditioning system of the Boeing 320.

1. Displacement chamber
2. Hot air collector
3. Cooling installation
4. Engine

    - 4.1 Engine
- 5. Left recirculation fan
    - 5.1 Right recirculation fan
- 6. Air start fitting
    - 6.1 Ground conditioning fitting
- 7. Mix line pressure regulator
    - 7.1 Rear cargo area line pressure regulator
- 8. Air mixing valve
    - 8.1 Emergency valve
- 9. Banding tap
    - 9.1 Ozone filter
    - 9.2 Air flow control damper
- 10. Equipment ventilation
    - 10.1 Front cargo compartment
    - 10.2 Flow valves
    - 10.3 Flow valves
    - 10.4 Exhaust fan
    - 10.5 Zone temperature sensor
    - 10.6 Exhaust fan
    - 10.7 Air release valve
    - 10.8 Line temperature sensor
    - 10.9 Kitchen/toilet ventilation

3.3. Ventilation System of the Boeing 320: Regulation, Operation, and Components

The system provides ventilation for the passenger salon and crew cabin in accordance with JAR norms, 25.831, and in all flight modes, including emergency situations.

Selected air from the circulation line through flow regulators is supplied to two identical independent cooling installations (Packs). Flow regulators can be switched to positions:

- "Low" (80%), which can be selected for fuel savings at the pilot's discretion with reduced passenger numbers or when surrounding conditions allow;
- "Normal" (100%), which corresponds to normal operating conditions;
- "High" (120%) - selected for abnormally hot surrounding conditions or for smoke removal;
- "closed" - for shutting down the installation.

If the "normal" or "low" mode is selected and one of the cooling installations fails, the flow regulator in the line of the other installation automatically switches to "high" mode.

3.4. Components and Operation of Aircraft Cooling Systems

The cooling system consists of several components: a primary air-to-air heat exchanger, a main air-to-air heat exchanger, a three-wheel turbo refrigeration machine (THU), a superheater heat exchanger, a condenser heat exchanger, and a moisture separator [7].

Cold air from the cooling system is directed to the cold air collector beneath the cabin floor, where it mixes with recirculated air. The cabin air enters the underfloor space, passes through filters by recirculation fans, and is then delivered to the collector through check valves. Typically, the recirculation airflow accounts for 37 to 51% of the total airflow under normal conditions.

The air conditioning system commonly used in turbine passenger jets is known as air cycle air conditioning, while vapor cycle air conditioning is more frequently found in reciprocating aircraft.

3.5. Air conditioning and environmental control systems on airplanes and its operation

The environmental system onboard the aircraft is often referred to as a "pack". Here's how it works [8]:

1) The air cycle system gets its air supply from the engine, where excess or bleed air is released and directed through a primary heat exchanger to cool slightly before reaching the air cycle machine (ACM). In the ACM, the air gets compressed, raising its temperature again.

2) The heated and compressed air then passes through a secondary heat exchanger, where it gets cooled by the surrounding outside air. Next, the air moves through an expansion turbine into an expansion chamber, where it cools down to near-freezing temperatures. From there, the cold air goes to a water separator to remove any moisture.

3) The cold, dry air flows into the mixing box, where a temperature mixing valve ensures the air reaches the desired cabin temperature while also providing pressurization. This process minimizes the amount of hot engine air reaching the cabin.

4) The Boeing 787 Dreamliner takes a unique approach by drawing air directly from the outside instead of using engine air, which helps increase engine efficiency.

5) About half of the air in the cabin is fresh, while the other half is recirculated. However, air from toilets and galleys is not recirculated; instead, it's replaced with fresh air to maintain cabin cleanliness. The recirculated air undergoes thorough filtration using high-performance HEPA filters, removing almost all microbes, including viruses and bacteria.

6) Temperature control is managed by a temperature sensor in the cabin, which sends data to the cabin temperature control panel. The controller adjusts the temperature mixer based on the comparison between the actual cabin temperature and the desired temperature, ensuring a comfortable environment by blending hot bleed air with cold air.

This advanced system not only prioritizes passenger comfort but also ensures high air quality and hygiene, making flying in the Dreamliner a safer and healthier experience.

