МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д.т.н, професор
______Сергій ІГНАТОВИЧ
«__» _________2022 р.

КВАЛІФІКАЦІЙНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА
ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Аналіз проблем проектування кабіни пілотів транспортної категорії»

Виконавець: _________ **Сергій БЕВЗ**

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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
DEPARTMENT OF AIRCRAFT DESIGN

PERMISSION TO DEFEND
The head of the Department
Dr. of .Sc., professor
______Serhiy IGNATOVICH
«___» ___________2022 .

MASTER DEGREE THESIS

ON SPECIALITY
”AVIATION AND SPACE ROCKET TECHNOLOGY”

Topic: «Design issues of flight compartment for transport category aircraft»

Fulfilled by: ______________ **Serhii BEVZ**
Supervisor:
Ph.D., associate professor ____________ **Tetiana MASLAK**

Labor protection advisor:
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Environmental protection adviser:
Ph.D. professor ______________ **Lesya PAVLYUKH**

Standards Inspector:
Ph.D. associate professor _____________ **Volodymyr KRASNOPOLSKYI**

Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Аерокосмічний факультет
Кафедра конструкції літальних апаратів
Освітній ступінь «Магістр»
Спеціальність 134 «Авіаційна та ракетно-космічна техніка»
Освітньо-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри
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__________С.Р. Ігнатович
«___» ___________202_ р.

ЗАВДАННЯ

на виконання дипломної роботи студента

БЕВЗА Сергія

1. Тема роботи «Аналіз проблем проектування кабіни пілотів транспортної категорії», затверджена наказом ректора від 5 жовтня 2022 року №1861/ст.

2. Термін виконання проекту: з 06 жовтня 2022р. по 30 листопада 2022 р.

3. Вихідні дані до проекту: геометричні параметри прототипу літака, нормативні документи з вимогами до проектування кабіни пілота.

4. Зміст пояснювальної записки: аналіз вимог до проектування кабіни пілота, аналіз компонування кабіни пілота, аванпроект транспортного літака, аналіз проблем комфорту пілота під час польоту, питання охорони навколишнього середовища та охорони праці.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: презентація Power Point, розрахунки у Excel, схеми.

6. Календарний план-графік

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1	Огляд літератури про вимоги, щодо проектування кабіни пілота.	06.10.2022–18.10.2022	
2	Вивчення факторів, що впливають на комфорт пілота повітряного судна.	19.10.2022-29.10.2022	
3	Аналіз існуючих проблем компонування кабіни пілота.	30.10.2022-07.11.2022	
4	Аналіз та вибір оптимальних вимірювань при проектуванні крісла пілота.	06.10.2022-31.10.2022	
5	Виконання розділів, присвячених охороні навколишнього середовища та праці.	01.11.2022-04.11.2022	
6	Оформлення дипломної роботи	05.11.2022-10.11.2022	

7. Консультанти з окремих розділів

Розділ	Консультанти	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці			
Охорона навколишнього середовища			

8. Дата видачі завдання: 5 жовтня 2022 р.

Керівник дипломної роботи: __________ Тетяна МАСЛАК

Завдання прийняв(ла) до виконання: ___________Сергій БЕВЗ

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Aerospace faculty
Department of aircraft design
Educational Degree «Master»
Specialty 134 «Aviation and space rocket technology»
Educational professional program «Aircraft equipment»

APPROVED BY
Head of department
Dr. of Sc., professor
_____Serhiy IGNATOVICH
«___» ___________2022 р.

TASK
For the master degree thesis
Bevz Serhii

1. Topic: « Design issues of flight compartment for transport category aircraft », approved by the Rector's order № 1861 «05» October 2022 year.
2. Period of work execution: from 05 October 2022 year to 30 November 2022 year.
3. Initial data: geometrical parameters of the prototype aircraft, regulatory documents with requirements for the design of the cockpit.
4. Content: analysis of cockpit design requirements, cockpit layout analysis, transport aircraft preliminary design, analysis of pilot comfort problems during flight, environmental and occupational safety issues.
5. Required material: Power Point presentation, Excel calculations, diagrams.

6. Thesis schedule:

№	Task	Time limits	Done
1	Literature review on cockpit design requirements.	06.10.2022–18.10.2022	
2	Research of factors affecting the health of the aircraft pilot.	19.10.2022-29.10.2022	
3	Analysis of existing cockpit layout problems.	30.10.2022-07.11.2022	
4	Analysis and selection of optimal measurements in the design of the pilot seat.	06.10.2022-31.10.2022	
5	Implementation of the sections on environmental and labor protection.	01.11.2022-04.11.2022	
6	Edit and correct the draft, modify the format.	05.11.2022-10.11.2022	

7. Special chapter advisers

Chapter	Consultants	Date, signature	
		Task Issued	Task Received
Labor protection			
Environmental protection			

8. Date: 8 September 2022 year.

Supervisor: _____________ Tetiana MASLAK

Student: ______________ Serhii BEVZ

АНОТАЦІЯ

Пояснювальна записка дипломної роботи магістра "Аналіз проблем проектування кабіни пілотів транспортної категорії"

68 с., 14 мал., 14 табл., 40 джерел

Об'єктом дослідження є проектування кабіни пілота літака транспортної категорії та методів розташування допоміжного обладнання. Предметом дослідження є підвищення комфорту пілота під час польоту на повітряному судні.

Метою магістерської роботи є визначення оптимального методу проектування кабіни пілота та розташування дисплеїв з максимальним дотриманням ергономічних та антропометричних вимог.

Методами дослідження є: аналіз вимог до проектування кабіни пілота, аналіз наукових статей з проблем комфорту під час польоту (розташування приборних панелей, дизайн крісла, тощо).

Практична цінність полягає у визначенні основних факторів, що забезпечують максимальний комфорт пілотам під час польоту для ближньомагістрального транспортного літака. Матеріали кваліфікаційної роботи можуть бути застосовані в освітніх програмах авіаційної галузі з проектування, обладнання літальних апаратів та пасажирських перевезень.

Аванпроект, транспортний літак, кабіна пілота, проектування, компонування, крісло, ергономіка.

ABSTRACT

Master degree thesis “Design issues of flight compartment for transport category aircraft”

68 pages, 14 figures, 14 tables, 40 references

The object of the study is the preliminary design of the cockpit of the transport category aircraft and methods of arrangement of auxiliary equipment**. The subject of the study** is to increase the comfort of the pilot during the flight on the aircraft.

The aim of the master's thesis is the optimal method of designing the cockpit and the location of the displays with maximum compliance with ergonomic and anthropometric requirements.

Research and development methods analysis of the requirements for the design of the cockpit, analysis of scientific articles on the problems of comfort during the flight (location of instrument panels, seat design, etc.).

The practice value is in determining the main factors that provide maximum comfort to pilots during flight for short-haul transport aircraft

Preliminary design, transport aircraft, cockpit, design, layout, seat, ergonomic

CONTENT

ABBREVIATIONS

CSO – Combined sewer overflow;
MFD – Multifunctional display;
FCU – Flight Control Unit;
PFD – Primary Flight Display;
ND – Navigation Display;
MAC – Mean aerodynamic chord;
CG – Center of gravity;
LG – Landing Gear;
VTU – Vertical Tail Unit;
HTU – Horizontal Tail Unit;
FAR – Federal Aviation Regulations;
ANSUR – The US Army Anthropometric Survey;
CAESAR – The Civilian American and European Surface Anthropometric Resource;
GAL – Ground Air Layer;
IATA – International Air Transport Association;
TLC – Take-off and Landing Cycle.

INTRODUCTION

The ergonomic layout of the cockpit in transport category aircraft has a significant impact on both the effectiveness of the flight crew's operation and the safety of flights. With proper cockpit design, both the highest degree of pilot comfort and the best system performance may be accomplished. Despite the fact that the ergonomics of cockpits for aircraft in the transport category continue to present serious issues. First off, there are operational concerns that might arise due to the lack of clarity and comprehensiveness in the ergonomic design components of the transport category airplane. Second, there is no consistent structure to support the ergonomics design activity and process for the cockpit.

The offered thesis aims to create a conceptual framework for the ergonomics of a transport airplane's cockpit. We look at the ergonomic design elements of the cockpit. The parts are assembled using industry standards, new-generation cockpit features, and airworthiness criteria. The cockpit design process is discussed, along with the ergonomic design components that are allocated to each of the stages, and the ergonomic design features are assessed and described for the cockpit of a transport category airplane.

PART 1. DESIGN ISSUES OF FLIGHT COMPARTMENTS FOR THE TRANSPORT CATEGORY AIRCRAFT

1.1. Regulatory requirements for the pilot cabin

In the cabin are their work spaces. They are made up of an instrument panel and control levers.

The windscreen has mechanical wipers and hydrophobic defense against snow and rain. The windshield's durability is planned for a potential contact with birds.

The cabin of a passenger aircraft is divided from other areas by an armored wall with lockable doors.

The crew cabin has undergone steady change throughout aviation history, and only 40 years ago did it start to become more uniform. Modern cabins are nearly entirely computerized. An electric control system with a touchscreen interface and a steering wheel with electronic side grips has taken the place of the manual one.

The incorporated flying instruments of a modern cockpit are:

1. Airplane mode control.
2. Main flight display.
3. Navigation data indicator.
4. Radio direction finder.
5. Engine control lever.
6. System for alerting crew members and indicating the state of the power plant.
7. Radar.
8. Navigation controls.
9. Backup devices.
10. Flight control unit.

Engineers hope to install specialized converters in the cockpit in the future, enabling pilots to view a simulated three-dimensional view of the outside of the aircraft. The proximity of other aircraft, the surrounding landscape, and exits to the airfield area will all be depicted graphically in this visualization of sight outside the aircraft. Thus, even in the absence of visibility, successful flights will be possible with virtual three-dimensional equipment. Future improvements to the warning system and other technologies will make flying even safer.

According to the level of access required, consoles and shields are arranged in different groups. The most practical locations for major systems, including those used frequently by pilots, are chosen.

Control over key components is given to both pilots in order to improve the accuracy of aircraft control.

On the dashboard are backup and primary indicators for the power source, retractable landing gear, onboard systems, navigation parameters, and flight.

The CSO, navigation and flight indicators, the CSO control panel, and lighting control sensors are all located on the top. There are controls for wing mechanization, the power plant, trimming, air brakes, radio navigation, navigation, and communications on the central panel. Shields for the air conditioning, hydraulics, fuel supply, exterior lighting control, and fire prevention are located on the upper console.

There are auxiliary, individual, emergency, and serial devices, as well as indicators, on the right and left side consoles (front wheel control handles, storage places for documentation, oxygen masks, electric flashlights, closed-type ashtrays, and holders for cups with drinks).

The observer's location has emergency rescue, radio communication, and service equipment installed.

Protection against unlawful access and damage from firearms is carried out in accordance with international regulatory requirements.

The following things guarantee the safety of the airline crew:

1. Construction of reinforced partitions and doors.
2. Door locks resistant to common shock loads.
3. A lock that only the flight attendant can use to access the cabin.
4. A camera system that enables crew members to keep an eye on the cabin's passenger section next to the cockpit.

An armored door and reinforced barriers were built to make the compartment resistant to direct gunshots.