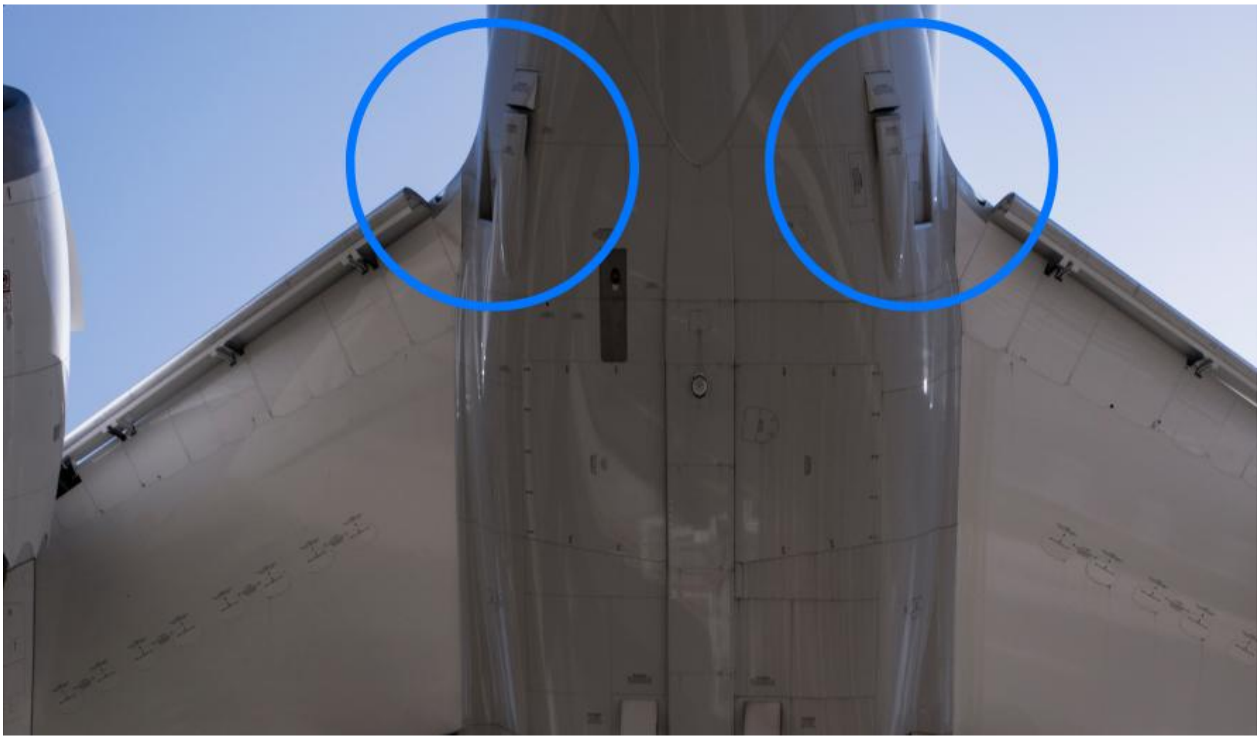

Fig. 3.3 Input open the RAM for air

The term RAM in aerodynamics refers to air that gains speed due to the movement of the aircraft. During the flight of an aircraft, as it moves forward, air is pushed into the aircraft's ventilation system or other aerodynamic systems as a result of this movement. In the context of your text, "cool outside ram air" indicates that the cooled external air is taken in as a result of the aircraft's movement through the air.

3.6. Components of the air conditioner of a Boeing aircraft

- Air Conditioning Packs: to cool and condition the air.
- Air Distribution Ducts: to send the conditioned air to different parts of the aircraft.
- Air Filters: to remove contaminants and enhance the air quality.
- Recirculation Fans: to maintain the flow of air.
- Control Panels: typically controlled by panels in the cabin and, at times, in the cockpit.
- Temperature and Pressure Sensors: to monitor the internal conditions.
- Air Purge Systems: often used to purge the air from the engines and provide compressed air for various functions within the aircraft.

- Pack Valves: to regulate the airflow and help maintain the desired cabin pressure.

3.7. The Efficiency of Engine Shutdown During Takeoff White: Full Savings and Operational Considerations

When pilots tell a packed cabin they're planning to keep the engines turned off to save fuel during a lengthy runway wait, naturally, there are those questioning whether it's truly necessary and effective.

The answer to that query: "yes."

With engines as large as those on big airplanes, there can be noticeable and measurable fuel-saving benefits from shutting engines off at the gate. Since pilots plan ahead for their fuel needs, including reserves, if they were to keep engines running and burning fuel during extended gate holds, it could lead to even longer delays due to the need for refueling before takeoff.

3.8. Optimizing Aircraft Cooling Systems: Engine Shutdown, APU Usage, and Ground Air Supply

If the plane's engines be shut down, the main air conditioning system ain't getting powered in its usual way.

Instead, an Auxiliary Power Unit (APU) provides the necessary electrical and pneumatic juice for the cooling system, saving on fuel, costs, and emissions [9]. If the engines be off but the APU ain't running yet, the air conditioner won't be operational.

Sometimes, the engines might still be running, but since the compressed air that chills the aircraft relies on higher engine RPM for effectiveness, idling engines can make it seem like the AC be off. Switching on the APU can help supplement the main air conditioner while the plane be parked at the gate.

Another method of cooling planes at the gate be through ground air. This involves an external air conditioning unit pumping cold air into the cabin via a hose. While ground air be in use, the internal air conditioner system of the plane typically be turned off.

Once ground air supply be disconnected shortly before closing the boarding door, there might be a brief period without AC until the plane's APU or engines power up to operate the onboard air conditioning system.

Table 3.1

Distance flight (km)	Fuel consumption with air conditioning (l)	Fuel consumption without air conditioning (l)
500	1000	950
1000	2000	1900
1500	3000	2850
2000	4000	3800

Table 3.2

Factor	With air conditioning	Without air conditioning
Fuel consumption	Higher	Lower
Fuel savings	0%	1-2%
Environmental impact	Greater	Smaller
Passenger comfort	May be lower	May be higher
Passenger health	May be risk of overheating	May be risk of catching a cold
Technical considerations	May be limitations	No limitations

3.9. Enhancing Efficiency in Air Conditioning Systems: Strategies for Improvement

Enhancement of Equipment: Replace old, less efficient components with newer, more energy-efficient models. This includes upgrading to high-efficiency compressors, motors, and fans.

Optimization of Operation: Introduce intelligent control systems and planning systems to ensure that the conditioning system operates only when necessary and at optimal levels. This may involve using occupancy sensors, programmable thermostats, and automated planning.

Improved Insulation: Improve aircraft insulation to minimize heat transfer and reduce the load on the conditioning system. This includes upgrading insulation materials and sealing any air leaks in the cabin and ducts.

Airflow Optimization: Optimize airflow in the cabin to ensure effective distribution of conditioned air. This can involve redesigning ductwork, adjusting ventilation openings, and minimizing obstacles that obstruct airflow.

Incorporate renewable energy solutions like solar panels or wind turbines into the conditioning system to supplement power usage. By harnessing these sustainable sources, reliance on conventional energy grids can be diminished, subsequently lowering overall energy consumption and promoting environmental sustainability.

Regular Maintenance: Implement a comprehensive maintenance program to ensure that the conditioning system operates at the highest level of efficiency. This includes regular cleaning, inspection, and servicing of components to avoid energy loss due to inefficiencies or malfunctions.

3.10. Enhancing Aircraft Efficiency: Redesigning Air Conditioning Systems for Optimal Energy Utilization

In order for the air to be suitable for comfortable stay of passengers and crew members both during flight and before takeoff, a large amount of energy is currently being expended. The diagram (fig. 3.4) below shows how the energy of the air changes along the air conditioning system duct. Arrows indicate the inflows and outflows of air energy moving along the duct of the conditioning system. In general, it can be seen that the energy of the air sharply increases from the atmospheric values outside the aircraft to the values of the air in the engine compressor, and then it is reduced to normal atmospheric values and supplied to the aircraft cabin through boxes located in the upper part of the cabin, along its entire length.

This method is not economical because a large amount of energy is taken from the engines, which reduces the engine's output power by approximately 15%, accordingly decreasing the efficiency and maximum takeoff weight of the aircraft.

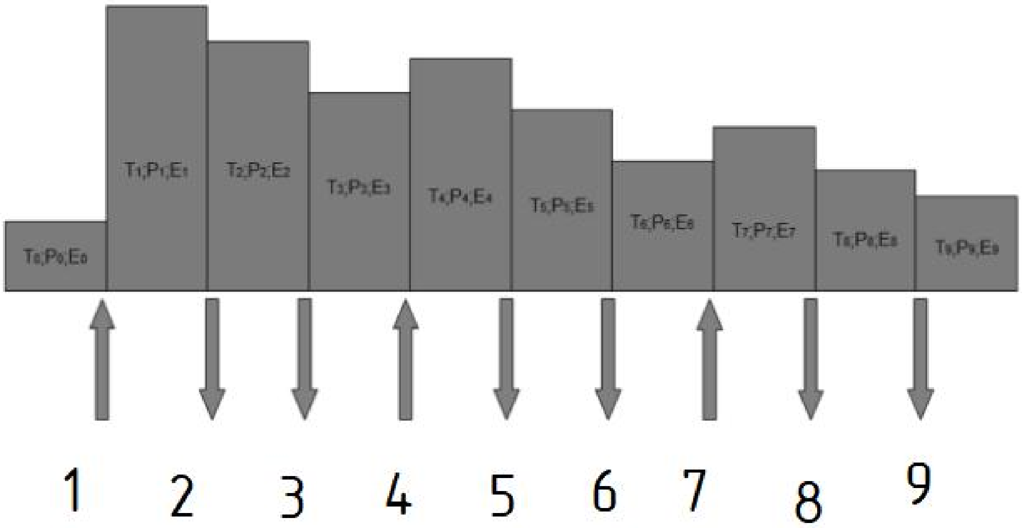

Fig. 3.4. Distribution of the air energy along the channel of the air conditioning system.

1. Turbo-jet Engine Compressor
2. Flow Regulation Valve
3. Double Heat Exchanger
4. Heating in Air Cycle Machine Compressor
5. Second Circuit Heat Exchanger
6. Cooling in Condenser
7. Preheating for Liquid Droplet Evaporation
8. Turbine
9. Condenser

3.11. Main Steps of ACM Compressor Design

1. Determining performance requirements involves defining necessary air parameters like pressure, temperature, and airflow rate, considering specific cooling and pressure needs for aircraft types such as the Airbus A320.

2. Choosing the compressor type entails considering various options like centrifugal or axial compressors based on performance requirements, with centrifugal compressors often preferred for their efficiency at high speeds and air compression capabilities.

3. Aerodynamic design focuses on developing compressor blade geometry and shape for maximum efficiency, utilizing Computational Fluid Dynamics (CFD) for airflow analysis and blade optimization.

4. Selection of materials and technologies involves choosing materials capable of withstanding high temperatures and mechanical loads for compressor blades and casing, typically opting for lightweight and durable options such as titanium or special alloys.

5. Thermal analysis assesses thermal loads and temperature distribution within the compressor, implementing cooling methods like air or liquid cooling to prevent overheating of components.

6. Mechanical analysis calculates mechanical stresses and deformations of compressor components, utilizing Finite Element Analysis (FEA) to ensure structural integrity and durability.

7. Balancing and vibration analysis aims to minimize vibrations and ensure stable operation through rotor balancing and detailed vibration analysis to detect and address potential issues.

8. Testing and validation involve manufacturing compressor prototypes for experimental testing under real working conditions to confirm design compliance with all performance and safety requirements.

3.12. Design features of the ACM compressor for the aircraft

- Weight and dimensions: The compressor must be as compact and lightweight as possible to reduce overall installation weight and comply with space constraints on the aircraft.
- Efficiency: High air compression efficiency is crucial for reducing energy consumption and increasing overall conditioning system efficiency.
- Reliability and safety: All compressor components must have a high level of reliability and durability, as failure of the conditioning system during flight can have serious consequences.
- Noise and vibration: The compressor should operate with minimal noise and vibration levels to ensure comfortable conditions for passengers and crew.

Thus, designing the compressor section of the ACM involves a multi-stage process with numerous analyses and optimizations to achieve maximum efficiency, reliability, and safety.