1.2. Guidance related to flight deck displays and controls

In today's electronic cockpit, electronic flight instruments are considered essential MFD (figure 1.1), PFD(figure 1.2), ND (figure 1.3), EICAS (figure 1.4), FMS / CDU (figure 1.6), and standby instruments.

Figure 1.1 – Multifunctional display

Course, airspeed, altitude, vertical speed, and vertical and lateral navigation can all be managed via the multifunction display, which is often a long, narrow screen positioned in the center of the pilot's view. Additionally, it can be used to activate or deactivate the autothrottle and autopilot. The section of the panel is typically referred to as a "glare panel". The unit that allows you to choose and set parameters for various automatic flight functions is known by the Boeing designation MFD (informally regarded as the generic unit/panel name); the equivalent unit on an Airbus aircraft is known as the FCU (flight control unit).

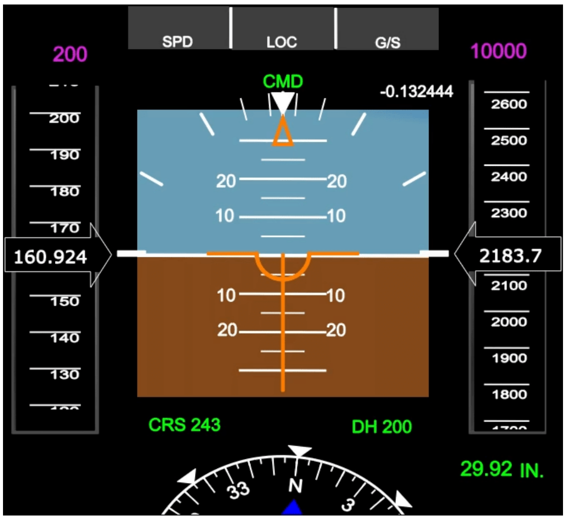

Figure 1.2 – Primary flight display

The primary flying display is typically prominently placed in the cockpit's center or on either side. The direction indicator, airspeed and altitude indicators (often in the form of a strip display), and a vertical speed indication will all typically be displayed digitally. A heading indicator and ILS/VOR deviation indications are frequently included. The active flying and guard modes, as well as some kind of indication of the chosen altitude, airspeed, vertical speed, and heading, will frequently be present. This trade option with ND might be being tested.

Figure 1.3 – Navigation Display

Next to the PFD is a navigation display that shows the route as well as details about the next waypoint, wind speed, and direction. This PFD replacement option could be seen as an experiment.

Figure 1.4 - Engine Indication and Crew Alert System

Figure 1.5 - Electronic Centralized Aircraft Monitor

The pilot can keep an eye on the following data with the help of the Engine Indication and Crew Alert System (used by Boeing) or the Electronic Centralized Aircraft Monitor (used by Airbus): N1, N2, and N3 value, fuel temperature, fuel consumption, electrical system, cockpit or cabin temperature and pressure, control surfaces, etc. By clicking a button, the pilot can decide whether to display the information.

Figure 1.6 – Flight Management System

The pilot can enter and confirm the following data using the flight management system/control unit: the flight plan, speed control, navigation control, etc.

A battery backup instrument system will be incorporated with a magnetic compass that shows crucial flying data including speed, altitude, heading, and direction of travel in a less noticeable area of the cockpit in case other instruments malfunction.

1.3. Anthropometric measurement data in designing an airplane cockpit

The height of the pilot in the seat position is the most crucial design factor for the cockpit of an aircraft, hence anthropometric measurement data is also crucial (seat height).

In order to make it easier for the pilot to reach the buttons and enable the pilot to manage the aircraft without worrying about the distance between the pilot and the aircraft's instruments, the distance between the pilot and the buttons is also taken into consideration.

Additionally, when designing an aircraft cockpit, the designer is necessary to take measurements of the possible pilot's body components in order to determine the ideal cockpit size and shape for the pilot to utilize comfortably. To make it simpler for the designer to get the required measurements, the prospective pilot's physique will be measured using an anthropometric chair.

Today, however, anthropometric data is also utilized to determine whether a prospective pilot's physique is the perfect criterion for becoming a pilot who will fly this passenger aircraft, as well as to build the cockpit of commercial aircraft.

PT Solo Abadi Indonesia's anthropometric chairs were utilized by a number of aircraft manufacturing companies to collect anthropometric data for designing cockpits that suit the needs of the end user. A designer can use this chair to design chairs for passengers as well as the interior of an airplane cabin.

Use of anthropometric chairs in assisting cockpit design:

1. Measuring height when sitting

This measurement is crucial because it allows the designer to create an airplane seat that is comfortable for the pilot by taking into account the height of the person seated.

2. Measuring the length of the hand reach

These anthropometric measurements are used to calculate the distance between the pilot and the aircraft's instruments.

3. Height measurement

The height of the pilot will provide a general notion of the height of the cockpit, and once the interior cockpit dimensions have been obtained, the designer can also calculate the size of the aircraft's head.

4. Foot length measurement

Because the foot will be utilized to brake the aircraft, its length is considered. The aircraft's tail may be turned by using the legs to control the tail.

These are some of the considerations that will be made when constructing a commercial airplane cabin; however, much more information may be required. It can also be designed based on the purpose and purpose of the aircraft after getting the necessary dimensions for the fuselage, the optimal size for the wing, and the size of the tail of the aircraft.

Conclusion to the part

Throughout the history of aviation, changes to the crew cabin have been constant. The majority of modern cabins are computerized. The future installation of specialized converters in the cockpit will let pilots to see a virtual three-dimensional vision of the outside of the aircraft, according to engineers.

The most important design element for an aircraft's cockpit is the height of the pilot when seated. In order to determine the optimal cockpit size and shape for the pilot to utilize comfortably, the designer will need to collect measurements of the potential pilot's body parts.

PART 2. PRELIMINARY DESIGN OF A SHORT-RANGE CARGO AIRCRAFT

2.1 The analysis of prototypes and choice of design parameters.

The chapter seeks to finish a rough draft before moving on to the basic information about prototypes and market demands. The selection of data from the study of the prototypes displayed in table 2.1 is the initial stage of the job. The An-148-100A, An-178, and CRJ-900 are three short-haul aircraft that will serve as the prototypes for the future aircraft. The designed aircraft must meet the requirements of the chapter task and be a short-haul, transport cargo aircraft with a maximum payload of 16 tons.

Tables 2.1 and 2.2 list the geometric specifications, statistics, and flight performance of prototypes.

Table 2.1

Performance and technical data of the prototypes

Parameter	Aircraft		
	AN 148-100A	CRJ-900	AN-178
Crew/flight attend. persons	2/2	2/2	2/2
Maximum payload, kg	9000	10319	18000
Cruise speed, km/h	820	848	830
Flight altitude, m	11000	12500	12200
Maximum range, km	1920	2955	5500
Thrust to weight ratio, N/kg	3,25	3,19	3,66
Take-off distance, m	1580	1779	2500
Landing distance, m	1600	1596	2300
Take-off weight, kg	38550	36514	51000
Type of engine	2ТРДД	2ТРДД	2ТРДД
Take of thrust кN, кVт	62,7	58,4	77,8
Pressure ratio	21	23,09	21
Bypass ratio	4,8	5,13	5,6

Table 2.2

Main geometrical parameters of prototypes

Parameter	Aircraft		
	AN 148-100A	CRJ-900	AN-178
Fuselage shape	Circular	Circular	Circular
Fuselage diameter	3,35	2,69	3,55
Fineness ratio of the fuselage	7,82	11,8	8,38
Sweep back angle 1/4 chord	25	24	25
Wing aspect ratio	9,5	9	10

The initial weight estimation, wing loading optimization, and engine selection are the next design steps. After the first iteration is finished, it is able to begin the preliminary design of the wing, fuselage, tail, and landing gear layout, figure out how much wing and tail area is needed to support the cargo, and calculate where the center of gravity of the aircraft should be located.

The presented aircraft is a high-plane with a T-shaped tail section, two turbojet engines located on pylons under the wings, and tricycle landing gear retractable into the fuselage. It is based on the prototype configuration. A design like this guarantees excellent lift device efficiency, simple aircraft trim during flight, a tail section that decreases destabilizing moments, and smaller vertical and horizontal stabilizer surfaces. The Department of Aircraft Design used a specific computer software to gather the first data for the developed aircraft, which are presented in Appendix A.

2.2. Aircraft geometry calculation

2.2.1. Wing geometry

The take-off weight m_0 and the specific load on the wing P_o are used to calculate the geometrical properties of the wing. The computer software, which was especially created at the aircraft design department, received this data.

The first estimation is the wing area:

$$S_w = \frac{m_0 \times g}{P_0} \frac{53122 \cdot 9.8}{4223} = 87.32m^2$$

A wing span is determined by multiplying the aspect ratio by the wing area:

$$l = \sqrt{S_w \cdot \lambda_w} = 28{,}92 \text{ m},$$

where λ_w – aspect ratio of the wing.

The following equation can be used to determine the wing's root chord:

$$b_0 = \frac{2S_w \times \eta_w}{(1 + \eta_w) \times l} = 4{,}84m,$$

where η – taper ratio.

Tip chord:

$$b_t = \frac{b_0}{\eta_w} = 1{,}19m$$

A wing with two spars is positioned relative to the other spars along the chord as follows: $\overline{X}_1 = 0{,}2$; $\overline{X}_2 = 0{,}6$.

The position of the spars in the root of a wing:

$$X_1 = \overline{X_1} \times b_0 = 0{,}2 \times 4{,}84 = 0{,}968\, m$$

$$X_2 = \overline{X_2} \times b_0 = 0{,}6 \times 4{,}777 = 2{,}904\, m.$$

The position of the spars in the tip of a wing:

$$X_1 = \overline{X_1} \times b_K = 0{,}2 \times 1{,}19 = 0{,}238\, m$$

$$X_2 = \overline{X_2} \times b_K = 0{,}6 \times 1{,}18 = 0{,}714\, m$$

The geometrical approach is used to determine the mean aerodynamic chord of the wing (MAC). (Fig. 2.1.).

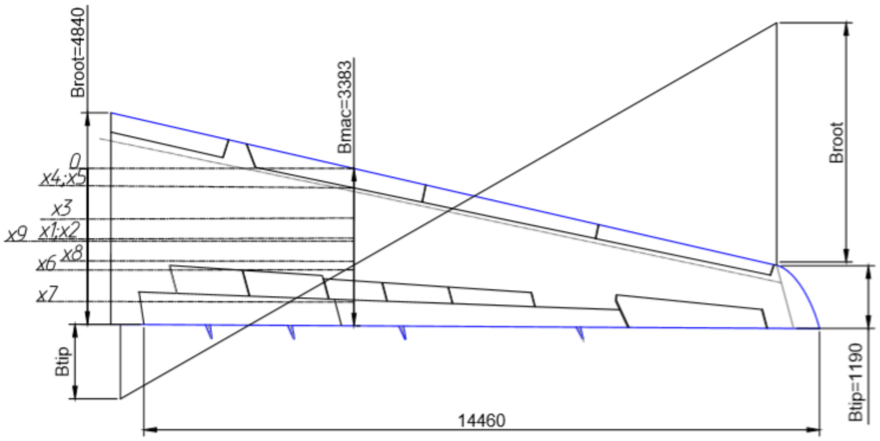

Figure 2.1 - Mean aerodynamic chord of the wing

The measured value of the aerodynamic chord's mean is b_{mac} = 3,341 m.