Air is drawn in through the inlet air filter for purification. The compressor then increases the air's pressure and temperature. The compressed air passes through a diffuser to convert kinetic energy into static pressure. Cooling follows as the compressed air travels through primary and potential intermediate heat exchangers. Moisture is removed through a moisture drain after cooling. Air then undergoes expansion as it passes through the turbine, reducing pressure and temperature. If available, a heat exchanger can further regulate air temperature based on system needs. This compressor section process ensures effective air compression, cooling, and drying vital for aircraft conditioning systems.

Main forces acting on a compressor impeller:

1. Centrifugal Forces:

- Formula:

$$F_c = m \cdot r \cdot \omega^2;$$

where F_c is the centrifugal force, m is the mass of the impeller blade, r is the radius of rotation, and ω is the angular velocity.

- Result from the high rotational speed of the impeller, inducing significant stresses in the material.

2. Aerodynamic Forces:
   - Arise from impeller blade interaction with airflow.
   - Include lift force (compression of air) and drag force (opposition to motion).
   - Varied based on compressor operating conditions.
3. Thermal Stresses:
   - Arise due to temperature differences in the impeller.
   - Increased air temperature during operation causes thermal expansion of the material.

Impeller Design:

1. Materials:
   - Selected for lightweight, strength, and high thermal resistance.
   - Examples: titanium, Inconel, composites.
2. Geometry:
   - Blade shape optimized to reduce aerodynamic drag and ensure even load distribution.
   - Computer modeling used for optimization.
3. Testing:
   - Experimental tests verify reliability and durability under real conditions.
   - Bench tests and analysis on vibration and thermal loads conducted.

Compressor impellers are crafted from various high-performance materials known for their robustness, thermal resilience, corrosion resistance, and fatigue strength. The primary materials used for crafting compressor impellers encompass titanium, aluminum alloys, nickel alloys (superalloys), and composite materials.

Titanium and its alloys, such as Ti-6Al-4V, rank among the most prevalent choices for impellers due to their high strength, corrosion resistance, excellent fatigue strength, and lightweight properties. However, they come with drawbacks such as high cost and complexity in processing.

Some impellers are manufactured from high-quality aluminum alloys like 7075-T6, prized for their lightweight nature, good machinability, and relatively low cost. Nonetheless, they exhibit lower strength and fatigue resistance compared to titanium and nickel alloys.

Nickel-based alloys like Inconel are frequently employed for impellers operating under high-temperature conditions. These alloys offer high-temperature resistance, corrosion resistance, and excellent strength at elevated temperatures. However, they are associated with high cost and processing complexity.

In certain instances, composite materials based on carbon fibers or glass fibers are utilized for impeller construction. These materials offer extremely lightweight properties, high strength, and good fatigue resistance. Nevertheless, they pose challenges in manufacturing complexity, high cost, and limited thermal resistance.

The selection of impeller materials is meticulously done based on the specific requirements and operating conditions of the compressor to ensure optimal performance and durability.

Titanium is chosen for the impeller in the A320 for several reasons. Firstly, it offers a high strength-to-weight ratio, providing structural integrity without adding unnecessary weight. Additionally, titanium exhibits excellent corrosion resistance, ensuring durability in harsh aerospace environments. Its lightweight nature contributes to fuel efficiency and aircraft performance. Furthermore, titanium's superior fatigue resistance allows the impeller to withstand repetitive loading cycles without degradation. It also maintains its mechanical properties at elevated temperatures, ensuring consistent performance. With a long history of successful usage in aerospace applications, titanium meets stringent industry standards for performance and safety. Lastly, its machinability enables precise manufacturing of complex impeller designs. These attributes collectively make titanium an optimal choice for impellers in the A320, ensuring reliability and longevity in demanding operational conditions.

We utilized CATIA, a robust CAD software, to meticulously design and engineer the 3D model of the ACM impeller. Leveraging CATIA's advanced tools and features, we were able to achieve precise geometry and ensure optimal performance of the impeller within its intended application.

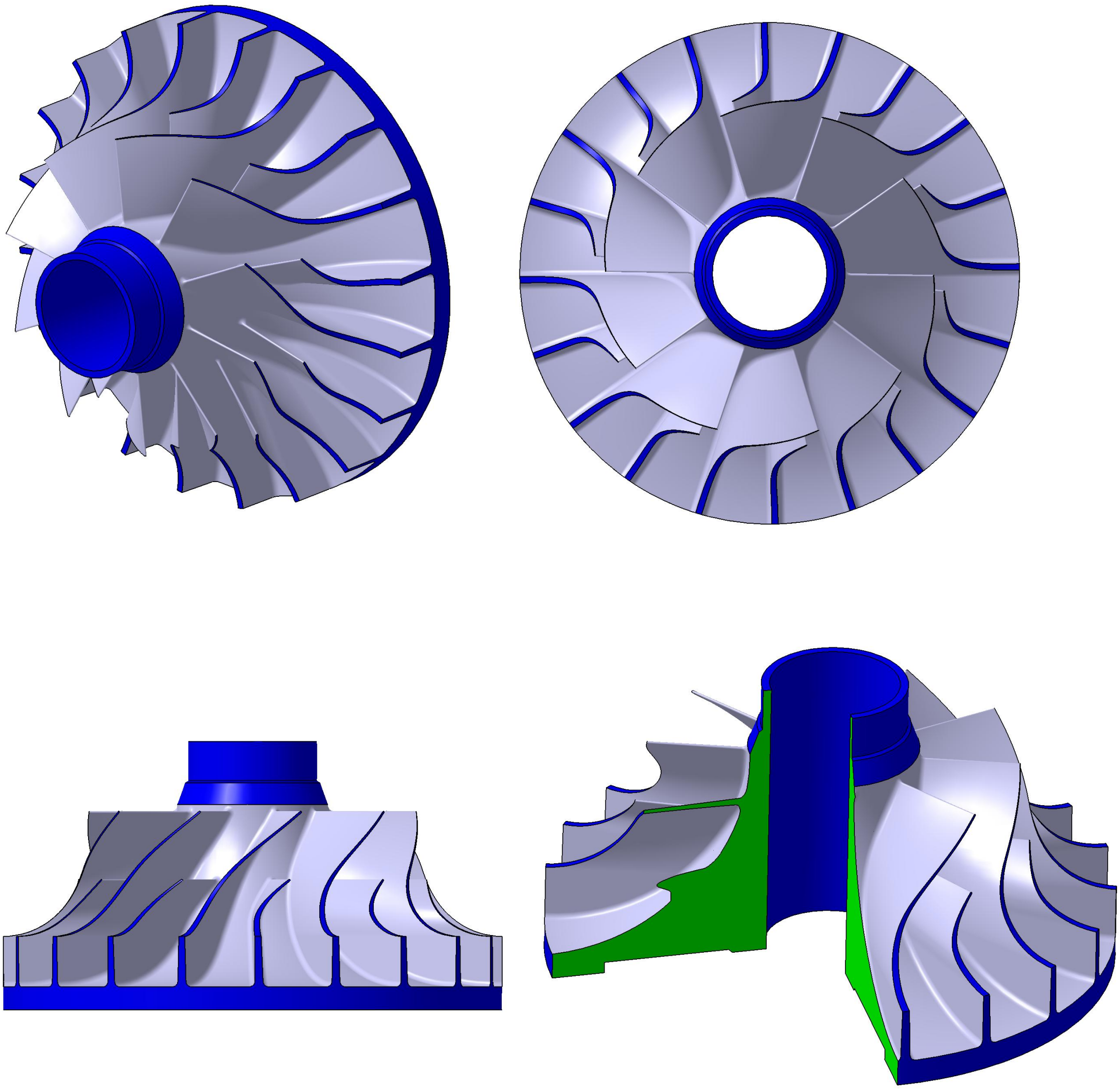

Fig. 3.5. Impeller 3D visualization.

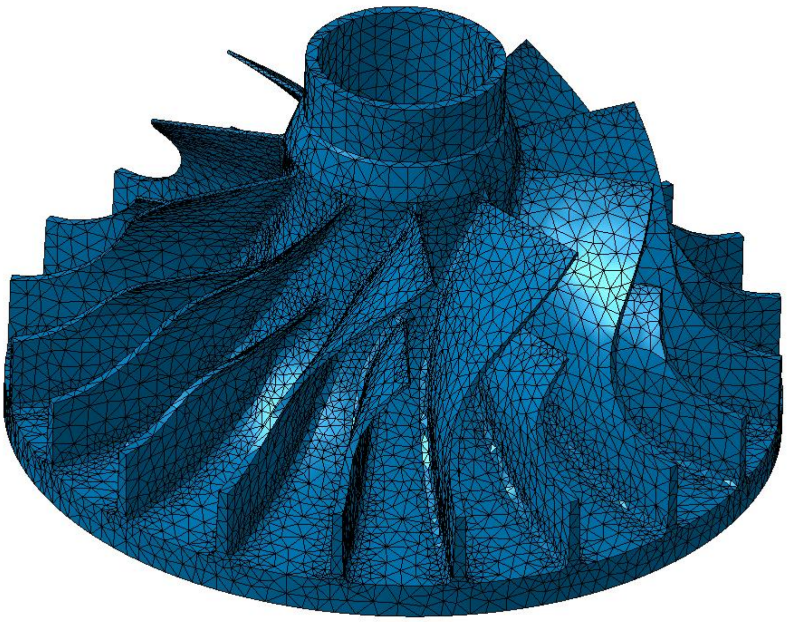

Fig. 3.6. Impeller mesh model.

We conducted thorough calculations to analyze the impeller's performance under operational conditions characterized by a rotational speed of 20,000 revolutions per minute. These calculations involved assessing various parameters such as internal stresses and deformations. By simulating the impeller's behavior at this specific speed, we aimed to ensure its structural integrity and functionality within the intended application.

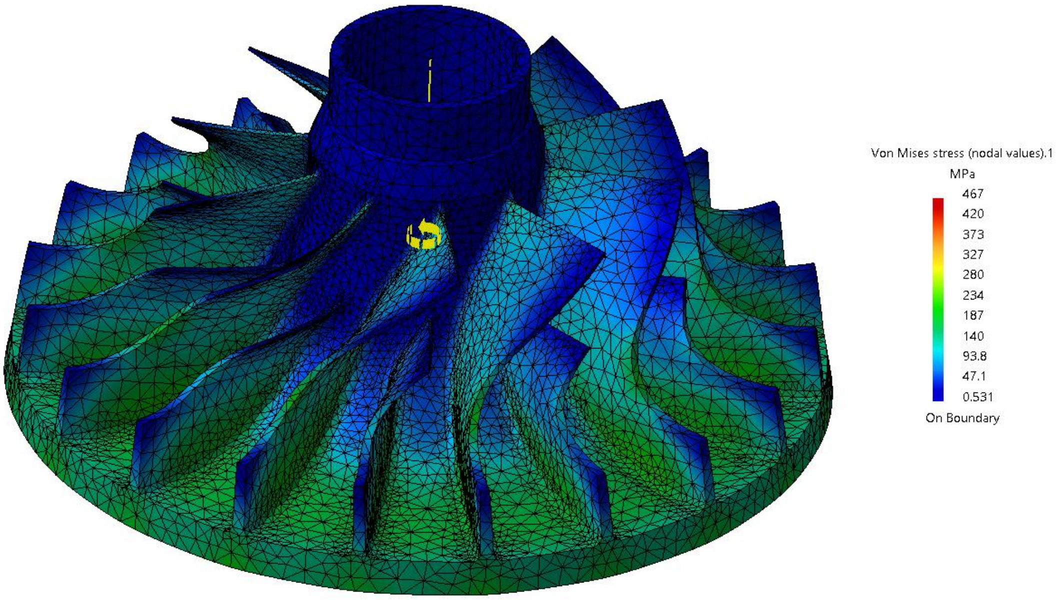

Fig. 3.7. Impeller Von Mises stress distribution (magnification x50)