The companies who create the wings for the prototypes also use their experience to determine the airfoil's thickness, $\bar{c}_i$=0.118.

Consequently, the airfoil's thickness at its root and tip is:

$$c_{root} = \bar{c}_{root} \times b_0 = 0{,}118 \times 4{,}84 = 0{,}571 \text{ m.}$$

$$c_{tip} = \bar{c}_{tip} \times b_0 = 0{,}118 \times 1{,}19 = 0{,}14 \text{ m.}$$

As extendable components on the wing, double-slotted flaps, spoilers, and ailerons without aerodynamic balance are employed.

High-lift equipment's main purpose is to add more lift during takeoff and landing. The following equations can be used to determine the slats' area:

$$S_{slat} = 0{,}1 \times S_{wing}$$

$$S_{slat} = 0{,}1 \times 87{,}42 = 8{,}742m$$

The following formula can be used to calculate the size of the flaps:

$$S_{flaps} = 0{,}17 \times S_{wing}$$

$$S_{flaps} = 0{,}17 \times 87{,}42 = 14{,}86m$$

Ailerons line the trailing edge of the wing tip.

The aileron’s span is:

$$l_{ail} = 0{,}375 \times \frac{l_w}{2} = 0{,}375 \times \frac{28{,}92}{2} = 5{,}72m;$$

The aileron area is:

$$S_{ail} = 0{,}065 \times \frac{S_w}{2} = 0{,}065 \times \frac{87{,}32}{2} = 2{,}83m^2$$

The range of the aileron deflection is equal to upward deflection $\delta_{ail} \geq 20^\circ$ and downwards $\delta_{ail} \geq 10^\circ$.

2.2.2 Fuselage layout

Choosing the size and form of the fuselage cross-section requires starting with the aerodynamics criteria. Shock wave drag has essentially minimal impact on transport aircraft, whose maximum speed is less than the speed of sound (V 800 km/h). Therefore, it is important to choose a shape that ensures the lowest values of the associated form drag C_{xp} and friction resistance C_{xf}.

The nose section of the fuselage is where transonic aircraft should be found:

$$L_{ns}=(2\ldots3)\times D_f,$$

where D_f - fuselage diameter.

When selecting a fuselage cross-section, the layout conditions (particularly for cargo aircraft) and strength needs must be considered in addition to the aerodynamic requirements.

The best form for the cross-section of the fuselage must be acknowledged as a circular cross-section in order to give the least amount of weight. The skin of the fuselage will be as thin as possible in this situation.

The geometric parameters of the fuselage include:

- the diameter of the fuselage D_f;
- the length of the fuselage $L_{f;}$

- fuselage fineness ratio:

$$\lambda_f = \frac{D_f}{L_f}$$

- fineness ratio of the nose of the fuselage:

$$\lambda_{ns} = \frac{l_{ns}}{D_f};$$

- fineness ratio of the tail part of the fuselage:

$$\lambda_{tp} = \frac{l_{tp}}{D_f}$$

where l_{ns} and l_{tp} - respectively, the lengths of the nose section and tail part of the fuselage.

The length of the fuselage is determined by the aircraft layout, features layout, and center, as well as the landing angle of attack $\alpha_{lan.}$

Determine the following fuselage parameters:

$$l_f = \lambda_f \times D_f = 8 \times 3{,}35 = 26{,}8m;$$

$$l_{ns} = \lambda_{ns} \times D_f = 3{,}1 \times 3{,}35 = 10{,}3m;$$

$$l_{tp} = \lambda_{tp} \times D_f = 2{,}1 \times 3{,}35 = 7{,}035m;$$

The minimum mid-section of the fuselage must also be made. The size of the cargo compartment determines the midsection of the fuselage for freight airplanes.

2.2.3 Crew cabin

The number and relative positioning of the crew members' workstations determine the length of the cockpit. The typical cockpit length ranges from 2300 to 3300 mm. The wall, which has a door with a lock, that separates the cockpit from other parts of the fuselage.

The pilot must be able to see the portion of the runways that allows him to control the flight path and avoid any collisions of any part of the aircraft with other aircraft or objects.

This should be taken into consideration while building the cockpit. In actuality, the minimum angles of view during cruise flight, takeoff run, run, and taxiing guarantee this.

When designing an airplane, the front view should be 17° down and 20° up from the pilot's predicted eye position. Therefore, areas are established in which objects should be absent to ensure proper inspection, as well as areas in which the size of these items should be restricted, such as areas where the cockpit canopy racks should not be present since they restrict the field of view. The windows of the cockpit canopy are constructed in a particular shape for the same reason.

2.2.4 Landing gear design

The landing gear of the retractable tricycle is chosen. For contemporary aircraft, this is the type of landing gear that is utilized the most. The airplane's weight is entirely supported by the wheels during takeoff, and it also has improved lateral stability on the ground.

Only a portion of the landing gear geometrical parameters may be established during the early design stage, when the center of gravity has not been calculated and there are no general layout drawings of the aircraft.

The distance between the primary landing gear strut and the center of gravity is:

$$e = 0{,}2673 \times b_{MAC} = 0{,}2673 \times 3{,}38 = 0{,}903m.$$

The landing gear base is found by the expression:

$$B = 0{,}4526 \times L_f = 0{,}4526 \times 26{,}8 = 12{,}129m.$$

The nose landing can be calculated using the following formula because the nose landing gear can support 6–10% of the aircraft's total weight:

$$d_{ng} = B - e = 11{,}226 \text{ m}.$$

One of the key factors in designing an aircraft is the wheel track, which is calculated using the following formula:

$$T = 0{,}6072 \times B = 0{,}6072 \times 12{,}129 = 7{,}36m$$

The takeoff weight of the aircraft, the length of the runways required for takeoff and landing, the takeoff speed, and the landing speed are taken into consideration while choosing the tires for the wheels of the landing gear. Dynamic loads are also considered when choosing the nose landing gear tires. The runway surface that the aircraft is designed to operate on determines the type of tires and the pressure in them. The main wheels have brake wheels, and the nose landing gear support has a shimmy decipher. Determined are the wheel loads:

For the main landing gear wheels load is equal:

$$P_{MLG} = \frac{(9{,}81 \times (B - e) \times m_0)}{B \times n \times z} = \frac{(9{,}81 \times (12{,}129 - 0{,}903) \times 53122)}{(12{,}129 \times 2 \times 2)} = 219240{,}5N$$

For the nose landing gear the wheel load is equal:

$$P_{NLG} = \frac{(9{,}81 \times e \times k_g \times m_0)}{B \times z} = \frac{(9{,}81 \times 0{,}903 \times 1{,}8 \times 53122)}{(12{,}129 \times 2)} = 71924{,}008N$$

K_g =1,5...2,0 - dynamic load factor.

The dimensions of tires for designing aircraft are shown in table 2.3.

Table 2.3

Tires characteristics

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1244x431	32	990x330	16

The tires on airplanes can sustain pressures of about 13 bar (200 psi, 13 atm).

2.2.5 Tail unit parameters

The placement of the horizontal tail is one of the most crucial aerodynamic layout challenges. The center of mass of the aircraft must be in front of the aircraft's focus in order to ensure longitudinal static stability under overload; the distance between these two places, known as the mean aerodynamic chord (MAC) of the wing, determines the moment of longitudinal stability:

$$m_x^{Cy} = \overline{X}_T - \overline{X}_F < 0$$

where m_x^{Cy} - moment coefficient, $\overline{X}_T$ and $\overline{X}_F$ respectively, the relative coordinate of the center of gravity and focus. If $m_x^{Cy} = 0$, then the aircraft has neutral longitudinal static stability.

Based on the analysis of statistical data of prototype aircraft, we have:

$$S_{HTU} = \frac{b_{MAC} \times S_W}{L_{HTU}} \times A_{HTU} = \frac{3{,}38 \times 87{,}32}{9{,}46} \times 0{,}55 = 18{,}87 m^2;$$

$$S_{VTU} = \frac{l_W \times S_W}{L_{VTU}} \times A_{VTU} = \frac{28{,}92 \times 87{,}32}{9{,}46} \times 0{,}09 = 18{,}87 m^2$$

where L_{HTU}, L_{VTU} – horizontal and vertical tail;

l and S – span and wing area;

A_{HTU}, A_{VTU} – coefficients of static moments.

Values of L_{HTU}, L_{VTU} depend on several factors. The length of the nose and tail portions of the fuselage, the sweep angle, the placement of the wings, as well as other factors that contribute to the stability and controllability of the aircraft, all have an impact on their value. At the first iteration, we can assume that $L_{HTU} \approx L_{VTU}$.

The elevator area is usually taken:

$$S_{el} = 0{,}2765 \times S_{HTU} = 5{,}21 \text{ m}^2.$$

The rudder area is usually taken:

$$S_{rud} = 0{,}2337 \times S_{VTU} = 4{,}94\ m^2.$$

Determination of the span of the horizontal tail.

The wing span and span of the il unit are connected by statistical data

$$L_{HTU} = (0{,}32\ldots0{,}5)\times l_w = 0{,}323\times28{,}95 = 9.3\ m.$$

Vertical tail height h_{VTU} is determined by the placement of the wings due to the fuselage. The tape ratio of the horizontal and vertical tail should be selected from the range: $\eta_{HTU} = 2\ldots3$ and $\eta_{VTU} = 1\ldots1{,}33$. Based on the analysis of statistical data of prototype aircraft we take $\eta_{HTU} = 2{,}51$ and $\eta_{VTU} = 1{,}367$.

The aspect ratio for subsonic aircraft: $\lambda_{VTU} = 0{,}8\ldots1{,}5$ and $\lambda_{HTU} = 3{,}5...4{,}5$. Based on the analysis of statistical data of prototype aircrafts we take $\lambda_{VTU} = 0{,}95$ and $\lambda_{HTU} = 4{,}5$. Determination of the b_{tip}, b_{root} performs according to the formulas:

For horizontal tail unit:

$$b_{root} = \frac{b_{tip}}{\eta_{HTU}} = \frac{2{,}89}{2{,}51} = 1{,}15m$$

$$b_{tip} = \frac{2 \times S_{HTU} \times \eta_{HTU}}{(1+\eta_{HTU)} \times\ l_{HTU}} = \frac{2 \times 18{,}87 \times 2{,}51}{(1+2{,}51) \times 9{,}32} = 2{,}89m$$

For vertical tail unit:

$$b_{root} = \frac{b_{tip}}{\eta_{VTU}} = \frac{5{,}32}{1{,}367} = 3{,}89m$$

$$b_{tip} = \frac{2 \times S_{VTU} \times \eta_{VTU}}{(1+\eta_{VTU)} \times\ l_{VTU}} = \frac{2 \times 21{,}15 \times 1{,}367}{(1+1{,}367) \times 4{,}59} = 5{,}32m$$

The tail's sweep back angle is 3...5° more than the wing sweep. The purpose of doing this is to give the airplane control when wave drag develops on the wing.

2.2.6 Engine selection for the designing aircraft

The value 3.2 is determined for the intended aircraft, taking into account the prototypes' thrust to weight ratio. We choose the bypass turbojet engine D436T1 whose characteristics are listed in Table 2.4 based on the required thrust and the engine parameters chosen earlier in the initial data.