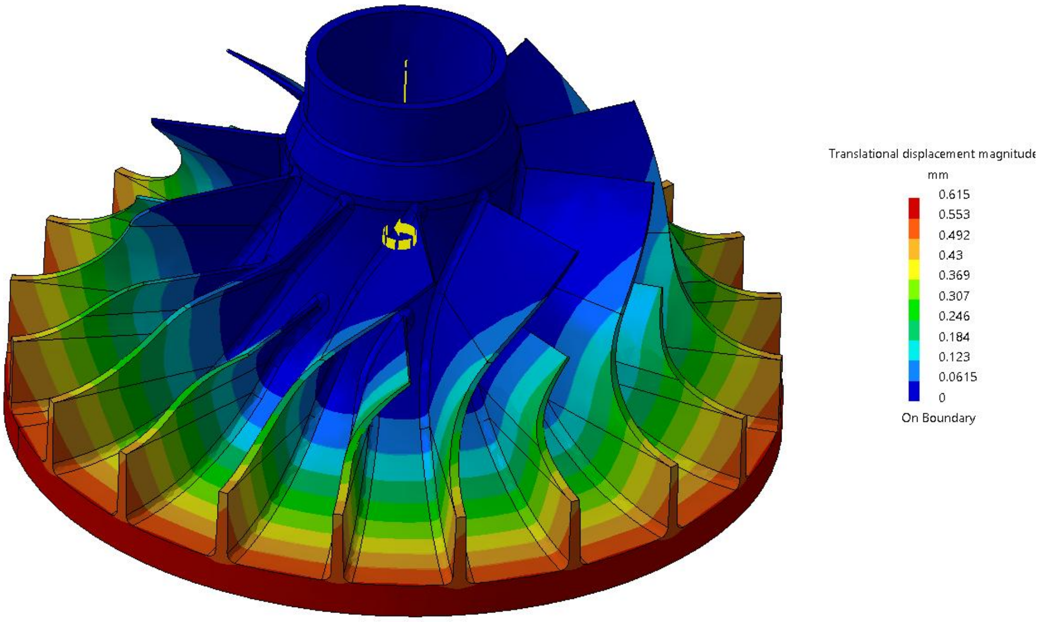

Fig. 3.8. Impeller displacement distribution (magnification x1)

Conclusions to the special part

The use of composites provides significant advantages in various aspects of structural design. Thanks to the use of composites, in particular CFRP (Carbon Fiber Reinforced Polymer), the weight of the structure can be reduced by 32%. This weight reduction not only improves overall design performance, but also contributes to fuel economy, reduced operating costs and environmental impact.

The introduction of composites leads to a noticeable decrease in the maximum load on the structural cladding. This reduction in stress levels significantly extends skin life, resulting in significant reductions in airworthiness maintenance costs. The improved strength and durability offered by composites ultimately contribute to increased operational efficiency and lower costs throughout the life of the structure.

GENERAL CONCLUSIONS

1. In this comprehensive study, we have delved into various aspects of the design and analysis of a long-range passenger aircraft.

Beginning with an analysis of prototypes and a concise description of the envisioned aircraft's main components, we set the stage for a detailed examination. Each part, from the fuselage to the landing gear, was meticulously explored, considering factors such as geometry, layout, and performance characteristics.

2. Moving forward, calculations for critical elements like wing geometry, fuselage layout, and landing gear design were conducted, ensuring the aircraft's structural integrity and operational efficiency. The determination of the center of gravity position further enhanced the aircraft's stability and maneuverability.

3. The focus then shifted to the air conditioning system, a vital component ensuring passenger comfort and safety. Through an in-depth exploration of various air conditioning and ventilation systems, including those utilized in the Boeing 320, we uncovered strategies for optimizing efficiency while maintaining optimal environmental conditions within the cabin.

4. By examining the efficiency of engine shutdown during takeoff and exploring strategies for enhancing air conditioning systems' efficiency, we aimed to contribute to the ongoing efforts towards sustainable aviation practices.

5. In conclusion, this study provides valuable insights into the design, analysis, and optimization of long-range passenger aircraft, addressing crucial aspects such as structural integrity, operational efficiency, and passenger comfort. Through our research, we have identified opportunities for improvement and innovation, paving the way for a more sustainable and passenger-friendly aviation industry.

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Done by	Semenchuk S.D.		
Supervisor	Vlasenko Y.V.		
St.control.	Krasnopolskyi V.S.		
Head of dep.	Yutskevych S.S.		