Table 2.4

Characteristics of the D436T1 engine

№	Engine Data	Units of measurement	Value
1	Type of engine	-	turbojet
2	Take-off power	kN	73,57
3	Power in cruise flight mode	kN	14,71
4	Specific fuel consumption	kg/N×hour	0,062
5	Engine pressure ratio	-	24
6	Dry engine mass	kg	1450
7	Bypass ratio	-	4,95

2.3 Aircraft center of gravity calculation

The next step in the pre-design stage, after the initial geometric parameter calculation and after selecting the schemes of aircraft components, is to calculate the weight of the primary components of the airplane using statistical data. A plane's weight is broken down into the weight of an empty plane and the weight of a plane that is fully loaded. It is normal practice to combine several systems, components, and pieces of aircraft equipment.

The following general requirements for aircraft layout: The airplane's cargo should be distributed throughout the aircraft where it will be most beneficial; The aircraft's design should enable the control and upkeep of its components, as well as their mounting and repair; The structural plan should give least weight with maximum strength and durability and ease of total aircraft structure assembly.

2.3.1 Centre of gravity of equipped wing

The construction of the equipped wing, the weight of the machinery, and the weight of the fuel are all included in its weight. In the MAC projection to the plane, the start of the center of gravity's coordinates is chosen.

Table 2.5

Treem sheet of equipped wing

№	Name	Mass m_i		C.G. coordinates x_i, m	Moment m_i x_i, kgm
		Units	Total mass m_i, kg		
1.	Wing (structure)	0,11993	6370,92	1,4196	9044,16
2.	Fuel system 40%	0,00152	80,75	1,4196	114,62
3.	Control system (30%)	0,00219	116,33	1,014	117,96
4.	Electrical equipment (10%)	0,00208	110,49	0,338	37,34
5.	Anti-icing system (70%)	0,01197	635,87	0,338	214,92
6.	Hydraulic system (70%)	0,01358	721,39	2,028	1462,99
7.	Power units	0,08915	4735,82	2,65	12549,93
8.	Equipped wing without fuel and LG	0,24042	12771,59	1,8433	23541,95
9.	Fuel	0,13088	6952,60	1,4534	10104,91
	Equipped wing	0,3713	19724,19	1,7058	33646,87

The following formula is used to determine the equipped wing's center of gravity:

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

2.3.2 Centre of gravity of equipped fuselage

In the projection of the fuselage on the horizontal axis with the origin in the nose part of the fuselage, all coordinates of the fuselage masses (table 2.6) are chosen. The X-axis is assumed to be the horizontal line of the fuselage.

$$x_f = \frac{\sum m_i^{/} x_i^{/}}{\sum m_i^{/}}$$

After calculating the mass of the fuselage's center of gravity, we must determine where to attach the wing. It is necessary to calculate *Xmac:*

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

where x_{MAC} - position of the front part of the MAC relative to the nose of the fuselage.

The value x_{MAC} can be calculated by next formula:

$$x_{MAC} = \frac{m_f x_f + m_w \times x_w^{/} - m_0 C}{m_0 - m_w} = 10{,}9.$$

where: m_f – the mass of equipped fuselage, m_w – the mass of equipped wing.

c – distance from the front of MAC to the center of mass of the aircraft.

$$c = (0{,}28 \ldots 0{,}32) \times b_{MAC}$$

The table displays the values for the equipped fuselage's center of masses.

Table 2.6

Centre of gravity of equipped fuselage

№	Object name	Weight m_i		Coordinate of C.G., m	Mass moment, kgm
		Units	Total, kg		
1.	Fuselage	0,12476	6627,5	13,41	88881,41
2.	Horizontal Tail Unit	0,0174	928,04	0,91	844,51
3.	Vertical Tail Unit	0,02031	1078,9	2,07	2233,33
Equipment					
4.	Anti-Ice System, (15%)	0,00256	135,99	21,45	2917,03
5.	Air-cond. system(15%)	0,00256	135,99	13,41	1823,79
6.	Thermal and sound isolation	0,0062	329,35	13,41	1823,79
7.	Control system, (70%)	0,00511	271,45	13,41	3640,46
8.	Hydraulic system, (30%)	0,0058	308,1	18,77	5783,17
9.	Electrical Equip.(90%)	0,0187	993,38	13,41	13322,23
10.	Location equipment	0,0059	313,41	1,081	338,8
11.	Navigation equipment	0,0088	467,4736	1,88	878,85
12.	Radio communication equipment	0,0044	233,73	1,081	252,66
13.	Dashboard	0,0103	547,15	2,58	1411,66
14.	Seats of crew	0,00056	29,96	2,78	83,29
15.	Seats for ac. person	0,00037	19,97	3,6	71,9
16.	Cabin equipment	0,0006	31,87	6,26	199,52
17.	Cargo equipment	0,02845	1511,32	23,59	35655,08
18.	Atypical equipment	0,0037	196,55	896	1761,1
19.	Service equipment	0,01594	846,76	6,99	5918,88
20.	Nose landing gear	0,00297	157,77	2,78	438,6
21.	Main landing gear	0,04153	2206,15	12,4	27356,34
	Equipped fuselage with no payload	0,26286	13963,94	11,65	162754,77
22.	Cargo	0,295	15670,99	13,6	213125,46
23.	Crew	0,00564	299,6	2,78	832,91
	Total	0,999	53122	18,25	608589,72

2.3.3 Centre of gravity for different types of loading

We already know where the wing of the airplane will be located in relation to the fuselage on the drawing we have created at this stage of the basic design. The centers of gravity for the wing and fuselage have previously been determined. The centers of gravity for various aircraft loading and flight modes must therefore be determined. An airplane's center of gravity is shown as a percentage and is defined as the CG's position in relation to the MAC. Tables 2.7 and 2.8 display the results of the computations for each mass's center of gravity.

Table 2.7

Summary list of centers of gravity

№	Object name	Weight m_i, kg	Coordinates, m	A static moment of mass, kgm
1.	Equipped wing (without fuel and LG)	12771,59	13,84	176867,3
2.	Removed nose LG	157,77	1,78	280,83
3.	Removed main LG	2206,15	12,4	27356,34
4.	Fuel	6952,6	12,37	86003,75
5.	Equipped fuselage	13963,64	11,65	162754,77
6.	Cargo	15670,99	13,6	213125,46
7.	Crew	299,6	2,78	832,91
8.	Opened nose LG	157,77	2,78	438,6
9.	Opened main LG	2206,15	12,4	27356,34

Table 2.8

Center of gravity for different aircraft modes

№	Loading options	Weight, kg	A static moment of mass, kgm	Center of the mass, m	Centering, %
1.	Takeoff weight (opened LG)	53122	664159,15	12,76	22,53
2.	Takeoff weight (removed LG)	53122	664121,38	12,76	22,51
3.	Landing option (opened LG)	48422,2	603382,24	12,46	15,48
4.	Transportation option (no payload)	36351,4	454095,91	12,49	16,39
5.	Parking option (no fuel and payload)	29099,16	367417,02	12,62	18,37

Conclusion to the chapter

In this section, a draft design for a short-range cargo aircraft with a maximum payload of 16 tons was created. The primary components and features of the intended airplane were taken into account.

We now have a preliminary design of the airplane with a wingspan of 28.92 meters, an estimated fuselage length of 26.8 meters, and a fuselage diameter of 3.35 meters as a consequence of this chapter of the master's thesis. Due to the D436T1 engine's low fuel consumption, low weight-to-thrust ratio, low emissions, and low noise level, it was chosen to supply thrust in all flying modes. The placements of the Center of Gravity were also computed. The leading edge of the mean aerodynamic chord, where the center of gravity is located most forward, is at 15.48%, and the leading edge of the chord, where the center of gravity is located most rearward, at 22.53% for takeoff mode. These computations allow us to verify that the airplane's masses are all in equilibrium.

PART 3. ERGONOMIC DESIGN OF PILOT CABIN

3.1. Ergonomic design elements

The efficiency of the flight crew's operation and the safety of flights are greatly impacted by the ergonomic design of the cockpit of transport category aircraft. The maximum level of pilot comfort and the best system performance can both be attained with good cockpit design. Even though there are still significant problems with the ergonomic design of cockpits for the transport category aircraft. First off, the transport category airplane's ergonomic design components are not apparent and comprehensive, which could result in operational risks. Second, the ergonomics design activity and process for the cockpit are not supported by a uniform framework.

The goal of the presented thesis is to make the concept of the framework for the cockpit ergonomics of transport airplane. The cockpit's ergonomic design components are examined. The components are gathered from the industry standards, from the features of new-generation airplane cockpits and airworthiness requirements. The ergonomics design elements are analyzed and described for the cockpit of a transport category airplane, the cockpit design process is described, and the ergonomic design components are assigned to each of the phases.

In CCAR/FAR/CS-25 (Airworthiness standards: transport category airplanes) [1,2,3], there are some paragraphs (shown in Table 3.1) that provide the airworthiness requirements, such as “each pilot compartment and its equipment must allow the minimum flight crew to perform their duties without unreasonable concentration or fatigue” to airplane cockpit.

The majority of airworthiness requirements are top-level design specifications and cannot be directly applied to early cockpit ergonomics design constraints. For instance, the equipment (displays or controls) that could cause the flight crew to focus too much or become exhausted have not been given by the specifications. If it is the displays that cause glare or fatigue, then there are still task that need to be covered by the designers. As a result, the airworthiness requirements are examined, their motivations and those of suggested recommendations are looked at, and the variations among CCAR, FAR, and CS are developed.

Table 3.1

The airworthiness chapters for cockpit design requirements

Paragraph of the FAR 25	Title of paragraph
25.771	Pilot compartment
25.773	Pilot compartment view
25.775	Windshields and windows
25.777	Cockpit controls
25.779	Motion and effect of cockpit controls
25.781	Cockpit control knob shape

Before the flight pilots typically analyse information about the flight route and environment situation by scanning the area outside the cockpit, watching the displays, and directing the aircraft in accordance with the operation procedures at each stage of the flight profile. The operational skills and experiences of pilots are important to the cockpit layout of aircraft in the transport category as flight technology advances. Therefore, it is crucial to study the interaction process in order to learn the elements that affect the flight crew's comfort and productivity. Figure 3.1 demostrates a typical interaction flow that takes place as a flight crew completes a task.

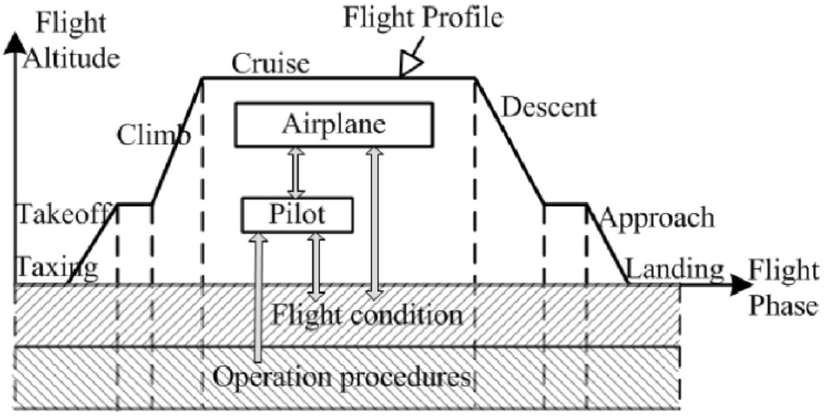

Figure 3.1 - The process of a typical flight profile

Taxing, takeoff, climb, cruise, descent, approach, and landing are the seven stages that make up the flight phase of an airplane, according to the flight profile. The pilot will decide on normal, abnormal, or emergency procedures for each phase, depending on the flight environment, and will use the rudder pedals, thrust power, and buttons to steer the aircraft as safely as possible. Consider the airplane as an example [4], when taxing before takeoff, the pilot can control the aircraft using the pedals on straight taxiways. The provide the yawing, which may be considerable in the event of an engine failure during taxing or side wind action, could cause a quick deflection from the runway centerline. For this reason, rudder and braking will be used along with a fast closure of the propulsion thrust to achieve directional control. After the analysis of the requirements and regulations for the elements of pilot cabin, the experts [5] performed the classification of the main design element which ply an important role in the workload of pilots (table 3.2).