References

list	sheet	sheets
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Appendix

Appendix A

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Performed by: Semenchuk Serhii
Supervisor: Krasnopolskyi Volodymyr

                       PRELIMINARY DESIGN OF THE AIRCRAFT
                      INITIAL DATA AND SELECTED PARAMETERS

Passenger NumberFlight                                           150
Crew Number                                                            2
Flight Attendant or Load Master Number                           4
Mass of Operational Items                                        1470.29  kg
Payload Mass

Cruising Speed                                                         840 km/h
Cruising Mach Number                                             0.7831
Design Altitude                                                  10.5 km
Flight Range with Maximum Payload                                5000 km
Runway Length for the Base Aerodrome                             2.95 km

Engine Number                                                          2
Thrust-to-weight Ratio in N/kg                                   2.9
Pressure Ratio                                                         31
Assumed Bypass Ratio                                             5.5
Optimal Bypass Ratio                                             5.5
Fuel-to-weight Ratio                                             0.22

Aspect Ratio                                                           9.5
Taper Ratio                                                      4.2
Mean Thickness Ratio                                             0.12
Wing Sweepback at Quarter Chord                                  29 degree
High-lift Device Coefficient                                     1.05
Relative Area of Wing Extensions                                 0
                       Wing Airfoil Type - supercritical
                       Winglets - yes
                       Spoilers - yes

Fuselage Diameter                                                4.2 m
Finess Ratio                                                           9.6
Horizontal Tail Sweep Angle                                      35 degree
Vertical Tail Sweep Angle                                        40 degree


      CALCULATION RESULTS


Optimal Lift Coefficient in the Design Cruising Flight Point   0.46324

Induce Drag Coefficient                                              0.00913

ESTIMATION OF THE COEFFICIENT    Dm = Mcritical - Mcruise

Cruising Mach Number                                                 0.78305
Wave Drag Mach Number                                                0. 79505
Calculated Parameter Dm                                              0. 01200

Wing Loading in kPa (for Gross Wing Area):
                           At Takeoff                                  5.741
                           At Middle of Cruising Flight          4.891
                           At the Beginning of Cruising Flight  5.538

Drag Coefficient of the Fuselage and Nacelles              0.01201
Drag Coefficient of the Wing and Tail Unit                       0.00914
```

```
Drag Coefficient of the Airplane:
                    At the Beginning of Cruising Flight    0.03252
                    At Middle of Cruising Flight                 0.03131
Mean Lift Coefficient for the Ceiling Flight                     0.46324

Mean Lift-to-drag Ratio                                          14.79407

Landing Lift Coefficient                                               1.596



Landing Lift Coefficient (at Stall Speed)                  2.394
Takeoff Lift Coefficient (at Stall Speed)                  1.975
Lift-off Lift Coefficient                                        1.442
Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.620
Start Thrust-to-weight Ratio for Cruising Flight                 2.473
Start Thrust-to-weight Ratio for Safe Takeoff              2.928

Design Thrust-to-weight Ratio                                    3.075

Ratio  Dr = Rcruise / Rtakeoff                                   0.845


                       SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):
                 Takeoff                                         35.6231
                 Cruising Flight                           58.2543
                 Mean cruising for Given Range       61.7455

                             FUEL WEIGHT FRACTIONS:

                                        Fuel Reserve       0.03756
                                        Block Fuel         0.24811

                      WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:
                        Wing                                     0.10952
                        Horizontal Tail                          0.00991
                        Vertical Tail                            0.00984
                        Landing Gear                             0.03889
                        Power Plant                        0.09403
                        Fuselage                                 0.09059
                        Equipment and Flight Control       0.13078
                        Additional Equipment                     0.00367
                        Operational Items                  0.01948
                        Fuel                                     0.28568
                        Payload                                  0.20771

                Airplane Takeoff Weight              75467 kg
        Takeoff Thrust Required of the Engine  116.01 kN

Air Conditioning and Anti-icing Equipment Weight Fraction        0.0224
Passenger Equipment Weight Fraction                                    0.0161
(or Cargo Cabin Equipment)
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction  0.0090
Furnishing Equipment Weight Fraction                                   0.0100
Flight Control Weight Fraction                                         0.0063
Hydraulic System Weight Fraction                                       0.0171
Electrical Equipment Weight Fraction                                   0.0325
Radar Weight Fraction                                                  0.0032
Navigation Equipment Weight Fraction                                   0.0047
Radio Communication Equipment Weight Fraction                    0.0024
Instrument Equipment Weight Fraction                                   0.0055
Fuel System Weight Fraction                                            0.0084