Table 3.2.

Ergonomic design elements of a pilot cabin

Layout and arrangement	General	Workspace and equipment
		Human-machine interaction
		Layout
	Workspace	Workspace in different regions
	Visibility	Windshields and windows
		Vision outside
		Vision inside
	Reachability	Standing operations
		Seated operations
		Reachability of main controls
		Manipulation comfort
	Equipment	Seats
		Display devices
		Controls
		Marks and signs
Displays	Display content	Flight information
		Flight data
	Information distribution	Relative location
		Absolute location
		Arrangement
	Display mode	Color match
		Contrast
		Brightness
		Saturation
		Color temperature
		Display format
		Frequency
		Amount of information
		Appearance
Environment	Temperature	Uniformity
		Range
		Rate of change
	Humidity	Range

The method used to design airplane cockpits is complicated, unpredictable, and non-standard. The expertise and experiences of the people involved in each program are fully dependent on the method. In general, the design process of the cockpit should proceed the same rate as the development of any part of the aircraft. According to this process the main design phases are [6], the requirements, conceptual design, initial design, detail design, and flight test phases are typically used to check the entire layout of airplane cabin [7]. This process is presented in fig. 3.2, where the overlap between two successive phases presents design interactions.

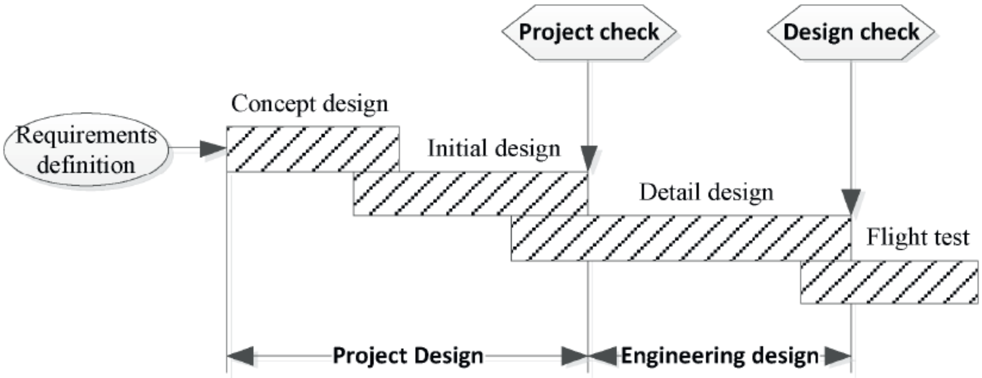

Figure 3.2 – Cockpit design stages

Based on the design elements and airplane design process, the cockpit ergonomics design framework, which directs cockpit design, is created. The ergonomic design components of the cockpit are assigned to each phase of the airplane design process. The cockpit requirements and anthropometric features of the pilot are also significant inputs in the requirements definition phase. The concept design establishes the principal manipulators, display interfaces, and their configurations. The initial design phase should take into account windows management, operational processes, and function allocation between humans and machines. In a thorough design phase, the workload of the flight crew, human mistakes, and task complexity are assessed. The final stage is the flight test, which verifies the whole performance. The ergonomics design components assigned to the design phrases and their interactions are shown in fig. 3.3.

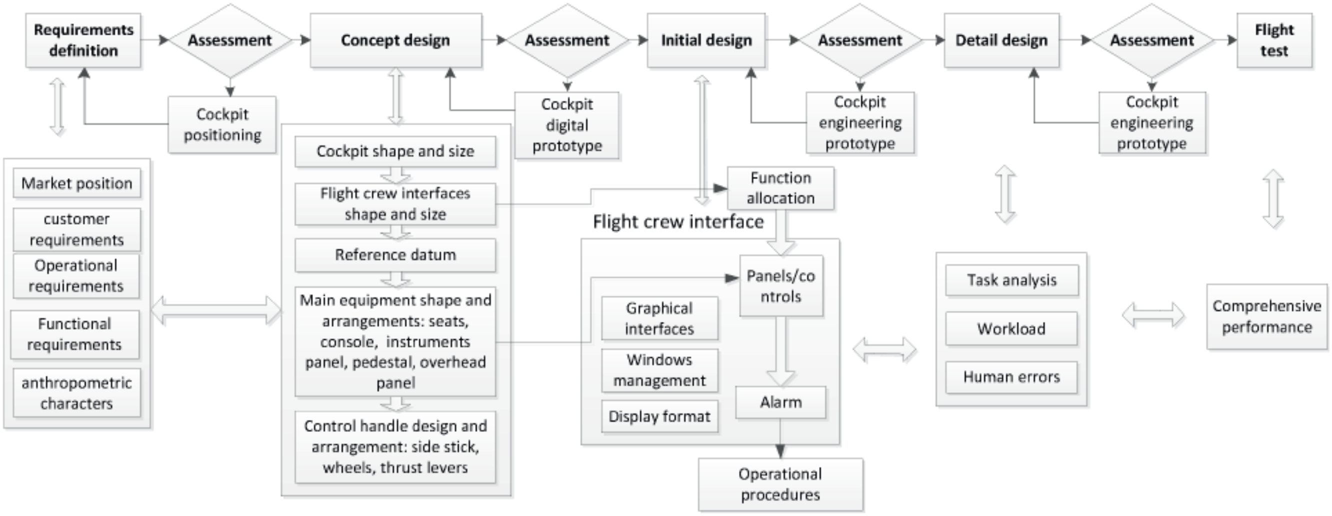

Figure 3.3 – The ergonomics design elements and their relationships in the design process of the pilot cabin

The cockpit's ergonomic design components are examined. The components are gathered from the interaction process analysis findings, industry standards, features of new-generation airplane cockpits, and airworthiness requirements. The ergonomic design elements are grouped based on the hierarchical cluster approach, and the ergonomic design elements for the cockpit of a transport category airplane are identified. The ergonomics design aspects of the cockpit are assigned to each of the phases, providing a framework for cockpit design. The approach is given based on axiomatic design theory.

3.2. Ergonomics assessment for pilot cabin design

Pilots manage the aircraft on the flight deck during various flying stages. The physical and mental health of the pilots must be maintained since flight safety is of the most significance. This can be done, among other things, by properly designing the facilities and navigational equipment in the cockpit. For this reason, the cockpit design must take into account the pilots' sensing and reaction capabilities as a crucial limitation. An aircraft is a wide class of devices that require active contact or continuous control by the pilot. This is in addition to a number of related human-machine interfaces, such as control layout, display location, and seat position.

Human factors and ergonomics, commonly referred to as comfort, functional, or user-friendly system design, is the process of creating goods, procedures, or systems while properly accounting for how they will interact with the users for whom they are meant. Many different disciplines have made substantial contributions to the development of this particular topic. Basically, designing systems or products with human factors and ergonomics in mind has two basic objectives: the productivity of the users as well as their health. A good ergonomic design is concerned with the ‘fit’ between users and their technological tools [8]. A good interface design for the cockpit allows the pilots to quickly access all the necessary control panels in any circumstance.

Every year, pilots from all over the world report having low back pain and feeling uncomfortable while flying. A pilot may become easily exhausted and stressed after a long flight or when flying in poor physical circumstances for a variety of reasons [11]. In fact, the majority of pilots have come to embrace these obstacles as part of the job. However, a proper cockpit design should eliminate discomfort and keep pilots' muscles relaxed, especially for those who must sit in such a small space for extended periods of time [9]. This prevents pilots from establishing a habit of tolerating pain or ignoring it. The criticisms persist despite a variety of pilot's seat designs that have been created based on standards and certain modifications to the seat's materials, size, and firmness to improve comfort. It has been discovered that there are discrepancies between the norms and anthropometric study of the pilot's seat for contemporary civil aircraft, according to a survey that was done on five distinct transport aircraft designs [10]. In light of this perspective, the purpose of this study is to discuss some potential inconsistencies and offer some solutions.

In order to get the reply pilots' opinions on the ergonomic issues with the cockpit design based on their own experiences, a questionnaire with 90 questions was created and given to the respondents. Be aware that the pilot's seat design is the primary subject of this study. The respondents are asked to grade the topic or parameter under consideration using a 0–20 grading scale that was modified from Ref. [12]. The participant may choose a number between two extreme situations, for example, either too low (20) or too high (0), whereas the number ten (10) is viewed as the correct design value. The scale measures participant satisfaction with numerous seat factors.

The answers are gathered and averaged based on their answers to the questions. These details may be utilized to determine whether there is indeed a design issue with the cockpit.

Twenty pilots working on international flight routes for various airlines, representing a variety of ethnicities, have all replied to the poll. The remaining 5% of responders are female, making up 95% of the group. Figure 3.4 shows more details on the respondents' demographics and the kind of aircraft they are flying. This background knowledge is essential for determining whether or not the responses are skewed toward particular aircraft designs.

Figure 3.5 displays a summary of the survey's findings on the comfort of the pilot's seat. As can be seen, it demonstrates that the current pilot seats do not provide pilots with the option to adopt a comfortable sitting position. The anthropometric dimensions in this instance may have been poorly chosen or taken into account. The findings can be utilized to identify the seat component that needs modification, and the parameters of the seat are compared to anthropometric dimension standards to identify any design inconsistencies.