           Additional Equipment:
Equipment for Container Loading                                        0.0000
```

No typical Equipment Weight Fraction (Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0037

TAKEOFF DISTANCE PARAMETERS

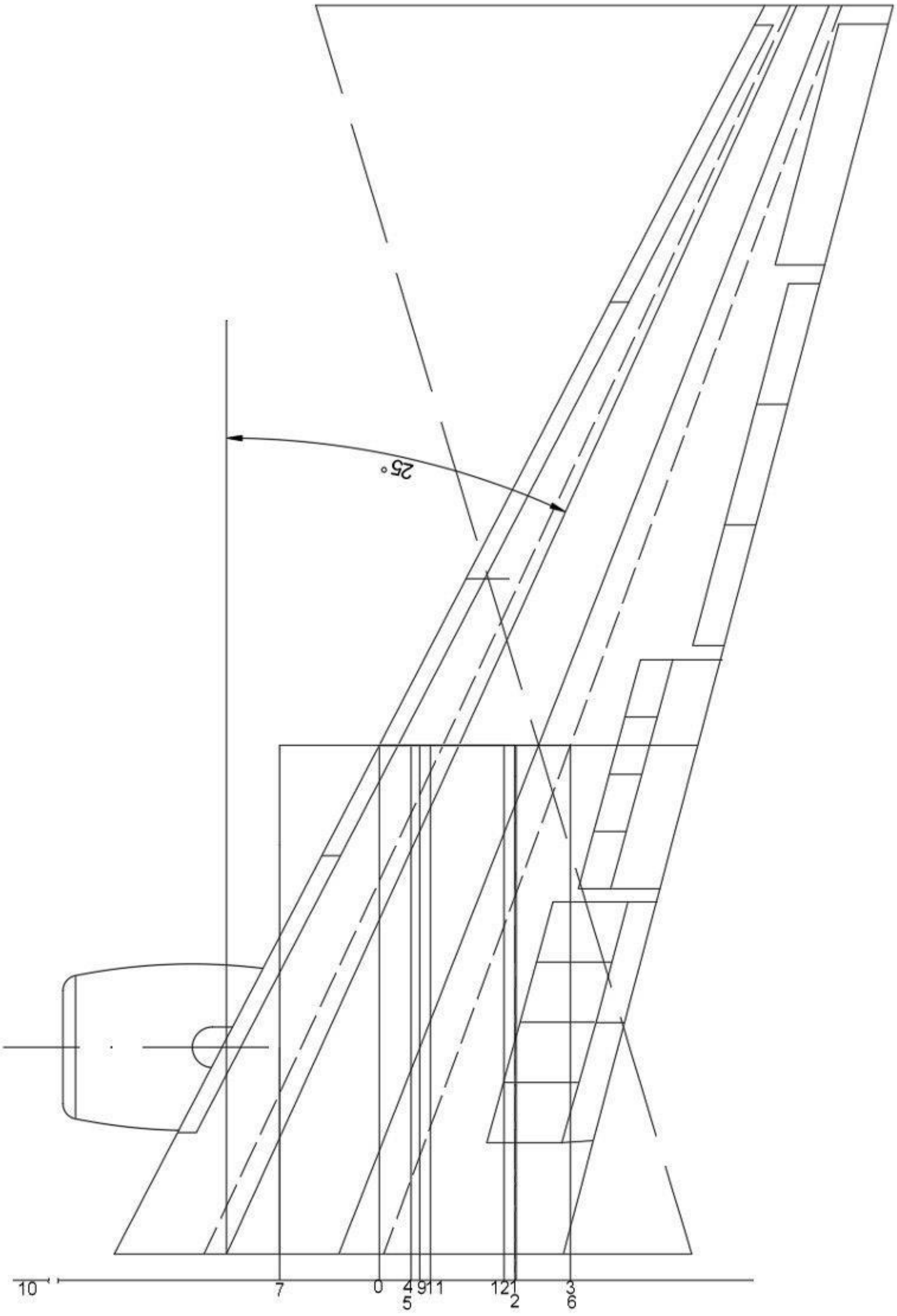
Airplane Lift-off Speed	287.22km/h
Acceleration during Takeoff Run	2.39 m/s^2
Airplane Takeoff Run Distance	1330 m
Airborne Takeoff Distance	578 m
Takeoff Distance	1909 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	272.86 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.29 m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	2237.77 m
Continued Takeoff Distance	2816.15 m
Runway Length Required for Rejected Takeoff	2917.05 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	59985 kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	20.8 min.
Descent Distance	48.61 km
Approach Speed	261.72 km/h
Mean Vertical Speed	2.09 m/s
Airborne Landing Distance	522 m
Landing Speed	246.72 km/h
Landing run distance	818 m
Landing Distance	1339 m
Runway Length Required for Regular Aerodrome	2237 m
Runway Length Required for Alternate Aerodrome	1902



Ch.	Sh.	№ doc.	Sign	Date
Done by		Semenchuk S.D.		
Checked by		Vlasenko Y.V.		
St.control.		Krasnopolskyi V.S.		
Head of dep.		Yutskevych S.S.		

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Centre of gravity of the wing

List	Sheet	Sheets
Q		

Appendix B

Sheet	Sheets

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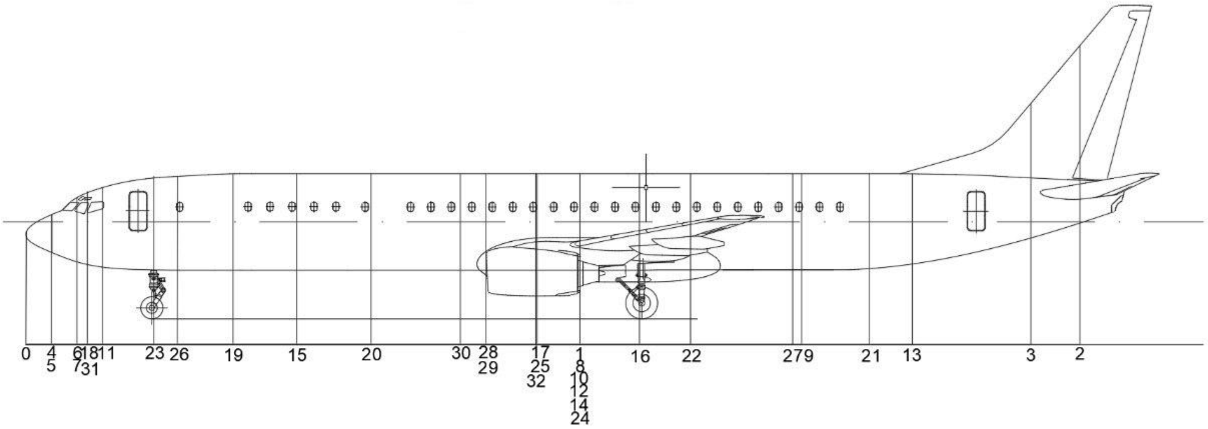

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Ch.	Sh.	№ doc.	Sign	Date
Done by		Semenchuk S.D.		
Checked by		Vlasenko Y.V.		
St.control.		Krasnopolskyi V.S.		
Head of dep.		Yutskevych S.S.		

Centre of gravity of the wing

List	Sheet	Sheets
Q		

Sheet | Sheets

Appendix C

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