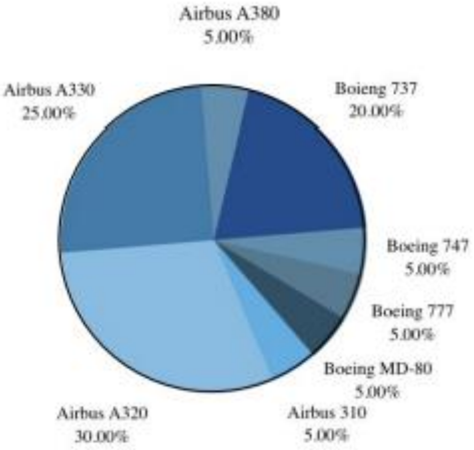

Figure 3.4 - Distribution of participants by the types of aircraft they operate

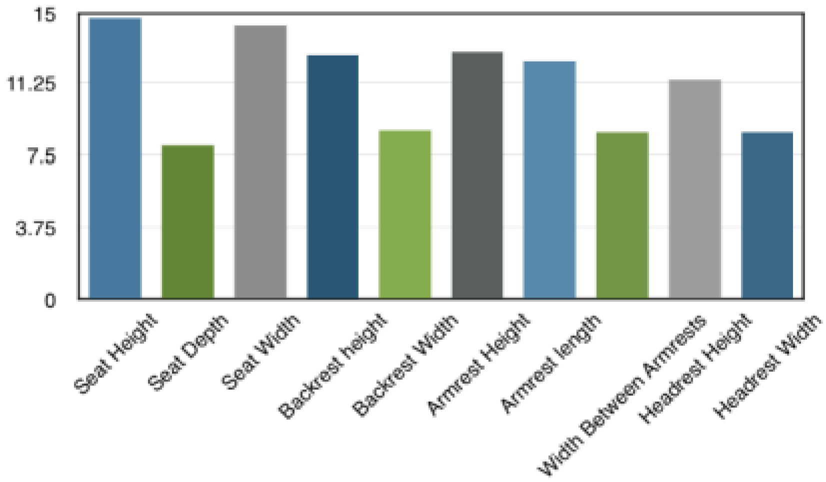

Figure 3.5 – Seats components which provide the comfort

The presented results of survey describe comfort as a sensation of relief and pleasure. According to some experts, comfort is a condition of harmony between a person and their surroundings and circumstances. Some people define comfort as the lack of discomfort. On lengthy international flights, it is typical for pilots to fly nonstop for up to ten hours. Pilots typically need to stand and walk after a few flying hours to relieve pressure on their backs and legs from the prolonged sitting. The typical and uninhibited movements of a pilot while seated in the cockpit involve shifting from one buttock to the other, and then eventually pushing himself forward yet being held back by the shoulder harness. Consequently, he begins to experience pain under one of his thighs. The discomfort soon intensifies and spreads to both thighs. When a pilot or member of the air crew experiences excruciating agony, they may struggle to focus on the flying controls and instead become preoccupied with their physical discomfort [13]. On the other side, exhaustion and sleepiness are what lead to fatigue. The sensation of tiredness is a key sign of fatigue. The most typical types of weariness experienced by pilots are visual, monotonous, chronic, and circadian, all of which significantly slow down a pilot's reaction time and increase the likelihood of catastrophic mistakes [14]. The flight deck must be a highly comfortable place for the pilots in order for them to operate safely. Unfortunately, the pilots have not been trained how to raise their level of comfort in order to maximize their small workstations while maintaining a comfortable posture for extended periods of time in the air [14]. It may be difficult to believe that poorly designed flight deck systems for a particular demographic may result in a terrible accident due to a lack of anthropometric design consideration.

Anthropometric measurements, such as shoulder width and grip strength, show both static and dynamic dimensions. The US Army Anthropometric Survey (ANSUR) is one of the most well-known anthropometric databases. The Civilian American and European Surface Anthropometric Resource (CAESAR), which is compiled from data on the people in the US and Europe, is a further extensive database [15]. Data from a few different regions, including North America, Italy, and the Netherlands are represented by CAESAR for both boys and females [16]. The book "Body Space" by Pheasant, which also compiles data from populations in North America and Europe, is a crucial ergonomics resource in this area [17]. Table 3.2.1 displays the anthropometric measurements for the typical office chair design that were gathered from various literatures and ergonomics experts.

For the minimum and maximum designs, the anthropometric dimension employed for the overall seat design is set to correspond to the 5th of female to the 95th of male as the general population. This indicates that 90% of people can utilize it [19]. Values between these percentiles are adequate for most people, and the seat should be able to support a wide range of users. The fact that a woman in the fifth percentile of sitting height has thighs that are shorter than the fifth percentile, however, is meaningless. As a result, the design is made based on her vision height, and she may experience pressure while sitting for extended periods of time on the back of her knees [20].

1. Seat Height

The seat height dimension should take into account the 5th percentile of female to the 95th percentile of male popliteal height. According to earlier research, a 2.5 cm tolerance for shoe heels should be used [18].

2. Seat Depth

The 95th percentile male buttock popliteal length is 54 cm, which is 10 cm longer than the 5th percentile female length, according to ANSUR anthropometric measurements. Contrarily, the 95th percentile male buttock popliteal length in CEASAR is 48 cm (12 cm greater than the 5th percentile female length). Therefore, the maximum size for seat cushion length should be 10 cm, especially for pilots who tend to be more male than female [20].

Table 3.3

Anthropometric data for first pilot seat design [12, 18]

Seat Requirements	Anthropometric Measurement	BSR/ HFES100.2002	BIFMA	DREYFUSS	WOODSON	Grandjean	Diffrient
Seat height, cm	Popliteal Height+ Shoe Measure	38.36	38.10 – 50.50	36.80-48.30	38.10-45.70	38-53	35-52
Seat depth, cm	Buttock Popliteal Length - Clearance Measure	More than 43	49.90	40.60	40.60	38-42	33-41
Seat width, cm	Hip Breadth in sitting posture+ Cloth Measure	Less than 45	More than 45.70	40.60 - 55.90	48.30	40-45	41
Backrest lumbar, cm	-	12-15	15-24.90	17.80-29.20	17.80-25.40	NA	NA
Seatback width, cm	-	more than 31.5	NA	NA	NA	32-36	33
Backrest height (upper body support), cm	-	Less than 45	More than 31	More than 33	More than 20.30	48-50	NA
Armrest height, cm	Elbow Rest Height	18-27 (adjustable)	17.50-27.40	19.10-25.40	21.60	NA	18-25
Armrest length, cm	-	NA	NA	25.40-30.50	30.50	NA	15-21
Distance between armrests, cm	Hip Breadth in sitting posture + Cloth Measure	46	45.70	More than 48.30	48.30	NA	48-56

3. Seat Width

The widest hip breadth within the sample population should be measured and used for the seat width dimension. Women have wider hips than men do while seated [20], according to anthropometric measurements. The breadth of the seat should be comfortable for the pilots' arms in addition to their seat and clothing allowance. The 95th percentile of hip width has been advised, taking into account 4 to 5 cm for clothing allowance [21]. Another suggestion is to add 5 cm for heavy clothing and use a female hip measurement of 95 or 99 cm [22].

4. Backrest Height

The sitting shoulder height is taken into consideration when determining the backrest's upper body support dimension. The 95th percentile for men and the 5th percentile for women are used [23].

5. Armrest Height

The anthropometric dimension in the armrest height is determined by the data on sitting elbow height, which ranges from the 5th percentile for females to the 95th percentile for males. Only the female 5th percentile is taken into account for the fixed armrest. The armrest in this instance should be moveable to better accommodate a large multinational population. Applying elbow height from 5th to 95th when seated [24].

6. Armrest Length

Armrests are helpful for supporting the upper limbs and maintaining balance in the body. The elbow to wrist measurement of a 95th percentile male is the most accurate anthropometric measurement for armrest length. To be more comfortable, it should support at least two-thirds of the forearm [24].

7. Width between Armrest

For comfort and ample room for clothing, armrests should be able to support 95th percentile females with the largest hip breadth [25]. They feel that the minimum distance between armrests should allow for the 95th percentile male's elbow breadth based on the opinions of various ergonomists [22]. Other specialists add three millimeters to the elbow width of 95 men and 5 women to account for bulky clothing [26].

8. Backrest Width

Shoulder width or bideltoid breadth should be used to calculate the backrest's width [27]. Maertens recommended 95th percentile male waist breadth to specify the backrest width, while Reynolds advocated 95th percentile male chest width to determine the minimum width in the upper section of the backrest seat [20].

9. Headrest Height

The distance from the chin to the crown must be measured to determine the headrest height. The 5th percentile of females to the 95th percentile of men for minimum and maximum headrest is used to accommodate a larger population [28].

10. Headrest Width

The maximum width across the ear is used to determine the headrest's width. The 5th percentile of females to the 95th percentile of men for minimum and maximum headrest is used to accommodate a larger population [28].

Overall, Table 3.4 compares the two anthropometric database standards, ANSUR and CAESAR, with AS290B (Aerospace standards and biomechanical criteria).

Table 3.4

Anthropometric data for the flight deck seat design [10, 29, 30]

Seat Requirements	AS290B	ANSUR	CAESAR
Seat height	33 - 51	38 - 51.5	33.44 - 44.87
Seat depth	41 - 45	44 - 54.60	36.66 - 48.09
Seat width	min 43	48.22 - 50.32	50.10 - 55.66
Backrest height (Upper body Support)	min 65	53.92 - 67.66	52.29 - 65.58
Seatback width	20 - 32	17.57 - 27.37	19.25 - 28.70
Armrest height	min 28	23.78 - 31.61	21.33 - 29.20
Armrest length	min 47	41.47 - 62.06	40.20 - 64.52
Distance between armrests	43 - 46	39.70 - 53.48	38.47 - 55.03
Headrest height	NA	21.41 - 23.41	22 - 26
Headrest width	NA	13.66 - 16.08	13 - 16.24

Conclusion to the chapter

The presented results show that there are a number of discrepancies between the pilot's seat design dimensions guidelines and the widely used anthropometric databases in North America and Europe. To solve this problem, the following points might be taken into account while establishing new measurements for existing seats:

- The minimum dimension in ANSUR is more than the standards, whereas the maximum dimension in CAESAR is less than the dimension in AS290B. Standards are exceeded by AS290B and ANSUR's minimum dimension.

- The maximum seat depth of AS290B and CAESAR are not compatible with one another. The maximum dimensions based on ANSUR are 54.60 and 9.60 cm, which differ from the specifications for aircraft. The maximum seat depth in the standards is less than the anthropometric data from populations in the USA and Europe.

- The shoulder height used to calculate backrest height by ANSUR and CAESAR differs from the minimum and maximum height specified by the AS290B standard.

- According to CAESAR and ANSUR shoulder width data, backrest width differs from AS290 standard. While the maximum dimension in the AS290 standard is also smaller than the male 95th percentile in the CAESAR and ANSUR, the minimum is larger than the fifth shoulder width.

The findings of this study support the hypothesis that the design standards for pilot seats may not be sufficient to accommodate the diverse anthropometric characteristics of today's pilots. To enhance the pilot's seat's design in the future, the mismatch should be considered.

PART 4. ENVIRONMENTAL PROTECTION

4.1. Environmental safety of the aviation industry

Since its inception, aviation has been tied to the oil refining industry. In recent years, there has been a trend in the air transport industry to reduce the cost of operating aircraft. Both military and civil aviation are actively looking for ways to minimize these costs. Today, about a quarter of the cost of a flight is the price of fuel. Since oil resources as raw materials for the production of fuels are exhausted, their price is constantly growing. In this regard, soon the aviation industry will face the need to replace traditional aviation fuels with alternative ones. In addition, the state of the environment is of concern. Fuel production is associated with the extraction of fossil energy sources from the earth's interior, which leads to an increase in the amount of CO_2 in the atmosphere, increasing the global greenhouse effect.

Today, one of the ways to solve the problems of aviation’s impact on the environment, as well as the issue of exhaustion of traditional energy resources, is the transition to alternative fuels. The introduction of biofuels in the aviation industry will allow the future to increase the efficiency of the use of motor fuels, the functioning of the air transport and energy sectors, as well as to minimize the anthropogenic impact on the environment.

Against the background of growing technogenic pollution of the environment in urbanized areas, negative processes are manifested, namely, that threaten the health and life of people. As a result of a sharp increase in the intensity of aircraft traffic, the emergence of heavy jet aircraft in operation, as well as significant urbanization of the territories adjacent to aviation facilities related to the operation of aircraft engines (airport, air base, etc.), the assessment of their impact on the environment is now becoming particularly relevant. Exhaust gases from aircraft fuels have the most adverse anthropogenic impact on ecosystems in the vicinity of airports. At the same time, most of the pollutant emissions occur in the two-meter ground air layer (GAL) - the breathing zone of people. Therefore, it is necessary to introduce alternative aviation fuels to reduce emissions into the environment and to make people's lives easier.

4.1.1. The impact of the aviation industry on the environment.

Today, the state of the environment, which is steadily deteriorating, is of particular concern. First of all, it is about global warming, which is intensifying as a result of the processes of energy resource extraction, processing, and use. The main products of the combustion of energy resources, including aviation fires, are CO_2 and H_2O. The result is an increase in the global greenhouse effect on the planet. Today, the concentration of CO_2 in the atmosphere becomes close to 400 ppm (0.04%), which was twice as much lower until the beginning of the industrial revolution of the XVIII century. can reach 500 ppm (0.05%) [31-33]. At the same time, the International Energy Agency suggests that the share of carbon dioxide emissions as a result of air transport activity will become close to 2% (Fig. 4.1) and may reach 3% in the next hour [31].

The rapid increase in CO_2 content in the atmosphere is due to the active development of the aviation industry. The world volume of passenger air traffic is growing annually by 4-5 %. The expansion of the aircraft fleet and the increase in the number of flights leads to an increase in the consumption of aviation fuels [34,35]. According to the analytical site www.indexmundi.com, about 5.5 thousand barrels of jet fuel are produced and consumed daily in the world.

During the 10 years (2002 - 2012) the level of aviation fuel consumption increased by 17%. In addition to carbon dioxide, fuel combustion products contain several substances that adversely affect the environment. According to the results of research, aircraft exhaust gases contain about 200 harmful substances, the main of which are carbon dioxide, methane, soot, sulfur oxides, carbon monoxide, nitrogen oxides, unburned hydrocarbons, etc [36].

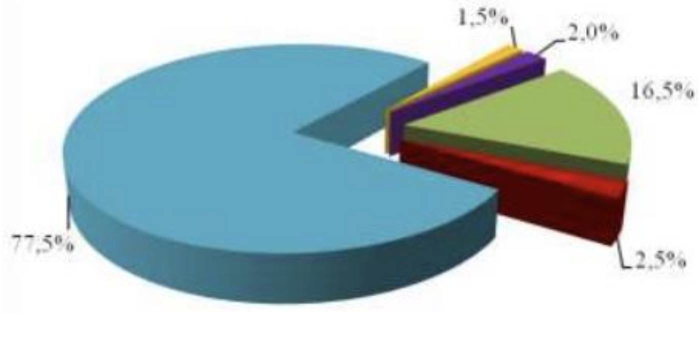

Fig. 4.1.1 Share of CO_2 emissions from aviation compared to other modes of transport: 1.5 % - international aviation; 2 % - international maritime transport; 16.5 % - road transport; 2.5 % - other modes of transport; 77.5 % - other energy sources.

Table 4.1.1

Composition of aircraft exhaust gases [37]

№	Connection	Mechanism of formation	Environmental impact
1	CO_2	Carbon dioxide is a product of the complete combustion of aviation fuel. Fuel carbon is oxidized by air oxygen to CO_2.	Carbon dioxide is the main greenhouse gas with a long lifetime (50-200 years). Its share in total jet engine emissions is approximately 70%. Dispersing in the atmosphere CO_2 causes the heating of the troposphere under the influence of solar radiation.
2	H_2O	Water vapor is another product of the complete combustion of fuel. In the process of combustion, hydrogen is oxidized to H_2O.	It makes up about 29% of all exhaust gases from jet engines. Does not cause a negative impact on the environment.
3	CO	Carbon monoxide is formed as a result of incomplete combustion of aviation fuel due to a lack of oxygen in the fuel-air mixture.	CO negatively affects all living components of ecosystems. In the human body, it blocks oxygen access to tissues and causes cardiovascular diseases.

4	NO_x	Nitrogen oxides are formed when air enters a combustion zone with high temperature and pressure, where molecular nitrogen combines with oxygen to form NO_x.	NO_x causes the formation of photochemical smog and the destruction of the ozone layer in the upper atmosphere. In the human body, they irritate mucous membranes, CNS damage.
5	C_xH_y	Hydrocarbons are emitted due to incomplete combustion of fuel in conditions of lack of oxygen in the fuel-air mixture.	Hydrocarbons are sources of environmental pollution by carcinogenic substances. In the human body, C_xH_y has carcinogenic, mutagenic, narcotic, and other toxic effects.
6	SO_x	Sulfur oxides are formed as a result of the oxidation of sulfur-containing compounds of aviation fuels by air oxygen during combustion.	Sulfur oxides in humid air form aqueous solutions of sulfuric acid that fall to the surface of the earth, reducing soil fertility and destroying chlorophyll in plants. SO_x cause corrosion of metals, reduce the durability of paint coatings, the strength of metals, buildings
7	Soot, solid particles of fuel		Particle fractions of up to 10 microns are retained in the atmosphere, reducing air transparency, reducing access to

			ultraviolet radiation, and worsening the microclimate of certain regions. In the human body, particulate matter affects the respiratory system, mucous membranes

Such impact of air transport on the environment forces international organizations, on the one hand, to increase environmental requirements for aviation fuels, and on the other hand, to promote the introduction of alternative environmentally friendly fuels. The International Air Transport Association (IATA) has set a goal to reduce CO_2 emissions from air transport by 50% by 2050. The European Parliament Resolution on reducing the impact of aviation on climate change (INI/2005/2249) calls for the promotion of biofuels, which will help reduce the impact on climate change. At the same time, the European Commission has approved a policy to reduce CO_2 levels by 60% by 2050, and the share of low-carbon fuels in aviation should reach 40% by 2050 [31-33].

Taking into account the current state of the fuel and energy complex of Ukraine, in particular the oil refining and aviation fuel supply industries, it is urgent to introduce and implement measures aimed at the rational use and economy of fuel and lubricants. As noted in the Energy Strategy of Ukraine until 2035, increasing the share of alternative fuels is one of the priorities of the modern fuel and energy complex, can become a tool to reduce Ukraine's dependence on imports of petroleum products on the one hand and expand the raw material base for the production of aviation fuels, on the other.

4.1.2. Current state of biofuel use in the aviation industry.

By definition, biofuel is made from natural renewable materials, so its use has a significantly lower impact on the ecological situation on the planet. It is the concern for the environment that has led to several serious decisions in the field of civil aviation, in particular on the production and use of alternative aviation fuel.

For use in aviation, alternative fuel should be not only relatively cheap but also similar in its physical and chemical characteristics to petroleum aviation fuel. In this case, the transition of the fleet to new types of fuel will not require the replacement or modernization of engines, which is fraught with additional costs, including the creation of such engines [38].

The most promising direction of biofuel development today is the creation of combined mixtures of plant and oil components. In other words, a fuel component is produced from various plant raw materials that have good but insufficient characteristics for use in aviation. This component is added to the oil fraction, and a complex of additives is introduced. Due to the efficient combustion process, such a mixture can be successfully used as an alternative to traditional petroleum aviation fuel [31,32].

4.2. Raw materials for the production of bio-additives for alternative aviation fuel

The variety of technologies provides the possibility of producing alternative fuels for jet engines using many types of raw materials. Among the range of raw materials, scientists currently consider plants with high oil content, algae, and some types of industrial and domestic waste to be the most promising [39].

Rye belongs to energy crops with high oil content. Its main consumers today are biofuel producers. Typically, camelina is used in agriculture as a crop rotation, which prevents the decline of land fertility and provides increased resistance of other crops to diseases and pests. In addition, camelina is unpretentious to climatic conditions, that is, it does not require careful cultivation and care. It is known that camelina seeds contain 40-50% of oil, which provides an oil yield of about 1250 l/ha. Another advantage of this crop is the possibility of using the meal (a by-product of the oil extraction process) as feed for farm animals and poultry. According to scientists, such characteristics of camelina will ensure the "sustainability" of the aviation biofuel production process without creating competition in the food industry. This culture has spread in the United States, Canada, and some European countries. According to some experts, the production of camelina in Ukraine will grow rapidly in the coming years [38].

Rapeseed has been the main crop for biofuel production for the last 10-15 years. During 2000-2010 the leading producers of rapeseed oil were Canada, the USA, and such European countries as Germany, France, the Czech Republic, Poland, and Great Britain. By chemical composition and main technical characteristics, rapeseed oil is suitable for the production of alternative fuels. Now the question has arisen about the feasibility of growing rapeseed as a biofuel raw material. Scientists point out that rapeseed culture demands growing conditions, requires constant fertilization, and other care significantly depletes the soil in areas traditionally used by agro-industrial complexes.

It should be noted that rapeseed is a typical crop for Ukraine, and during the last 8-10 years its mass production was observed. The most rapid increase in rapeseed production occurred in the period 2004-2008, which coincided with the growth of global demand for rapeseed oil as a raw material for biofuels. The area under rapeseed in 2011 amounted to more than 1.1 million hectares, and the average yield was 15-17 c/ha. During these years in Ukraine rapeseed was grown exclusively for export, and its domestic processing was almost not carried out. Only in recent years, there has been a slight decline in rapeseed exports and an increase in domestic processing volumes. Therefore, the possibility of producing alternative fuels for jet engines from rapeseed oil requires further research [39].

So, having analyzed the main types of biofuel raw materials, such as camelina and rapeseed, we can say that both crops are very promising. Rapeseed is more popular today, but the expediency of its cultivation for the biofuel industry in my opinion is not entirely appropriate. Rapeseed depletes soils and is very demanding to grow, while camelina is resistant to any conditions. The yield of oil per 1 hectare in both crops is approximately the same, but at the same time, rapeseed depletes the soil, and camelina ennobles them [38].

Since the oils of these two crops are the most advanced for the production of biofuels in the world, these oils were used by us to obtain bio-additives for alternative aviation fuel.

4.3. Environmental properties of new aviation biofuels.

The qualitative and quantitative composition of aircraft exhaust gases is determined by the design and efficient operation of the engine, as well as the environmental properties of jet fuels, which in turn are determined by the content of heteroatomic compounds such as sulfur. Sulfur compounds are the source of sulfur oxides in exhaust gases. The presence of aromatic hydrocarbons in jet fuels is an important indicator when assessing its environmental properties, as it is a source of soot in exhaust gases. To estimate exhaust emissions, ICAO has defined a reference take-off and landing cycle (TLC) at an altitude below 915 m (Fig. 4.3.1).

Figure 4.3.1. Reference take-off and landing cycle

This cycle consists of four phases to characterize the modes of takeoff, climb, descent and idle and is a greatly simplified version of the operational flight cycle (Table 3.1).

Table 4.3.1

Reference take-off and landing cycle of the aircraft

Take-off and landing cycle phase	Duration of take-off and landing cycle phases, min	The relative thrust of the engine, %
Takeoff	0.7	100
Height set up to 915 mm	2.2	85
Descent and landing from an altitude of 915 m	4.0	30
Idle running	26.0	7

The aircraft emissions assessed by ICAO recommendations are CO_2, H_2O, SO_2, CH_4, CO, C_nH_m, NO_x, and soot. The amount of exhaust gases also depends on the type of jet fuel, in particular its hydrocarbon and elemental composition.

Conclusions to the chapter

During this part, the impact of the aviation industry on the environment, dynamics, volumes, and structure of aircraft exhaust emissions are analyzed. It is shown that one of the priority ways to minimize the impact of aviation on the environment is the introduction of alternative fuels. The promising types of renewable plant raw materials that are the most appropriate for the production of aviation biofuels in Ukraine are considered and substantiated.

PART 5. LABOUR PROTECTION

5.1. List of production factors operating in the work area

Safety measures during the maintenance and repair of aircraft are regulated:

- state and industry standards of the system of occupational safety standards; guidelines for the production of flights, technical operation, and repair of aircraft;
- maintenance regulations, repair technology, guidelines, and instructions on occupational safety.

Installation, repair, and maintenance are carried out in the production or repair shop. The working area of the technician who installs, repairs, or maintains the system is the entire aircraft and the parking lot. The system is serviced in hard-to-reach and poorly lit places, in drafts, and at low or high (depending on the season) air temperatures in the working area.

The most dangerous and harmful factors are:

- moving mechanisms and machines; unprotected moving elements of aircraft (propellers, stabilizers, etc.);
- increased dust and gas pollution in the maintenance area (loading and unloading of equipment at unpaved airfields);
- increased noise, and vibration of ultra and infrasound (when hot air leaks, as well as during the operation of auxiliary power units);
- elevated surface temperature of equipment, materials (air supply pipelines)
- insufficient lighting in the workshop.

5.2. Technical and organizational measures to reduce the level of exposure to hazardous and harmful production factors

Several measures are envisaged to prevent the possible impact of the above harmful factors on the working staff:

- strict compliance with safety rules and regulations during operation, maintenance and repair of the system, and management of auxiliary supports;
- testing of units for strength, and tightness.

Tests of the units should be carried out on special stands and in laboratories in specially equipped rooms.

The vibration resistance of the units shall be tested in full compliance with the current standards and rules of testing.

To reduce the harmful effects of noise on the working personnel, which occurs during the testing of the system, it is recommended to test the system as a whole or its units in special boxes where noise silencers are installed.

To prevent possible exposure of personnel to hot air during pipeline rupture, personal protective equipment is used during testing.

During the operation, maintenance, and repair of the automatic pressure control system, strict observance of safety precautions and technology of work processes is provided. It is envisaged to manufacture pipelines from stainless steel AK-1 (aluminum alloy), as well as the use of titanium-based alloys for this purpose.

During work, the condition of a working person is greatly influenced by various environmental factors, which are characterized by the presence of harmful production factors, due to which the conditions of the working environment differ from the natural physiological for a person.

5 main production factors affect sanitary and hygienic working conditions: air of the working area (microclimate of the premises, composition of the air environment), light climate, noise climate, industrial vibrations, and radiation.

5.3. Calculation of workshop lighting

Assembly, installation, and fastening of pipelines, units, and assemblies of the air conditioning system is carried out in the general assembly workshop-hangar and is made on the already assembled airframe.

The functional systems affect the safety of flights and the aircraft as a whole. Therefore, for reliable visual control over the installation of components and assemblies, and most importantly, the joints of pipeline assemblies and for good visibility in the installation area (which will increase overall safety), the workshop must have optimal lighting.

The average illumination of the workshop is equal to:

$E_{ave} = \frac{n \cdot F_l \cdot \eta}{S \cdot k}$;

According to the State Construction Rules and Regulations P-4-79 $E_{ave} = 200$ lux

where n - number of lamps in the room;

F_l - luminous flux from one lamp [lumen];

$F_l = \frac{E_{ave} \cdot S \cdot k \cdot z}{\eta \cdot n}$;

where S - working surface area m^2;

k - safety factor $k = 1{,}5$;

η - luminous flux utilization factor of the lamp $\eta = 0{,}68$;

z - correction factor $z = 1{,}1$;

S - (workshop plane) = A·B

$A = 200$ m; $B = 150$ m;

$S = 200 \cdot 150 = 30000$ m^2;

$$\varphi = \frac{A \cdot B}{h_\circ \cdot (A + B)}$$

$h_\circ$ - the height of suspension of the lamp above the work surface;

$h_\circ = 25$m;

$\varphi = \frac{200 \cdot 150}{25 \cdot (200 + 150)} = \frac{30000}{8750} = 3{,}42$ - indicator of the room;

$$F_{l_t} \frac{200 \cdot 30000 \cdot 1{,}5 \cdot 1{,}1}{0{,}68 \cdot 150} = \frac{99 \cdot 10^5}{102} = 97058{,}8 \text{ lm}$$

$$F_{l_{one}} = \frac{F_{l_t}}{n} = \frac{97058{,}8}{150} = 647{,}05 \text{ lm}$$

Then:

$$E_{ave} = \frac{n \cdot 97058{,}8 \cdot 0{,}68}{30 \cdot 10^3 \cdot 1{,}5} = 200 \text{ lux}$$

$$n = \frac{E_{ave} \cdot S \cdot k}{F_{l_t} \cdot \eta} = \frac{200 \cdot 30 \cdot 10^3 \cdot 1{,}5}{97058{,}8 \cdot 0{,}68} = 137$$

The number of lamps in the room should be 137 pcs.

5.4. Fire and explosion safety in the working area of aircraft maintenance

Fire safety in the hangars should be ensured through organizational, and technical measures aimed at preventing fires, preventing the death of workers, as well as reducing property losses, creating conditions for a quick call to the fire brigade, and successful fire extinguishing.

The system is designed with several design features that ensure the safety of the system in terms of fire, and strict compliance with safety instructions during bench tests of units.

The main means of safety prevention are:

- isolation of possible sources of ignition from places in contact with electrical wiring, placement of system units, if possible, at a distance from fire-hazardous areas and units that may serve as a possible source of ignition;
- careful handling and storage of the paintwork materials
- the maximum possible distance between high and low-pressure cylinders and electrical wiring is maintained;
- fire-fighting devices should be available;
- it is necessary to organize the development and timely implementation of measures aimed at ensuring the safety of people in case of the occurrence of fire or ignition;
- ensure the serviceability of fire warning systems and

management of evacuation of people in case of fire;

- organize fire safety training for subordinate employees by the Standard Regulations on Special Training, Briefings, and Knowledge Testing on Fire Safety at Enterprises;
- not to allow persons who have not undergone fire safety training to work;
- ensure that employees are familiarized with fire safety requirements using posters, other visual agitation, or through a loudspeaker radio broadcasting network.

When working with tanks that operate under high pressure, technicians must adhere to the following rules:

1. After connecting the tanks to the air network, it is necessary to make sure that the safety valve is in good working order by blowing it up with a specially equipped lever.

2. Monitor the pressure in the tanks and devices for drainage of accumulated lubricating oil and water in the automatic pressure control system, valves, and shut-off and control valves during the change.

3. A warning poster "Caution, people working" should be posted on the storage

4. Removal of the poster "Caution, people working" is allowed only to the person responsible for the safe operation of the tanks.

5. Admission of personnel to independent maintenance of tanks should be issued by the order of the shop or enterprise.

6. The worker, being inside the aircraft, must be equipped with protective equipment: a suit, goggles, respirator, or hose-type gas mask PSh-1, PSh-2.

7. Blowing of air intakes from accumulated water and grease, the service personnel must do twice during the working shift, which is recorded in the log.

8. When the pressure in the tank has risen above the permitted pressure and does not decrease, despite the noise, the person must immediately stop the work.

9. The work must be stopped immediately when detected: leaks, leaks, rupture of gaskets, etc.

10. In case of injury or violations that may lead to an accident or accident, it is necessary to inform the foreman or the administration of the workshop.

Workers guilty of violating the instructions bear disciplinary, administrative, or criminal responsibility by the established procedure.

5.5. Basic rules of safety, fire, and explosion safety

Persons responsible for fire safety are obliged to carry out the following fire safety measures

- explain to subordinate personnel the requirements of fire safety rules;
- monitor compliance with the fire regime in the assigned premises and on the territory of the market;
- monitor the serviceability of heating appliances, electrical equipment, automatic fire protection, and fire warning systems and take measures to eliminate identified deficiencies;

- at the end of the work to check whether the workplaces are cleaned and the territory is secured, as well as the disconnection of electrical installations;
- ensure proper maintenance of available primary fire extinguishing equipment;
- develop instructions on fire safety measures.

The responsibility for fire safety based on regulatory legal acts develops and approves the general facility instruction on fire safety measures.

The general facility instruction shall establish the appropriate fire regime, including

- places of storage of PPM, tools, equipment, etc;
- the procedure for cleaning the territory and workplaces at the end of work;
- the procedure for de-energizing electrical equipment after the end of the working day and in case of fire;
- the procedure for conducting temporary fire and other flammable works;
- the procedure for inspection and closure of premises after working hours;
- duties of security guards to monitor compliance with fire safety regulations.

Employees of the markets are obliged to:

- know and comply with fire safety requirements on the territory of the hangar and at workplaces;
- during the work carefully handle flammable and combustible liquids, other flammable substances, and materials;
- in the event of a fire, notify the fire department, take all possible measures to rescue people, and property, and extinguish the fire.

Warehouses, auxiliary and administrative premises are equipped with automatic fire detection and (or) extinguishing systems by the list of similar objects to be equipped with automatic fire extinguishing and fire alarm systems.

The territory, working and other premises must be kept clean at all times. Garbage, packaging materials, and containers shall be removed promptly. Passages, exits, corridors, and vestibules should not be cluttered. Roads, entrances to fire hydrants, and tanks (reservoirs) shall be free, and in winter time shall be cleared of snow and ice.

Fire safety signs are installed on evacuation routes and other passages by State Standard ДСТУ EN ISO 7010:2019 «КОЛЬОРИ ТА ЗНАКИ БЕЗПЕКИ»[40].

Flammable and combustible liquids should be placed on shelves made of non-combustible materials, and in warehouses - in original containers.

It is prohibited to open the bottles or pour flammable and combustible liquids into other containers in the warehouses.

It is not allowed in the hangar:

- refuel vehicles with fuel;
- place parts, tools, etc. on evacuation routes and in passages and clutter them;
- to clutter the approaches to fire extinguishing and communication equipment, and power outage devices, as well as to lock the doors of evacuation exits with locks that are difficult to open from the inside during the market operation
- arrange thresholds, turnstiles, and stairs on the evacuation and personnel movement routes;
- reduce the standard width of evacuation routes;
- arrange premises for any purpose on the stairwells;
- use open fire;
- use homemade electric heating devices.

Conclusions to the chapter

Industrial sanitation and occupational health at the aviation enterprise, process safety and fire safety are analyzed. The grounding device was calculated and a conclusion was made about its suitability for use.

GENERAL CONCLUSION

The following sections make up the majority of the master's thesis: The consideration of cockpit design guidelines and the significance of auxiliary displays in assisting aircraft control were the main topics of the first chapter.

Making the basic design of a short-range aircraft that will serve as a prototype for improving cockpit design is the focus of the second chapter of the master's thesis.

The ergonomic layout of the flying compartment was examined in the third chapter of the thesis. AS290B was compared to two anthropometric database standards, ANSUR and CAESAR. The key items of ergonomic design of pilot cabin have been conducted based on the survey of pilots in Europe and USA.

The chapter on environmental protection talks about how the aviation sector affects the environment.

The workplace health and safety chapter also includes the supply engineer's occupational health and safety procedures.

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